Fertilizer INTERNATIONAL

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Indian market report

Fertilizer cooling equipment

Valuing phosphogypsum

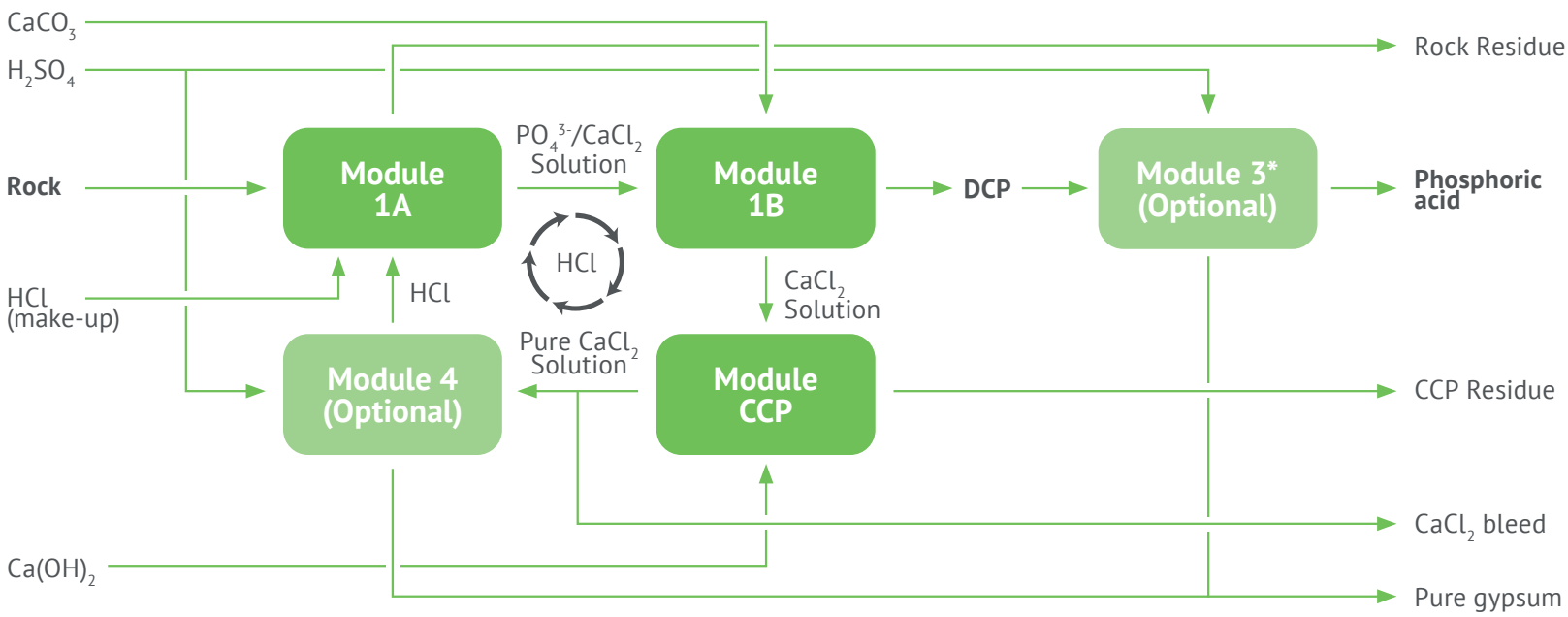
State of the art potash production

Prayon Technologies

ecophos by PRAYON

PHOSPHATE PRODUCTION PROCESS

LOW-GRADE RAW-MATERIALS | **HIGH QUALITY PRODUCTS** | **ENVIRONMENTAL FRIENDLY** PROCESS | **MODULAR** TECHNOLOGY



Calcium phosphate and/or phosphoric acid production through HCl route
** Prayon phosphoric acid technology*

USE OF LOW GRADE ROCK

Low P_2O_5

High organics content

High heavy metals content

High Al/Fe content

FLEXIBILITY OF ACIDIC SOURCES

Hydrochloric acid

Sulfuric acid

PRODUCING HIGH QUALITY PRODUCTS

Pure DCP that can be converted in various phosphate products (phosphoric acid and derivates) and address different markets: animal feed, fertilizer, technical...

CLEAN PROCESS

No gypsum or pure gypsum

Limited waste quantity

Limited effluent quantity or pure effluents

Limited energy consumption

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prt@prayon.com | **www.prayon.com/technologies**

Discover our new Web App for Phosphoric Acid Producers :
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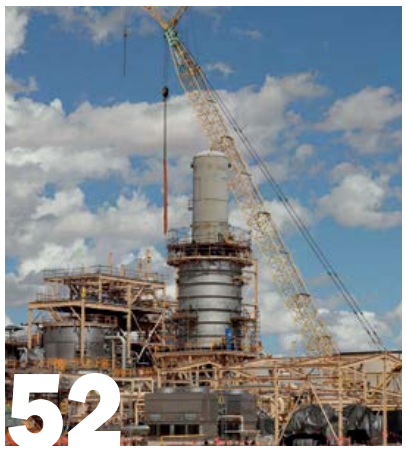
Cover: Tea plantation, Munar, India. Michel Arnault/shutterstock.com

Indorama's Port Harcourt plant, Nigeria



Lake Way SOP project, Western Australia

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PHOSPHATES AND POTASH INSIGHT

REGULARS

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Chris Lawson.

Fertilizer markets are rallying to an extent not seen in almost a decade. This is primarily being driven by strong demand fundamentals, with crop prices moving to their highest point since 2013. But low pipeline inventories and supply disruptions have also played a part. In this guest editorial, CRU's **Chris Lawson** explains what's driving this rally and highlights the key supporting factors.

What's driving the fertilizer price rally?

Where are we right now?

Before analysing the current rally, let's put current prices in their proper context. My first observation would be that our most recently assessed prices are not remarkably high compared to historical levels.

It's true that some fertilizer commodities and raw materials are at five- or ten-year highs. These include diammonium phosphate (DAP Tampa f.o.b.), granular urea (f.o.b. Middle East) and ammonia (f.o.b. Black Sea), which have hit levels not seen since December 2011, May 2013 and April 2015, respectively.

Sulphur (f.o.b. Middle East), too, has reached its highest price since November 2017, with muriate of potash (MOP cfr Brazil) also at a peak last seen in October 2019.

While these steep price trajectories have fuelled speculation that 2021 could be a 'new 2008', we believe this is highly unlikely – although the fundamentals suggest prices could remain elevated through most of 2021.

Tight grain and oilseed markets

This fertilizer price rally is demand driven. Crop prices have soared over the past six months, supported by a tighter global balance. This has bolstered crop prices and is likely to persist through 2021.

Global grain and oilseed market tightness has been intensified by China's corn import spree. Chinese demand for corn is accelerating as it rebuilds its swine herd, after its decimation by the African Swine Fever (ASF) outbreak in 2018.

This has triggered a sharp rise in Chinese corn imports, primarily from the United States and Ukraine. These imports are expected to leap again in 2021 – and are likely exceed 20 million tonnes.

Favourable affordability and falling inventories

During the second half of 2020, as crop prices increased while fertilizer prices did not, affordability moved to its most favourable level since our index started in 2003. Although fertilizer prices have spiked subsequently, they remain affordable and consequently we see very little chance of demand destruction. Especially as farmers around the world are benefitting from both high agricultural commodity prices *and* government payments to counter Covid-19 impacts.

Strong demand has also drawn down fertilizer inventories rapidly. Market players across markets in the US, Brazil and China have all told us that pipeline inventories were drawn down quickly through 2020.

Short-term supply squeeze

Have production disruptions also played a role in market tightness? That's certainly the case in the phosphates market. Producers in this segment pulled back at the end of 2019, due to very low prices, causing the market to tighten. Subsequently, Covid-19 lockdowns in India and China disrupted production, technical issues in Saudi Arabia reduced production and exports, and continued unrest in Tunisia hampered output and sales. Nevertheless, the phosphate production outlook for 2021 is more favourable, with producers ready to respond rapidly to higher prices.

The ammonia market has also tightened quickly, due in-part to supply outages. Prolonged low ammonia prices through 2020 eventually forced Nutrien's hand, prompting the indefinite idling of one of its four ammonia plants in Trinidad towards the end of last year. Gas curtailments have also prompted more recent supply disruptions on the island. Elsewhere, production cuts and interruptions at other ammonia plants in Europe and Japan are also lending price support. Cumulatively, these developments have shown that, having been uncharacteristically stagnant in recent years, ammonia is still a market where prices can escalate quickly.

In contrast, there have been few supply issues for either urea or potash. Indeed, the focus for these two markets is on the timing of impending capacity additions – and, in particular, when these will tip the market balance back into oversupply.

Rally likely to subside

In general, fertilizer producers will be able to take advantage of current higher prices, due to their ability to raise utilisation rates above current levels. There is ample capacity out there, in our view, with more projected to be added during 2021 and beyond.

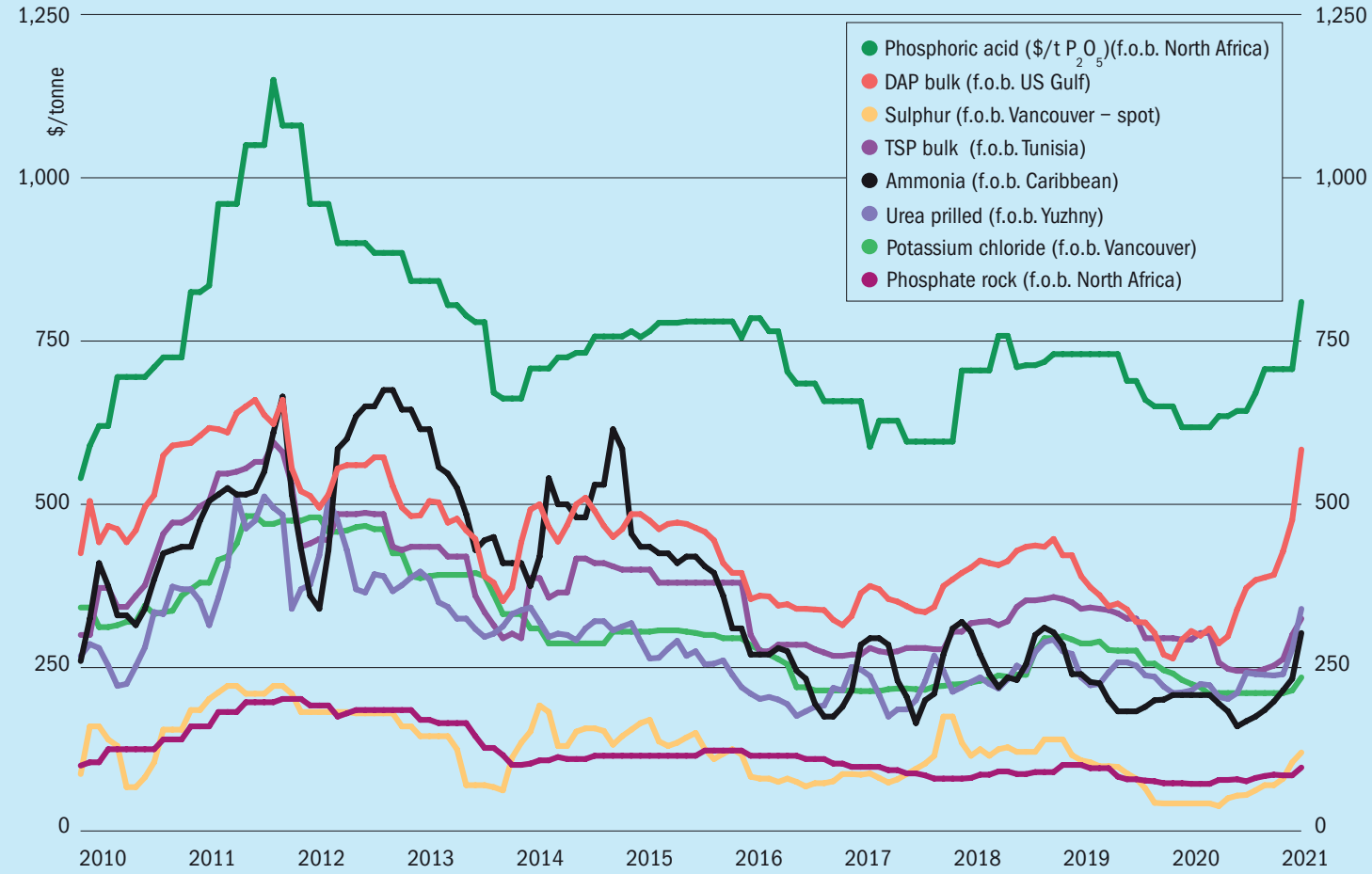
It is therefore highly unlikely that the wider industry will be squeezed for supply, as happened during the 2007 rally. Instead, capacity will respond to high prices and bring the market back into balance. The most important question is when.

So, while this is very much a demand driven rally, the industry has more than enough capacity to respond. Sure, the market is in for a wild ride over the coming months, as seasonal buying comes and goes. Nevertheless, the current price rally is a 'shot in the arm' – one that the industry has been seeking for some time.

Chris Lawson is Head of Fertilizers at CRU Group.

Market Insight

Historical price trends $/tonne



Source: BCInsight

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: The jump in freight rates has been a dominant market topic. Rates have continued to rise since the initial hike in late February, with Middle East-Brazil freight now quoted at $38-40/t, double the rate at the start of the year. New sales of urea have been impeded by the volatility and uncertainty this has created.

Urea prices have moved up in both Egypt and the US while remaining stable elsewhere. Egypt is benefiting from strong demand from Turkey, while the US needs to buy substantial quantities of granular urea for May arrival. Although US production plants are now restarting, after gas-related closures in February, additional imports will still be needed to cover lost output.

Elsewhere, the 2021 demand outlook looks very favourable, with crop plantings, spurred on by attractive grain prices, forecast to rise across the globe.

Key market drivers: agricultural demand, the US and freight.

Ammonia: Another spate of spot market deals were concluded at steep premiums to previous business. This pushed Black Sea f.o.b. prices and US Gulf cfr prices to highs not seen since late-2015.

Severe supply tightness continues to dictate sentiment. Consequently, producers are able to lift offers significantly as spot cargoes become available. The supply deficit is most concentrated around the US, where four production plants remain offline in the US Gulf. A number of plants also remain offline in other regions due to weather-related gas shortages.

Trinidadian producers are ramping up production as much as possible. Nutrien, whose production outage on the island continues, needed to step into the market at the end of February to buy more Algerian tonnes at a price netting forward to $470/t cfr US Gulf. Spot sales are adding upward pressure to the upcoming March Tampa settlement, with a huge increase on February's $330/t cfr price expected.

Key market drivers: US season concerns, the Ukraine (Pivdenny) price jump (over $40/t) and the Saudi Arabian outage.

Phosphates: US barge prices softened in late February, with MAP standing at $560-565/st f.o.b. Nola in the last week of February. This price is equivalent to about $611-617/t cfr – and therefore in-line with Brazilian MAP prices, which Argus assessed at $615-620/t cfr in late February. The change in price direction comes after weeks of hefty US premiums, with supply tightness driving up barge values ahead of spring application. The focus has now shifted to buyers lining up phosphates in Brazil.

Further strong gains were made in China in late February. DAP export prices rose to $530-563/t f.o.b., on business to Southeast Asia and Central America, compared with $515-520/t f.o.b. the previous week. Indian DAP import prices remain flat.

Market price summary $/tonne – Start March 2021

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	290-335	-	f.o.b. E. Europe 115-150	f.o.b. US Gulf	568-600	-	-
f.o.b. Yuzhny	300-370	300-380	-	f.o.b. N. Africa	480-525	325-375	760-860
f.o.b. Middle East	290-330	350-380**	-	cfr India	444-570	-	795*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	210-260	-	cfr US Gulf	70-100	f.o.b. Vancouver	140-175	-
f.o.b. Middle East	205-260	-	-	-	f.o.b. Arab Gulf	150-186	-
f.o.b. Western Europe	-	470-550	-	-	cfr N. Africa	121-160	-
f.o.b. Baltic	207-260	-	-	-	cfr India	170-209+	-

Prices are on a bulk, spot basis, unless otherwise stated. (= contract ** = granular). Phosphoric acid is in terms of $/t P_2O_5 for merchant-grade (54% P_2O_5) product. Sulphur prices are for dry material. (+ Quotes for product ex-Arab Gulf). n.a. = not available.*

Key market drivers: Indian importers raising the DAP maximum retail price (MRP), Jorf Lasfar loading delays and the softening of US barge prices.

Potash: Standard MOP prices rose in Southeast Asia, after fourth-quarter volumes sold into the local market dried up. Brazilian prices also continue to rise on supply constraints and high demand. SOP prices, meanwhile, remain steady in Europe, despite rising costs for Mannheim producers, although second-quarter negotiations are still to come in many cases. Freight rates for dry bulk vessels continue to rise, mitigating f.o.b. price increases.

Key market drivers: China's return to the market and pending decisions on contracts from suppliers.

NPKs: Late February f.o.b. prices held steady, for the most part, yet delivered prices continued to tick higher on a rising freight market. Spikes in both container and bulk freight prices have reduced export interest in seaborne trade. Many European producers have sufficient demand from their own domestic or neighbouring markets. Fulfilling this demand via train and trucked deliveries has been more cost-effective than small seaborne shipments. This is amid strong demand for vessels from a range of commodities and rising bunker fuel costs.

Indian import demand strengthened ahead of the forthcoming *kharif* season. Fact tendered to buy 25,000 tonnes of NPS (20-20-0+13S) for mid-April delivery, and separately tendered for 25,000 tonnes of NPK (16-16-16) for mid-May delivery. At least four Indian producers have planned maintenance across six NPK/NPS plants in March-April, temporarily curbing domestic output.

In Africa, One Acre Fund tendered for almost 7,000 tonnes of NPK (17-17-17), as well as DAP and urea for the Rwandan market, for delivery via Dar Es Salaam or Mombasa by 15 April.

Key market drivers: End of spring season in Eastern Europe and the forecast rise in global grain output.

Sulphur: Buyer resistance to the steep increments in recent f.o.b. sales is increasing and limiting deals. As a consequence, sulphur f.o.b. price levels are now out of touch with cfr pricing in some markets. To date, the limited supply situation has enabled suppliers to increase prices, despite firming freight costs. But resistance is increasing and most markets have yet to accept the above cfr price levels of latest offers ($215-220/t). The difficulty in booking vessels is also starting to have an impact. Despite buyer demand, product lifting may be a challenge if vessel availability remains very limited. The imminent announcement of March lifting prices is, however, expected to release some cargo to the market.

Key market drivers: rapidly firming f.o.b. prices coupled to greater buyer resistance to this.

OUTLOOK

Urea: Although price stability prevails in many areas, some marginal gains in f.o.b. levels are likely in March, possibly affecting North Africa and the US. The urea market is forecast to swing to a surplus in the second-quarter as demand wanes in the west and new capacity comes on-stream.

Ammonia: Some producers are already reporting to be sold out for April. Price increases into May are therefore widely expected. The trade balance is forecast to move into surplus in the second-quarter, prompting gradual price falls from April as production normalises.

Phosphate: Supply tightness is expected to persist into the second-quarter. Following recent sharp phosphates price rises, levels should remain firm through the first half of the second-quarter. The scarcity of duty-free MAP for the US market has supported prices across the globe. East of Suez, surging demand from regional Asian markets has pushed price levels higher, with Chinese producers continuing to focus on their domestic market. Anticipation of an Indian subsidy rise could act to support fertilizer buying on the subcontinent.

Phosphate: MOP price rises are set to continue, spurred on by the shortage in granular product availability and higher demand compared to this time last year. SOP prices are also expected to increase, especially from Mannheim producers, if only to cover rising feedstock and freight costs.

NPKs: Very limited spot supply and raw material prices rises are exerting an upward pressure on NPK fertilizer prices, despite the pause in the market.

Sulphur: Although pricing continues to experience upward pressure, the steep level of recent firming is not expected to be sustainable. The likely breaking point will happen when phosphate pricing begins to slacken, and/or when the sulphur supply situation eases, whichever occurs first. The market is then expected to undergo a potentially fairly swift price correction to the preceding rapid rise.

Fertilizer Industry News

BELARUS

BPC secures new Chinese and Indian potash supply contracts

The Belarusian Potash Company (BPC) has agreed new annual potash supply contracts with India and China.

The announcement to supply Indian Potash Limited (IPL) with 800,000 tonnes of potash in 2021 was announced on 29th January. This was followed on the 10th February by a similar supply agreement with a consortium of Chinese potash buyers (Sinochem, CNAMPGC, CNOOC) for an undisclosed volume.

Both contracts were agreed at a price of $247/t cfr. This represents an increase of $27/t and $17/t, respectively, on BPC's annual settlements with China and India last year.

The price level of the BPC-IPL settlement was immediately criticised by rival potash producers and exporters for undercutting the market.

Alexander Terletskiy, the CEO of Uralkali Trading, said: "Considering the positive market conditions demonstrated in the second half of 2020 and early 2021, as well as the continuous growth in demand for potassium chloride in the main consumer markets this year, Uralkali believes that the price of the contract signed with India is not in line with the current market trends, and does not meet the interests of leading producers of potash fertilizers."

Canpotex, the North American potash export consortium owned by Nutrien and Mosaic, said: "This [is] significantly below current market levels for potash in key offshore markets and a complete disconnect from the strong fundamentals currently being seen for major agricultural commodities in numerous growing regions throughout the world."

Nutrien was similarly critical. "We understand that the potash agreement with India was settled at the highest government level with limited commercial involvement," said executive vice president Ken Seitz, the CEO of Nutrien Potash. "This contract price in no way reflects the market-based pricing in the current key offshore potash markets which, like other fertilizers, is being supported by strong global crop fundamentals. Nutrien wholly supports Canpotex's position to not follow this price level for potential sales into India in 2021."

Despite the rhetoric, Canadian exporters do not seem unduly worried by the BPC settlements. Canpotex said it was fully committed for potash sales until the end April 2021, even without new contract settlements with its customers in China and India. The consortium also expects further export market demand growth in 2021, building on its record 2020 potash shipments. ■

WORLD

Jump in fertilizer freight rates

Average freight rates for dry bulk fertilizers have risen to new highs in recent weeks, reports Argus Media, citing a jump in shipping costs from Baltic ports.

A basket of fertilizer freight rates hit an average of $31.83/t in mid-February, their highest level since Argus first began collecting the data in September 2015. The average rate has risen by close to $10/t since the start of December – equivalent to a 45 percent jump.

The commodities and routes covered by Argus include shipments of urea from Algeria to Brazil, MAP from Russia to Brazil, potash from the Red Sea to India, and sulphur from the Black Sea to north Africa.

The factors behind the rise include ice-blocked Russian Baltic ports, surging commodity demand from China, and a rise in grain and soybean shipments from the Americas.

The rise in freight costs from Russia's Baltic ports in recent months has been particularly marked. The average cost of shipping 25,000-35,000 tonnes of MAP from the Baltic to Brazil, for example, hit $42-44/t in mid-February. This is the highest level on record, according to Argus, exceeding the previous high of $42.50/t set in 2013.

Winter weather conditions in the Baltic worsened towards the end of February, with the Russian ports of Vyborg, Vysotsk and St Petersburg imposing fresh restrictions on vessels from the start of March due to the build-up of sea ice.

From 1st March, only ships with an ice-class rating were permitted to enter St Petersburg port, unless accompanied by an ice-breaking vessel. These restrictions were conditional on the ice thickness reaching 15-30 cm. As of 10th March, an ice thickness of 35-45 cm was still being reported at St Petersburg by the Baltic Sea Ice Service. Similarly, ice 15-30 cm thick was also being reported by the service at Ust-Luga, a major fertilizer export hub.

Icebound Baltic conditions in the third week of February also led EuroChem to purchase a 15,000 tonne spot cargo of ammonia from the UAE at $405/t cfr for March delivery to Antwerp. Thick ice at Sillamae port prevented the company loading ammonia from its Kingisepp plant in Russia, a situation that was expected to last for weeks.

EuroChem generally ships around 40,000 tonnes of ammonia a month from the Russian port of Sillamae to Antwerp. But its current ammonia vessel, *Gas Snapper*, is not equipped for voyages through ice. Yara's *Coral Ivory*, in contrast, as well as other new vessels in Yara's fleet, are all ice-class ships, and can therefore continue to load from Sillamae, reports Argus.

UNITED STATES

February freeze forces nitrogen plant shutdowns

A number of US nitrogen producers were forced to temporarily cease production in mid-February due to the effects of extremely cold winter weather.

The shutdowns were prompted by a combination of high natural gas demand and low availability, as the US experienced its coldest February in 30 years. This affected nitrogen production across a swathe of the United States, from Texas in the south to Nebraska in north.

The severe weather affected urea plants with a combined production capacity of around five million short tons, according to Argus Media, equivalent to 90,000 st/week, as well as substantial ammonia and urea ammonium nitrate (UAN) production capacity.

The February freeze was caused by an arctic blast moving down from Canada into the US as far south as Texas. Some 73 percent of the continental US was covered by snow as of 16th February. Parts of Texas were colder than Alaska, with Dallas reaching a low of 4°F (-16°C) on 15th February, the coldest temperature in the city since 1989.

US natural gas supplies were severely affected during the freeze as some production facilities were shut off while heat-

ing demand simultaneously rocketed. As a consequence, natural gas prices across the country reached record levels as attempts were made to ration demand to compensate for the scaled-back supply. The Katy hub price in Texas, for example, rose to $377/mmBtu on 16th February.

While the unprecedented polar storm in mid-February caused a wave of petrochemical plant shutdowns across US Gulf Coast states, the impacts on US fertilizer production have proved more difficult to ascertain.

In Louisiana, both CF Industries' Donaldsonville and Nutrien's Geismar sites were reported to still be operating in mid-February. Operators in Texas, meanwhile, began shutting down nitrogen production in the state over the weekend 13-14th February, and were expected to remain off line the following week. PCI Nitrogen shuttered its ammonium sulphate plant, for example, while Nutrien's Borger site also went off line.

On 16th February, gas distributor Enable Gas Transmission told industrial consumers in Oklahoma to cease their offtake to preserve supplies for electricity generation and residential customers. Yet the extent to which this affected production at Koch's Enid nitrogen plant and the two CF Industries nitrogen plants in the state is not known.

Koch's Beatrice plant in Nebraska did, however, have its gas offtake cut by 90 percent at one point during the freeze. Some Iowa plants – including OCI Wever, CF Industries Port Neal and Koch Fort Dodge – were also believed to have been taken offline in mid-February, although this has not been verified.

US nitrogen plant closures, even if temporary, will affect the market, predicts Argus: "Though near-term retail fertilizer demand is low because of the widespread cold weather, lost supply because of the shutdowns will likely be felt in a snug market when demand returns."

US Borax launches two new fertilizer products

US Borax, part of Rio Tinto, has launched two new fertilizer products on the market.

Anhybor® and *Zincubor*® have both been created for fertilizer manufacturers wishing to produce micronutrient-enriched compound fertilizers.

The products are designed to address the micronutrient deficiencies faced by agricultural producers and meet increasing market demand for boron and zinc.

"A lack of boron in the soil is known to limit the development of a variety of crops, including corn, cotton, oil palm and soy," commented US Borax. "*Anhybor*® and *Zincubor*® were developed to help these crops reach their yield potential by providing the optimal amount of micronutrients."

Anhybor® is manufactured from borax using a dehydration and fusion process. The product can be used to coat the different fertilizer constituents of NPK blends, with the aid of a binder material, or applied directly to soils. For compound fertilizers, the high boron content of *Anhybor*® is an advantage according to US Borax, as less product is required to reach the target boron content.

Zincubor® is a two-in-one product that has "a perfect 2:1 zinc-to-boron ratio to meet the exact zinc and boron demands of most crops", says the company. It helps avoid zinc deficiency symptoms in crops. These include 'rosetting' and the characteristic clustering of small leaves at the top of plants. *Zincubor*® can also be used as a micronutrient coating for compound fertilizers, with the aid of a binder, or applied

directly to soils. Valuably, the product can also be used to produce suspension fertilizers.

Cleiton de Sequeira, the global market development manager for agriculture at US Borax, said "With these two new products, US Borax broadens the reach of the solutions it provides producers to achieve the maximum yield potential of their crops by addressing zinc and boron deficiencies. The proven performance, stability, and efficacy of *Anhybor*® and *Zincubor*®, combined with the flexibility both products afford distributors and retailers makes them excellent additions to the market."

CHINA

Stamicarbon licenses second ultra-low energy urea plant

Stamicarbon has signed a licensing and equipment supply deal for a second ultra-low energy urea plant in Jiangxi province.

The agreement is with Henan Xinlianxin Chemicals Group who are currently commissioning the first plant in China designed using Stamicarbon's *Launch Melt*™ ultra-low energy design.

The second urea plant for Henan Xinlianxin will have a production capacity of 2,334 t/d and features a pool reactor. It is expected to enter production in 2023. Stamicarbon has agreed to deliver the process design package, together with proprietary high pressure equipment in *Safurex*®, plus associated services for the urea melt plant and prilling plant.

The *Launch Melt*™ design – which recycles heat three times – offers unrivalled energy savings, according to Stamicarbon. It also reduces plant operating costs by cutting both steam and cooling water consumption.

This is the third licensing deal between the two companies in five years. The latest agreement follows an initial revamping project signed in 2016, and the award of the design license for the first ultra-low energy urea plant in 2017.

INDIA

Government to sell-off 20% of NFL

The Indian government has decided to sell 20 percent of its stake in National Fertilizers Ltd (NFL), India's largest public sector fertilizer producer.

India's Department of Investment and Public Asset Management has invited merchant banks to tender for contracts to manage the sale. Divesting 20 percent of NFL could net the government around $54 million in proceeds.

The sale, if successful, would still leave the state with a controlling 55 percent interest in NFL. Financial institutions currently hold a minority 25 percent share of the business.

NFL, which is headquartered in the northern state of Uttar Pradesh, is a major domestic urea producer. The company's five gas-based urea plants collectively produced 3.6 million tonnes of urea in 2019/20. It also imports large volumes of urea and diammonium phosphate (DAP) into India annually – these amounting to 1.19 million tonnes and 685,000 tonnes, respectively, in 2019/20.

NFL's well known *Kisan* urea brand has a domestic market share of around 16 percent currently.

The company's fertilizer sales reached an all-time record of 5.7 million tonnes in 2019/20. The combination of rising sales, healthy market share and the scale of its production and import capabilities should make NFL an attractive proposition for private investors.

Casale to debottleneck IFFCO's Kandla complex

IFFCO has asked Casale to debottleneck two production lines at its Kandla complex in Gujarat. The site is one of IFFCO's oldest phosphates and NPK production centres.

Kandla's two existing lines, which operate on Grande Paroisse's dual-pipe reactor (DPR) technology, were originally commissioned in 1999. This technology is now licensed by Casale, following its acquisition of Grande Paroisse's nitrates and phosphates technology portfolio in 2013.

"We are happy to announce that when IFFCO decided to debottleneck the two lines, it opted for Casale's Solid Fertilizers technologies and expertise," Casale said in a statement, adding: "Under the terms of the agreement awarded earlier this year, Casale will study the modifications required to boost output by 15-25 percent, depending on the fertilizer grade to be produced, as well as furnish, for each of the two lines, one new granulator pipe reactor (GPR) to replace the existing one in the granulator."

The new GPR can be easily installed into existing granulator drums without major modifications, according to Casale. The technology is central to the company's current revamping approach as it:

- Increases the phosphoric acid feed to the plant
- Increases the N/P molar ratio
- Minimises the impact on the scrubbing system and the rest of the plant
- Increase the plant's overall operational flexibility.

PAKISTAN

FFC plans second DAP plant

The Fauji Fertilizer Company (FFC) has announced plans to build a new diammonium phosphate (DAP) plant in Pakistan.

The proposed one million tonne capacity project could enter production as early as 2024, although its success will hinge on FCC securing natural gas for the plant at a discount.

A Pakistan government scheme is encouraging the construction of new domestic fertilizer capacity by offering to supply natural gas at discounted rates for 10 years. FFC has already applied to Pakistan's energy ministry requesting 30 million cubic feet per day of natural gas for the new plant at the concessionary rate – and is expecting a decision on this within months. Rival fertilizer producer Fatima is one of the scheme's current beneficiaries.

Natural gas is required as a feedstock in the production of ammonia, which in turn is a major raw material for DAP manufacture, alongside phosphoric acid.

FFC subsidiary company Fauji Fertilizer Bin Qasim Limited currently operates Pakistan's only DAP plant at Bin Qasim near Karachi. This manufactures around 800,000 tonnes of DAP annually using phosphoric acid imported from Morocco. This is supplied by Pakistan Maroc Phosphore (PMP), the jointly owned Fauji-OCP plant located in Jorf Lasfar. The second DAP production plant would similarly rely on imported acid.

Pakistan imported 1.3 million tonnes of DAP in 2019 and 1.1 million tonnes in 2020, according to Argus Media. Construction of the new plant could therefore reduce the country's annual DAP imports to around 300,000-500,000 tonnes, based on current figures.

IRAN

Lordegan urea plant begins exports

The Lordegan Petrochemical Company has exported the first ammonia shipment from its newly-commissioned ammonia-urea plant at Chaharmahal in Bakhtiari province.

The 2,500 tonne cargo was despatched to neighbouring Turkey, according to the company, with the plant's first urea export cargo also due to be shipped soon.

The recently-completed Lordegan plant has an annual production capacity for ammonia and urea of 670,000 tonnes and one million tonnes, respectively.

NORWAY

Yara secures partners for Porsgrunn green ammonia project

Yara International has linked-up with two new partners to help deliver the switchover to green ammonia production at its Porsgrunn production plant in Norway.

The company signed a letter of intent on 18th February with Norwegian state-owned Statkraft, Europe's largest renewable energy producer, and investment firm Aker Horizons.

Yara first unveiled its ambitious project to full electrify the Porsgrunn plant and produce 500,000 t/a of green ammonia at the end of last year (*Fertilizer International* 500, p10). This project could be delivered within 5-7 years, according to Yara, if enough renewable power was available and public co-funding was secured.

"With Statkraft and Aker Horizons on-board we gain key expertise within renewable electricity, power markets, industrial development and project execution, giving us a unique opportunity to realize the project," said Svein Tore Holsether, president and CEO of Yara.

Yara and its new partners will be targeting market opportunities for both green ammonia and green hydrogen in areas such as agriculture, shipping and industry. These will be pursued through the recently created Yara Clean Ammonia business unit.

"A partnership with Yara and Statkraft, two fellow Norwegian industrial pioneers, marks the beginning of a new industrial adventure in Norway," said Oyvind Eriksen, chairman of Aker Horizons. "The first project in Porsgrunn can be a lighthouse project – providing competitive advantage in a growing global hydrogen economy and building on existing capabilities in the Norwegian supplier industry to create new jobs for the future."

RUSSIA

Uralkali sponsors F1 Team

Russian potash producer Uralkali has signed a sponsorship deal with the Haas Formula 1 (F1) Racing Team.

The team will now be known as Uralkali Haas F1 Team for the 2021 FI race season with Uralkali as the team's title sponsor. Uralkali will also be redesigning its corporate logo as part of the sponsorship arrangements.

This year's F1 race calendar, which starts with the Melbourne Grand Prix in Australia on 21st March, features 23 races in 22 countries, ending with the 2021 season finale in Abu Dhabi on 5th December. Uralkali hopes its F1 sponsorship campaign will increase its global profile and enhance sales in key export markets. The company currently supplies potash to 16 countries on the F1 calendar.

F1 remains the world's largest annual global sporting event. The sport amassed a total TV audience of 1.5 billion in 2020, equating to an average of 87.4 million viewers per Grand Prix.

Uralkali's surprise sponsorship move is a first for both the fertilizer industry and F1. The top tier of motorsport is more typically associated with market-leading consumer brands and technology companies such as Coca Cola, IBM, Microsoft, Puma and Unilever.

The value of Uralkali's F1 sponsorship deal with Haas has not been disclosed. However, major sponsors and partners such as the denim brand Jack & Jones and Swiss watchmaker Richard Mille are believed to have contributed around $2 million each to the team in previous seasons.

CROATIA

Kutina plant restarts

Fertilizer producer Petrokemija has completed a $14 million programme of repairs and revamps at its Kutina chemical plant. This enabled production to partially resume at the site on 8th February.

Operations at Kutina were shut down on safety grounds following a magnitude 6.4 earthquake in Petrinja in central Croatia on 29th December last year. Repairs were subsequently required to fix damage to the site's ammonium nitrate (AN), calcium ammonium nitrate (CAN), NPK, sulphuric acid and urea plants, as well as associated water processing and power facilities.

Petrokemija has used the unexpected shutdown to its advantage by revamping Kutina's ammonia plant. This included a $3.5 million investment in a new air pre-heater for the plant's primary reformer.

Repairs to Kutina's AN and CAN plants are still ongoing with both plants scheduled to re-start soon, according to Petrokemija. ■

People

The Mosaic Company received the **2020 Robert W Campbell Award** from the US National Safety Council in February. This prestigious award celebrates the company's excellence in environment, health and safety (EHS) and its achievements over a decade of continuous improvement. During this period Mosaic's commitment to EHS has delivered an 80 percent improvement in its recordable injury rate and led to the creation of its Risk Reduction Program.

"Mosaic employees around the world are honored to receive this recognition for their commitment to safety and continuous improvement. While this validation of our efforts is worth celebrating, we believe that the journey to zero injuries and incidents is never over," the company said in a statement.

Deborah L DeHaas has been nominated for election to the board of directors of CF industries. Her election will take place at the company's annual shareholders meeting on 4th May. Following this, Deborah is expected to join the company's audit committee and environmental sustainability and community committee. She will be the seventh new independent director added to CF Industries' board in the last seven years.

"We are thrilled at the opportunity to have Deb join the CF Industries Board," said Stephen Furbacher, chairman of the board at CF Industries. "Deb's leadership and extensive expertise in accounting and finance, sustainability, human capital and corporate governance will serve the board and our management team well as the company advances its clean energy growth strategy. We look forward to her contributions as we work together to create long-term value for our shareholders."

Ms DeHaas was the vice chairman and managing partner of the Center for Board Effectiveness at Deloitte, before retiring in September last year. She held numerous leadership roles at Deloitte during her 18 years with the firm. Before joining Deloitte, Deborah was a partner at Arthur Andersen.

She has been the CEO of the Corporate Leadership Center (CLC) since November 2020 and also currently serves on the board and executive committee of the SASB Foundation. Deborah is also a trustee and chair of the audit committees at both Northwestern University and the University of Denver. Ms DeHaas also joined the board of global manufacturer Dover Corporation in February this year.

Holger Riemensperger will become chief operating officer (COO) of K+S at the start of April. He will also join the join the company's supervisory board as an executive director. As COO, Holger will assume operational responsibility for the management and development of the company's agriculture and industry customer divisions. His operational responsibilities will also cover a wide range of business functions at K+S, including production and engineering, supply chain, health & safety, quality & management systems and sustainability.

"We would like to sincerely welcome Holger Riemensperger to the K+S team. We have been able to attract an experienced manager to K+S with proven expertise in the fields of nutrition and health as well as comprehensive operating leadership experience, which he has gained at globally operating industrial companies," said Dr Andreas Kreimeyer, chairman of the supervisory board.

Mark Roberts, the former COO of K+S, is currently the CEO of US-based Morton Salt. He will continue his career outside of K+S once the imminent sale of the company's American operating unit to Stone Canyon Industries is completed.

"We would like to thank Mark Roberts for his significant contributions during the course of his 29-year career with K+S. As a dedicated leader, he has played a decisive role in shaping K+S, and we wish him success in his future endeavours and all the best personally," Dr Kreimeyer said.

Jeff Dallstream has become a sales executive at US-based Berndorf Belt Technology (BBT), covering North America's western region for the company. He is expected to cement BBT's position as a leader in steel belt production, process equipment technologies and customer support. In his region, Jeff will also be responsible for supporting process equipment sales for the recently-acquired SBS Steel Belt Systems.

Mr Dallstream is an industry veteran with over 15 years' experience. He has worked with multiple companies in both sales support and regional sales manager roles. This has involved selling carbon steel and stainless-steel belts and associated process conveying systems for the chemical, food and fertilizer industries. Jeff also spent 12 years working for an equipment finance company in Scottsdale, Arizona, arranging finance for fertilizer-based stainless steel belt systems. ■

Calendar 2021

! The following events may be subject to postponement or cancelation due to the global coronavirus pandemic. Please check the status of individual events with organisers.

MARCH

23-25

CRU Phosphates 2021, **Virtual event**
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

MAY

19

The Sulphur Institute Sulphur World Symposium, **Virtual event**
Contact: Sarah Amirie
Phone: +1 202 331 9660
Email: samirie@sulphurinstitute.org

26-28

IFA Plant Nutrition Solutions Conference, **Virtual event**
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

JUNE

28-30

IFA Annual Conference,
LISBON, Portugal
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

SEPTEMBER

20-22

TFI World Fertilizer Conference 2021,
BOSTON, USA
Contact: Mariana Gallo
Tel: 202-962-0490
Email: mgallo@tfi.org

OCTOBER

20-22

IFA Crossroads Asia-Pacific,
SINGAPORE
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

Mexico City was the venue for FLA in 2019.

PHOTO: BCINSIGHT

CRU/Argus Fertilizer Latino Americano 2021

More than 250 delegates from 36 countries participated in the 2021 Fertilizer Latino Americano Virtual Conference, 25-28 January 2021. To highlight this successful event, we report on selected keynote and regional presentations.

Canpotex keynote

"What a difference a year makes," commented Canpotex's CEO and president **Gord McKenzie** in the conference's opening keynote address.

He was commenting on the transformation of agricultural and fertilizer markets in the year since the start of the Covid-19 pandemic. But, equally, he could also have been talking about the change from in-person to virtual events since delegates last gathered for Fertilizer Latino Americano in Sao Paulo in January 2020.

Latin America's potash imports totalled more than 10 million tonnes last year. This contributed to making 2020 a good year for potash sales, Gord reported. Canpotex is Latin America's largest potash supplier. The Covid-19 pandemic, by reinforcing the importance of food security, has delivered at least one partially redeeming upside, McKenzie suggested.

Last year saw strong inventory consumption with an 800,000 tonne drawdown on global potash stock levels. The market was also supported by the strengthening of agricultural commodity prices to multiple year highs. China's agricultural imports have also reinforced these price levels. Export-oriented agricultural economies, meanwhile, have benefitted from the US dollar's strength during 2020.

Crop nutrition in Latin America is generally more balanced relative to the global average, Gord noted, due to a wide recognition that potassium is a key nutrient for cash crops such as soybean. Within the region, Brazil is Canpotex's number one global market and, correspondingly, Canpotex is Brazil's largest potash supplier. Overall, the country is the leading potash importer globally and the world's second largest consumer of potash.

Looking ahead, potash market demand fundamentals remain strong, Gord emphasised, with annual growth rates of 2-3 percent anticipated over the medium-term (2020-2025).

Green ammonia opportunities in Chile

CRU's **Josie Armstrong** outlined Chile's potential as a green ammonia marine fuel hub. Although obstacles remain, and current ammonia infrastructure is limited, the opportunity was a very real one, in her view.

Chile is the only country in the region to have published a hydrogen strategy to date. This adopts a three-stage approach: firstly, the local production of green ammonia to substitute for annual imports of 0.3 million tonnes (2023-2028); secondly, a move into green ammonia exports (2028-2032); thirdly, a focus on the use of green ammonia as a fuel (2032 onwards).

Chile's great potential for renewable energy is a particular advantage. Access to renewable electricity is essential for powering the front-end water electrolysis units used in green hydrogen generation and, ultimately, ammonia production. Northern Chile has high solar photovoltaic (PV) generation potential, for example, while high and consistent winds speeds in the country's south are ideal for wind power.

Chile's general proximity to sea lanes would also be advantageous, if it were to become a marine fuel hub.

Green ammonia is one of several low-carbon candidates (ammonia, hydrogen, methanol) that could fuel and clean-up global shipping in future. The maritime industry accounts for around 2.5 percent of global CO_2 emissions currently, with the International Maritime Organisation (IMO) and others pushing for a shift to low-carbon alternatives to traditional fossil fuels. Ammonia has key advantages over its rival green fuel candidate hydrogen. Ammonia's energy density is higher, for example, and it is also easier to liquefy. Indeed, green ammonia could become a major alternative fuel for shipping by 2050, suggested Josie, although full commercialisation was not expected until after 2030.

She also cautioned that, as a green ammonia hub, Chile faces strong competition from both Trinidad, the region's largest ammonia exporter with proximity to Mexico and Brazil, and the US, where companies such as CF Industries look set to invest heavily in green ammonia production.

Brazilian market overview

Cleber Viera of Agroconsult emphasised the critical role of five crops – soybean, corn, sugarcane, cotton and coffee – in his excellent summation of the Brazilian market. These collectively account for almost four-fifths of fertilizer consumption in Brazil.

The cultivation of corn, cotton and soybeans is also interconnected, as they are often grown on the same farms in rotation. Soybean, the winter crop, is typically followed by planting of corn or cotton as a second crop in summer. While corn can be planted as a first crop, this practice is in decline with farmers increasingly favouring soybean instead.

Around 17.6 million tonnes of fertilizers – 46 percent of the 38.6 million tonnes in total consumed domestically – were applied to Bra-

zil's soybean crop in 2020. Dry September-November weather in Brazil last year did delay soybean planting and, as a consequence, the 2020/21 crop production estimate has fallen by 2.3 million tonnes to 131.4 million tonnes, although this remains above the level of the 125.5 million 2019/20 harvest. Record soybean prices (e.g. BRL 170 per bag in Paranagua in November 2020), and correspondingly favourable barter ratios for fertilizers, have boosted the 2020/21 soybean planted area by four percent to 38.4 million hectares. Cleber concluded by giving the same highly positive outlook for both Brazilian soybean and corn in 2021: "High profitability, high confidence, with area expansion."

Micronutrient fertilization in the Pampas

Current crop nutrient strategies are limiting barley, corn, soybean and wheat yields in the Pampas region, suggests **Andres Grasso** of Argentina's Fertilizar Asociacion Civil. This is largely due to the current focus on nitrogen and phosphorus in fertilization recommendations to the exclusion of sulphur and micronutrients such as zinc. Yield gaps in the Pampas of 5-22 percent have opened up because of this. Low soil nutrient levels for sulphur, for example, are a particularly limiting factor in wheat and barley production.

Crop trial results have shown that zinc fertilization of corn in the Pampas is effective at delivering yield improvements. Similarly, applying zinc alongside phosphorous and sulphur has also been shown to improve soybean yields by four percent. Deficiency is, however, on the increase in the Pampas, with 67 percent of soils exhibiting zinc deficiency in 2018, compared to 47 percent in 2011.

However, new crop nutrition strategies, devised following 14 trials on eight sites during four campaigns between 2016/17-2019/20, are leading to higher yielding fertilizer recommendations for the Pampas. The resulting best practice manual published by Fertilizar in 2020, if followed by Pampas farmers, should help to close current yield gaps, Andres concluded.

Efficacy of biofertilizers and biostimulants in Argentina

Argentina is notably large global marketplace for biostimulant and biofertilizer products, reports **Martin Dias Zorita** of the Universidad Nacional de La Pampa. Almost 50 percent of Argentinian crops are treated with biofertilizers (inoculants), while some 13 percent of speciality fertilizers sold also incorporate biostimulants.

The evidence base is mixed but largely positive. In biofertilizer crop trials, for example, positive grain yield responses have been comprehensively demonstrated for Argentinian-grown corn, dry peas, soybean and wheat treated with inoculants.

In 2019/20 Argentinian trials, biostimulant (PGA) seed treatments for soybean also improved root nodulation in 80 percent of cases and delivered minor grain yield increases. Other biostimulant products (humic acid), however, while modifying soybean plant growth and development, did not ultimately improve yields. Overall, the positive contribution biofertilizers and biostimulants make to crop production does support their wider adoption, in Martin's view, although improvements are moderate and can be variable.

Potential DAPR markets in South America

Applying highly soluble phosphate rock offers farmers clear benefits in parts of South America, concludes **Martin Torres Duggan** of Tecnoagro. In recent evaluations, direct application phosphate rock (DAPR) has proved to be effective for P fertilization of rye grass and soybean, across different soil types and pH ranges. The effectiveness of DAPR does vary, however, with soil properties, crop type, tillage and climate, as well as fertilizer placement and timings.

Selecting the right type of DAPR product is also critical. Because phosphate rock is a naturally heterogeneous ore, different sources of DAPR require a thorough agronomic evaluation, under both greenhouse and field conditions, according to Martin. Generally, relative agronomic effectiveness (RAE) is highest (>90%) for those rock types where P_2O_5 is soluble above pH 5.7. Factors such as the reactivity, particle size and heavy metal content of DAPR are particularly important.

Latin America, due to widespread soil acidity and the large areas devoted to pasture, provides a great opportunity for DAPR. Brazil is already a sizeable DAPR market, currently importing around 200,000 tonnes annually through the port of Paranagua, mostly from Morocco and Peru. There is also great potential among the 'Southern Cone' group of countries. Parts of Argentina (Corrientes, Entre Rios and the Pampas) and eastern Paraguay could in future provide an annual market for DAPR of 70,000-100,000 tonnes and 50,000-70,000 tonnes, respectively.

Precise nutrient management in Brazil

Precision agriculture is providing Brazil's farmers with a range of tangible benefits, according to **Luciano Shiratsuchi** of the LSU Ag Centre. These include improvements in the use efficiency, productivity, quality, profitability and sustainability of agricultural production.

The aim of precision agriculture is to maximise profits, not just yields. Achieving this typically involves a long-term crop and nutrient management strategy that incorporates no tillage, diverse crop systems and the use cover crops. For precise nutrient management, monitoring the vertical distribution of nutrients in the soil profile is as important as their surface spatial distribution.

The use remote sensing technology and plant and soil sensors is on the rise in Brazil. Precision agriculture is mainly delivered by consultants, such as hired agronomists employed by large farms as managers. The main commercial technology providers currently are *Field View*, *Farmers Edge* and *Trimble*.

Stabilised nitrogen fertilizers in Brazil

Stabilised nitrogen fertilizers (SNFs) already have a good market share in Brazil, according to **Heitor Cantarella** of the Instituto Agronomico de Campinas (IAC). Some 15 percent of urea consumed by Brazilian agriculture, for example, is currently stabilised with urease inhibitors (UIs). These reduce ammonia volatilisation, a major contributor to nitrogen losses from surface-applied urea.

Nitrogen fertilizers are applied across more than 100 million hectares in Brazil at application rates of 20-100 kg N/ha. Urea is the main nitrogen source with around 2.6 million tonnes N applied annually. While losses of nitrogen to the environment are not generally a pressing priority for Brazil's farmers, larger agricultural corporations are highlighting the issue, and the sugarcane sector is also introducing legislation in this area.

Corn, cotton, fruit (oranges and bananas) coffee growing and pasture are all promising markets for stabilised nitrogen fertilizers in Brazil. "Prospects for increasing UI are very good," concludes Heitor. The use of UIs are not effective in all circumstances, however, particularly when soils are highly acid or if long dry periods occur after fertilization.

Indian fertilizer market report

We profile a selection of the leading players in India's large and dynamic domestic fertilizer industry.

Indian agricultural is the key driver and mainspring of fertilizer demand growth globally. The subcontinent is the world's largest fertilizer importer, second largest fertilizer market and third largest producer of fertilizer (Figure 1).

India's large fertilizer industry operates as a mixed economy with ownership divided between private, public and cooperative companies (Figure 2).

Urea accounts for around two-thirds of overall fertilizer consumption and, correspondingly, remains the prime focus of domestic production. India is aiming to achieve self-sufficiency in urea production by 2022 by reviving a number of currently mothballed plants, as set out in the government's New Investment Policy (NIP).

Indian fertilizer production rose to 46.2 million tonnes in 2019/20, according to the latest government estimates (Figure 3), an increase of 11 percent on the previous year. Currently, India's domestic industry operates:

- 32 large-scale urea plants
- 19 diammonium phosphate (DAP) and NP/NPK plants
- Two plants that produce ammonium sulphate (AS) as an industrial by-product.

Large-scale production units are a notable feature of the Indian fertilizer industry. To help service its massive domestic fertilizer requirements, more than 30 of the country's plants have a production capacity in excess half a million tonnes (Figure 4).

Below, we profile some of the leading players in India's large and dynamic domestic fertilizer industry, covering both the public sector (National Fertilizers Limited) and private sector (Coromandel International and Sulphur Mills Limited). We were also granted an exclusive interview with Rakesh Kapur, joint managing director of the Indian Farmers Fertiliser Cooperative Limited (IFFCO), India's largest fertilizer producer (see box).

National Fertilizers Limited

Founded in 1974, National Fertilizers Limited (NFL) is India's largest public sector fertilizer company and one of the country's largest urea producers and importers. The state-controlled company is headquartered in Noida in the northern state of Uttar Pradesh. The government retains a 75 percent majority stake in the business, with financial institutions and others holding a minority 25 percent share.

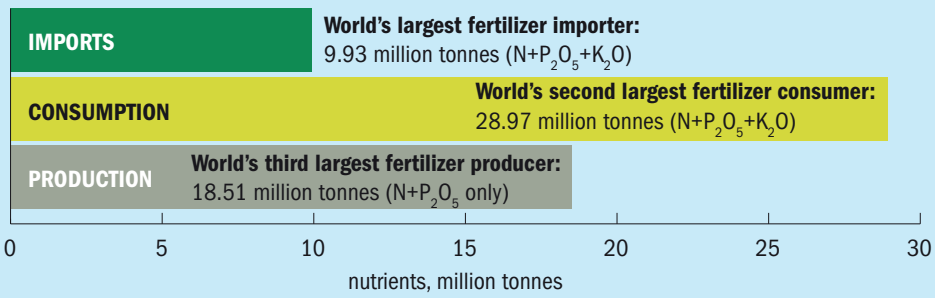
NFL owns and operates five gas-based urea plants. These have a combined annual production capacity of 3.6 million tonnes. They include:

- The 865,000 tonne capacity Vijaipur I and Vijaipu II urea plants in Madhya Pradesh
- The 512,000 tonne capacity Bathinda and the 479,000 tonne capacity Nangal II urea plants in Punjab
- The 512,000 tonne capacity Panipat plant in Haryana.

NFL is India's second largest urea producer. Its urea products, marketed under the well-known *Kisan* brand, have a domestic market share of about 16 percent currently. NFL also produces and sells biofertilizers, sulphur-bentonite, ammonium nitrate, water-soluble fertilizers (WSFs) and certified seeds to farmers.

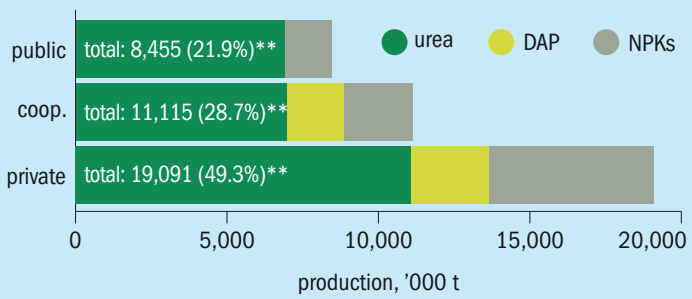
NFL benefits from having three plants located in Punjab and Haryana, two of India's biggest fertilizer-consuming states, and a country-wide sales and distribution network.

Fig. 1: **Key Indian fertilizer market facts, 2019/20**



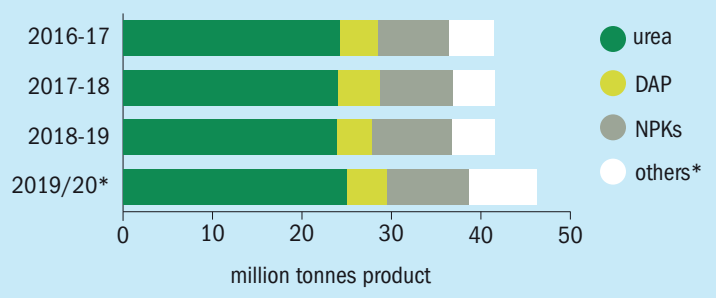
Source: Fertilizer Association of India

Fig. 2: **Indian fertilizer production by sector, 2019/20***



**Estimated*
***Excludes ammonium sulphate (AS) and single superphosphate (SSP)*
Source: Annual Report 2019-20, Indian Department of Fertilizers

Fig. 3: **India's domestic fertilizer, 2016/17-2019/20***



**Estimated*
***Mostly ammonium sulphate (AS) and single superphosphate (SSP)*
Source: Annual Report 2019-20, Indian Department of Fertilizers

Fertilizer market overview

With a sales turnover of around $17 billion, the Indian fertilizer industry produces around 42 million tonnes of fertilizer annually. These are distributed nationally through a network of 226,000 agricultural dealers. The subcontinent is the world's largest importer of fertilizer and fertilizer raw materials. Each year, the country typically imports:

- 19 million tonnes of fertilizers
- 14 million tonnes of phosphate rock, sulphur, ammonia and phosphoric acid
- Nine billion m^3 of liquid natural gas (LNG) feedstock.

India's fertilizer market remains heavily subsidised – at an estimated government cost of $10.0 billion in 2020/21. Although subsidies peaked at $21.7 billion in 2008/09, and have generally been on a downward trajectory since, the current annual subsidy bill is triple what it was twenty years ago. The Fertilizer Association of India (FAI) also reports huge arrears in subsidy payment ($8.45 billion) and an inadequate budget allocation ($10.04 billion) versus the budget requirement ($19.01 billion).

The Indian government has long supported self-sufficiency in urea production under its 2012 New Investment Policy (NIP). Implementation of this policy involves expanding domestic urea production capacity by funding the revival of a number of mothballed urea plants (Table 1). The policy is finally starting to deliver results – with Chambal Fertilizers & Chemicals Limited (CFCL) commencing production at its 1.3 million t/a Gadepan III urea project in Rajasthan in January 2019.

India's demand for urea is particularly high (33.5 million tonnes), accounting for around 55 percent of total fertilizer consumption in 2019/20 (60.6 million tonnes). Around three-quarters of this demand is met by domestic production with the remainder being imported (9.1 million t/a).

Most Indian urea plants use natural gas as feedstock. This accounts for around 70-80 percent of production costs. India has insufficient natural gas reserves to meet its national consumption needs. Consequently, the country relies on imported liquid natural gas (LNG) for around 60 percent of its total gas demand (*Fertilizer International* 495, p15).

For phosphate fertilizers, DAP and NP/NPK are preferred by Indian farmers. The combined demand for these two product types (19.7 million in 2019/20) equates to around one-third of total fertilizer consumption. Almost 50 percent of DAP and 7-8 percent of NP/NPK requirements needed to be imported in 2019/20. India also produces large volumes of single superphosphate (SSP) (4.2 million tonnes in 2019/20) for domestic consumption.

India is import-reliant for the majority of raw materials and intermediates (phosphate rock, phosphoric acid, ammonia and sulphur) consumed by its domestic phosphate industry. The country is also completely reliant on imported potash (3.7 million tonnes in 2019/20) for both direct application and NPK blends.

The emergence of the Covid-19 pandemic last year had mixed impacts on Indian fertilizer production (*Fertilizer International* 496, p18). CRU reported that eight of India's 13 DAP production plants and 14 of its 17 NPK production plants were idled in April 2020. Six of the country's 32 urea plants were also idled that month in response to lockdown measures.

Consequently, Indian DAP production, at 2.7 million tonnes for April-November 2020, was down 10 percent year-on-year. During the national lockdown, DAP production fell by 40 percent in April and 20 percent in May 2020, in comparison to 2019. This was linked to logistical snags, disruption to raw materials distribution and the shortage of labour and bagging materials. Domestic NP/NPK production, in contrast, rose to 6.1 million tonnes in April-November 2020, up by three percent year-on-year.

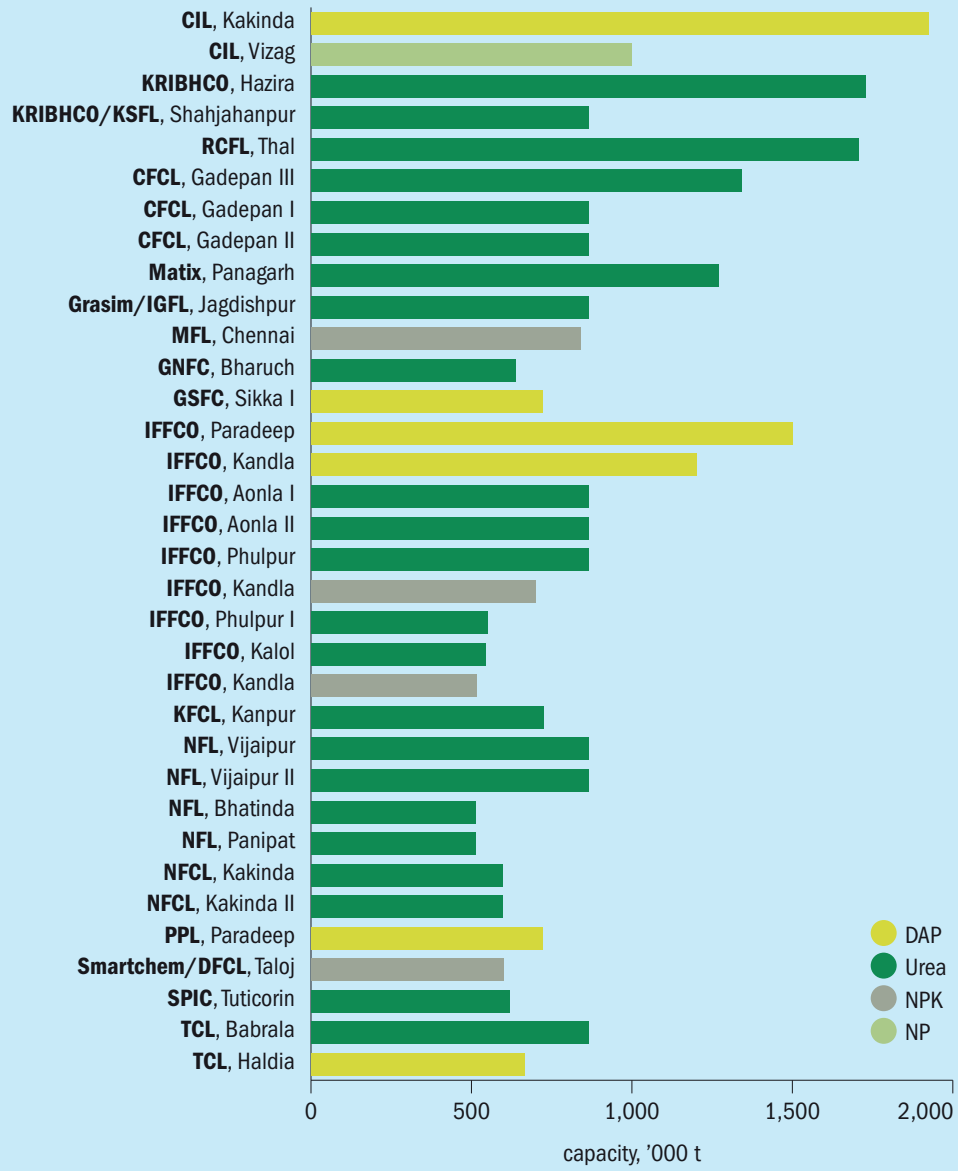
On the demand side, domestic fertilizer consumption remained buoyant last year. Indeed, overall *kharif* season sales – for urea, potash, DAP, SSP and NPKs – received a large boost during 2020, with Argus reporting April-July sales of 20.4 million tonnes, up from 14.1 million tonnes for the same period in 2019. Mid-year fertilizer buying was fuelled by a rise in *kharif* crop acreages and strong monsoon rains in 2020.

Table 1: **Indian urea project list, 2018/19-2023/24**

Company	Name and location	Capacity (million t)
Projects commissioned in 2018/19		
Chambal	Gadepan III, Rajasthan	1.34
Project to be commissioned in 2020/21		
Ramagundam	Ramagundam, Telangana	1.27
Matix	Panagarh, West Bengal	1.27
Under implementation, expected in 2021/22		
Hindustan Urvarak & Rasayan Ltd (HURL)	Gorakhpur, Uttar Pradesh	1.27
Hindustan Urvarak & Rasayan Ltd (HURL)	Barauni, Bihar	1.27
Hindustan Urvarak & Rasayan Ltd (HURL)	Sindri, Jharkhand	1.27
Planned, 2023/24		
Talcher Fertilizer Ltd	Talcher, Odisha	1.27

Source: Fertilizer Association of India

Fig. 4: **India's largest fertilizer production plants***



** Plants with a production capacity of more than 0.5 million tonnes only*

Source: Annual Report 2018-19, Indian Department of Fertilizers

Owning and operating the Bathinda, Nangal and Panipat plants does place NFL at a competitive disadvantage, however, due to their age and relatively small capacity (Figure 4).

NFL produced 3.73 million tonnes of urea in 2019/20 – some 15 percent above nominal production capacity – although production was slightly down on the 3.86 million tonne urea output for 2018/19, and represents the lowest production total in five years. Despite this, the company's fertilizer sales rose to 5.70 million tonnes in 2019/20, a new all-time record. This volume included 1.19 million tonnes of imported urea and 685,000 tonnes of imported DAP, as well as 3.61 million tonnes of self-produced urea.

NFL's fertilizer sales have risen year-on-year for the last five years and are now more than 50 percent higher than they were in 2015/16. With domestic production remaining static, sales have largely been driven upwards by growing import sales for urea and DAP.

Coromandel International

Coromandel International (CIL) is India's largest private sector phosphate fertilizer manufacturer, operating three DAP/NPK plants and eight SSP plants. The company, which started as a joint venture between IMC, Chevron and EID Parry in 1961, is currently part of the $5.4 billion Murugappa Group. It achieved a turnover of INR 132 billion ($1.8 billion) in 2019/20.

With a fertilizer production capacity close to 3.5 million tonnes, Coromandel owns and operates around one-quarter of domestic DAP and NPK production capacity in India. Its three main fertilizer plants are located in the south east of the country – at Vizag and Kakinada, both in Andhra Pradesh, and Ennore in Tamil Nadu. These plants have the flexibility to manufacture 13 different fertilizer grades. Many of these incorporate secondary and micronutrients and are unique to the company.

Coromandel is also India's largest manufacturer of water-soluble fertilizers (WSFs), thanks to a joint venture with Chilean producer SQM. These high-value speciality products are aimed at the foliar and fertigation market.

The successful commissioning of a second acid plant (450 t/d capacity) at Vizag in 2019-20 means this site is now self-sufficient in phosphoric acid.

Coromandel also runs India's largest farm retail network, owning around 750 rural stores across Andhra Pradesh, Telangana, Karnataka and Maharashtra. These offer a range of farm products and services – including crop advisory, soil testing and farm mechanisation advice – to around three million farm customers.

Coromandel's fertilizer production reached 2.98 million tonnes in 2019/20, a new company record. Fertilizer sales volumes also increased by four percent year-on-year to 3.14 million tonnes, with NPK and DAP accounting for 83 percent and 17 percent of these volumes, respectively.

Coromandel re-launched its NP+S product (24-24-0-8) last year under the brand name *GroSmart*. Additionally, strong SSP production for the year (600,000 tonnes) enabled the company's *GroPlus* brand to maintain its market-leading position.

Sulphur Mills Limited

Founded in 1960, Mumbai-based Sulphur Mills Limited (SML) has not only grown to become one of India's leading agrochemical companies, it has also established itself as the world's largest sulphur producer. SML is a global player, exporting products from three manufacturing plants in Mumbai and Gujarat to over 80 countries worldwide. The company also operates through wholly-owned subsidiaries in Europe, Australia, Latin America and Africa.

SML uses a patented process to manufacture 2-4 micron-size sulphur and zinc granules with excellent water dispersion properties. These water dispersible granules (WDGs) can be applied by drip irrigation, overhead sprinkler irrigation, side dressing or soil drenching etc.

Notable WDG products include *Fertis*® (also marketed as *Techno-S*®), a 90 percent sulphur fertilizer, and *Techno Z*® which combines 15 percent zinc content with 70 percent sulphur. Both products undergo extremely quick oxidation, rapidly providing S and Zn in plant-available form. They are particularly suitable for supplying sulphur and zinc to deficient crops via low-dose fertigation.

Fertis® disperses quickly in both water and soil. Only very low dosage rates are required, in comparison to traditional sulphur fertilizers, due to the product's faster sulphur release and more efficient crop uptake. The product's efficiency also provides farmers with a better return on investment relative to other sulphur sources. Other benefits include:

- Reduced pH in saline and alkaline soils
- Improved crop uptake and plant metabolism of other nutrients such as N, P, K and micronutrients
- Increased oil content in oil seed crops
- Better pest and disease resistance in crops.

Techno Z® is an advanced sulphur fertilizer enriched with zinc for balanced crop nutrition. The incorporation of patented *ORT* technology provides farmers with a better return on investment by prolonging zinc availability and improving crop uptake of this micronutrient. Its micro granular formulation also ensures zinc is uniformly distributed in soils. Similar to *Fertis*®, the presence of sulphur in *Techno Z*® helps balance pH and supports the uptake of other nutrients. Likewise, the product can also increase pest and disease resistance in crops.

In 2019, SML entered into an exclusive sales agreement with Tiger-Sul, the world's largest sulphur-bentonite producer. This landmark deal provides Tiger-Sul with the sole rights to distribute and sell Sulphur Mills' *Techno-S*® and *Techno-Z*® products in North America.

"This venture to work together in the US and Canadian market brings a great value proposition of these two important nutrients, sulphur and zinc, to the farming community," said Bimal Shah, SML's chief operating officer.

Murat Kamisli, SML's general manager of crop nutrition international business, added: "The same technology and delivery system of these two patented nutrition products have been great successes in many other countries and we are looking forward to even greater successes in the US and Canada, with this partnership with Tiger-Sul Products." ■

INTERVIEW

Rakesh Kapur

joint managing director, Indian Farmers Fertiliser Cooperative Limited (IFFCO)

The Indian Farmers Fertiliser Cooperative Limited (IFFCO) is India's largest fertilizer producer. The society is also widely credited as being the world's largest agricultural cooperative, expanding from just 57 cooperatives in 1967 to more than 35,000 today.

Dear Rakesh,
it's a pleasure to have the opportunity to interview you on behalf of *Fertilizer International* magazine. You're the immediate past chairman of the International Fertilizer Association (IFA), holding this position during a period of both change and reflection.

What do you feel were the main highlights and achievements during your tenure as IFA chairman – and was your chairmanship a timely recognition of the growing global status of the Indian fertilizer industry?

"It's difficult to summarise, as substantial work was done in so many areas at IFA while I was chairman – on safety, the environment, climate change impacts, nutrient use efficiency, emissions reduction, phosphogypsum, water conservation etc. etc. But a major priority was definitely making the industry more visible and changing how we were perceived. That led to improvements in public affairs and external communications through active engagement with the UN, FAO, UNEP, WHO and others.

"My tenure as chairman also saw IFA switch its strategic focus to plant nutrition. Future scenario planning, part of the IFA 2030 initiative, allowed us to look at how the world is changing – and exactly what that was going to mean for the fertilizer industry moving forward. Resulting from that, IFA setting up an advisory Scientific Panel on Responsible Plant Nutrition. We also moved to strengthen our market intelligence and statistics (IFASTAT) capabilities by re-structuring IFA secretariat.

"It was a privilege as a member from the Indian fertilizer industry to be IFA's chairman. In India, agricultural growth and fertilizer industry growth sustain one other. I am pleased to say that the Indian fertilizer industry is taking the lead in the transition towards a low-carbon and food-secure future. That will benefit both the country and the world overall in my view."

IFFCO's 2019-20 sales volumes rose by more than 15 percent year-on-year to reach 13.3 million tonnes, an all-time high. It was also record breaking year for production at all five of the society's sites. IFFCO notably produced 4.9 million tonnes of neem-coated urea and 4.3 million tonnes of NP/NPKs, diammonium phosphate (DAP) and water-soluble fertilizers (WSFs) last financial year. Since then, of course, the world has suffered an unprecedented coronavirus outbreak.

How did IFFCO respond to the Covid-19 pandemic last year – continuing to make deliveries to its customers, while keep employees safe and overcoming this major operational challenge?

"Locking down a country of 1.3 billion people was indeed an unprecedented situation. The industry faced a number of challenges, post-lockdown in March 2020, such as raw material availability, labour management, handling/distribution and logistics. Besides this, the health and safety of employees was a big concern. Massive relief and awareness campaigns were undertaken by IFFCO across the country during this period.

"The government of India gave us pro-active support too, by exempting all agricultural-related activities – including fertilizer plants – from lockdown restrictions. Remarkably, the timely provision of seeds, pesticides, fertilizers, machinery and agricultural credit made it possible for large areas to remain under cultivation during the lockdown. Overall fertilizer consumption actually increased considerably – with a sales increase of more than 10 percent from April 2020 to January 2021, compared to the previous year."

IFFCO has been prioritising energy efficiency by revamping all of its five ammonia-urea plants as part of a large-scale energy saving project (ESP).

Could you explain more about the rationale behind the ESP project and what's been achieved to date?

"IFFCO, since its inception, had been a front-runner by constantly upgrading technologies at its manufacturing plants. Recently, we invested $270 million implementing massive energy savings at all our five ammonia-urea manufacturing units as part of the ESP. Today, energy consumption at these units is comparable to any new gas-based plants globally.

"Previously, during 2005-06, we also adopted BAT (Best Available Technologies) to cut our energy consumption and carbon emissions. The embrace of new technologies shows what an inventive work environment and culture of continuous learning we have at IFFCO. Similarly, we've also been actively reducing the water footprint across our operations. These actions and plans ensure IFFCO is fulfilling its responsibilities towards meeting Sustainable Development Goals."

Water-soluble fertilizers are a market segment of growing importance to IFFCO. Growth has been phenomenal. Annual sales more than doubled year-on-year to almost 15,000 tonnes in 2018-19, for example, then increased by around one-third to more than 19,000 tonnes in 2019-20. This reflects the growing importance of fertigation in the cultivation of high-value crops such as fruit, vegetables, flowers and sugarcane. IFFCO also launched field trials for nanotechnology-based fertilizers in 2019.

How important is innovation and the development of new speciality/added-value products to IFFCO, and do they have an important role in raising crop productivity and improving water use and nutrient use efficiency in your view?

"We're witnessing a transformation in India's agricultural landscape currently. There's been a shift away from the productivity-led philosophy of the 'green revolution' towards sustainable agriculture led by 'green methods' instead. That's now leading to important changes in the way fertilizers are being produced and used.

"The emergence of the water-soluble fertilizer, specialty fertilizer and biostimulant segments holds the promise of lower fertiliser usage, improvement in water use efficiency and higher nutrient efficacy. These products are sold without any subsidy to farmers. We believe these new segments have the potential to reduce chemical fertilizer consumption by 25-30 percent overall.

"IFFCO is investing a lot in new products designed to help Indian farmers improve their productivity and profitability, and therefore become more competitive globally. We are shortly going to launch a new range of nanotechnology-based fertilizers. These products, particularly *Nano Urea*, really are going to be game-changers for nutrient management.

"Besides this, our liquid biofertilizer and seaweed extract product *Sagarika* is gaining popularity with farmers. *Sagarika* functions as a plant growth promoter and, by improving stress tolerance and pest resistance, increases yields across all crops by 10-15 percent."

What role do you see IFFCO playing in meeting the goals set for India's fertilizer and agricultural sector by government and others?

"IFFCO's business model coincides completely with the government's agenda of creating a sustainable food system and raising rural incomes in future. We are working hand-in-hand with government to achieve Prime Minister Narendra Modi's ambition to double the income of farmers. IFFCO's neem plantation campaign, digital agro-advisory services, agri-commodity exchange, rural finance, e-commerce and retail centres are just a few examples of how IFFCO is helping to achieve this. Affordable rural insurance is another unique IFFCO initiative that helps farmers mitigate the risks they face.

"IFFCO has collaborated with government's e-service for the sale of fertilisers and other agricultural inputs across the country. We have also promoted the government's digital initiative by integrating our e-commerce system with the *Krishi Platform* digital payment app. This allows us to cater to the agricultural needs of all the farmers, from sowing to harvesting."

Looking ahead, how is IFFCO continuing to improve farm incomes and the welfare of farmers?

"IFFCO was an outcome of the 'Green Revolution', being formed in 1967 to meet the fertilizer needs of farmers and ensure food security in the country. Today, more than 35,000 cooperative societies cater to over 50 million farmers, reaching the country's remotest rural areas. We have always had a clear business strategy from the very beginning – to enable Indian farmers to prosper through the timely supply of agriculture inputs and to undertake extension services to improve their welfare in a sustainable manner. Although this strategy has not changed, how we are delivering it has.

"IFFCO recently set up a vegetable processing project in Punjab as part of a joint venture with a leading food processing company from Spain. This should improve the income of farmers by reducing the wastage of perishable farm produce. Recently, we also formed an organic food venture, Sikkim IFFCO Organics Ltd, jointly with the Sikkim Government to benefit and incentivise the state's farmers by adding value to their organic produce.

"IFFCO has extended its market access through its 1,400 retail outlets. These act as one-stops-shops for various agricultural inputs, and can even provide medical assistance.

"Our digital online store IFFCO Bazar, launched in 2016, delivers products and services to 30 million farmers nationally. The *Smart Farm* digital platform, offered through our subsidiary IFFCO Kisan Sanchar Limited, also offers a range of digital services, such as weekly farm health checks, pest and disease prediction and recognition, and irrigation and fertigation planners."

What have been the highlights, major achievements and changes you have witnessed since joining IFFCO?

"Ensuring fertilizer availability was a challenge for the country when I first joined IFFCO in 2000. IFFCO responded by successfully setting up joint ventures in resource-rich countries like Oman, Jordan, and Senegal. We also expanded our in-house production capabilities. That included acquisition of a large underperforming integrated phosphate fertilizer unit and turning it into a profit centre.

"I've also contributed, in many ways, to IFFCO's diversification into general insurance, telecoms services, trading, rural finance, commodity exchange, retail business, food processing, organic farming, urban gardening, etc. As a responsible company, we are now providing goods and services that will help farmers grow more food, economise on their input costs, improve their incomes, and protect the environment as well." ■

PHOTO: YARA

Nitrogen market adjusts to the new normal

ICIS, the independent commodity intelligence company, provides an overview of the nitrogen market. The world supply of urea looks set to outpace market demand in 2021, as several new projects come on-stream. Global ammonia demand, in contrast, is expected to rebound strongly this year after a difficult 2020. The flurry of recent green ammonia projects announcements is another significant market development.

Above: Yara's Porsgrunn production site in Norway will be the site of a major new green ammonia project.

UREA

Urea market braces itself for new supply

A significant increase in world supply of urea in 2021 will outpace global demand, as several new projects come on-stream. This is likely to pressure prices in the second half of the year, although delays to the start-up of new plants should cushion the market impact.

Record prices

In January, urea prices increased to record highs as buyers in Europe rushed to cover their positions, following unexpected early demand from the US. Egyptian prices, for example, touched a six-year high in late January. Since then prices have cooled slightly, although a second wave of demand from India and the US is likely in March.

The major rally in urea export pricing, which began in mid-December last year, appeared to plateau in early February (Figure 1). The upswing in the Brazil cfr price, which began in early November, is also showing sign of levelling off (Figure 2).

Major new capacity emerges

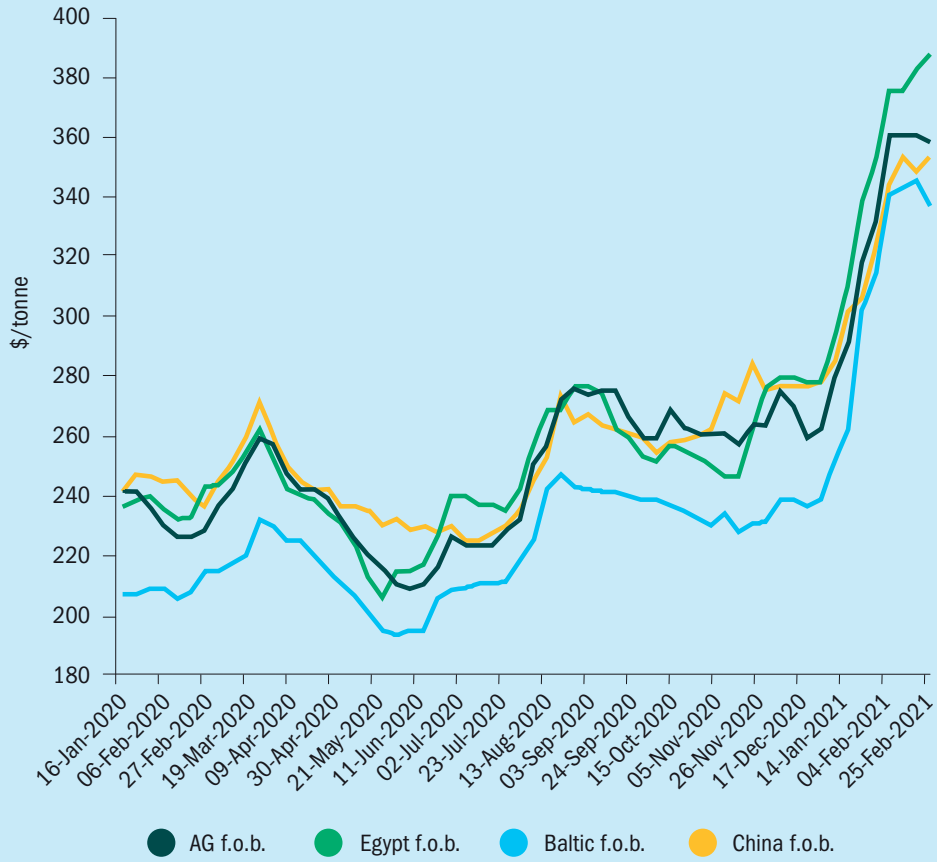
Originally, a total of 12.6 million tonnes of new capacity from India, Nigeria, Russia, Brunei and Iran was projected to come on-stream in 2021. This covers well-advanced production capacity that is either under construction or has already been built. Urea capacity increases expected in 2021 include rises of at least:

- 2.6 million tonnes in India
- 2.6 million tonnes in Nigeria
- 1.9 million tonnes in Russia
- 700,000 tonnes in China.

However, latest projections suggest most of these plants will be now be delayed until late 2021 or 2022 – meaning only around 2.5-3 million tonnes of new urea supply is now expected to hit the market in 2021.

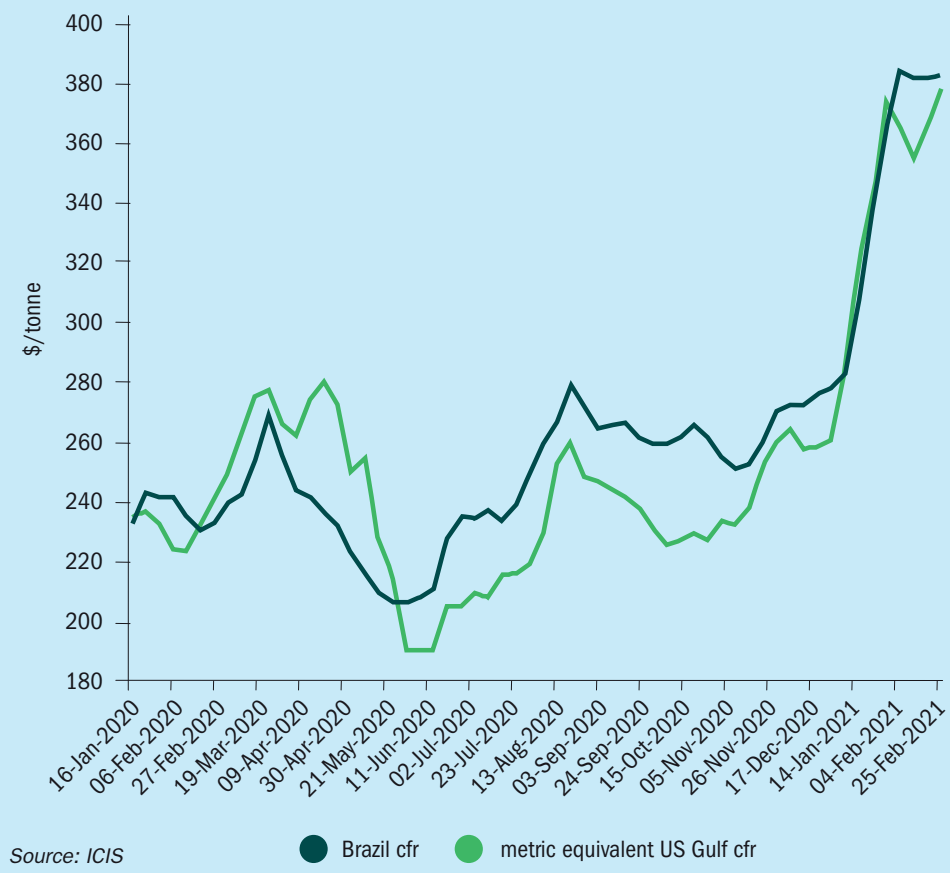
Only one of the four government-owned 1.3 million t/a urea production units in India, for example, is now expected to come on-stream in 2021 due to project delays. Nevertheless, the similar sized

Fig. 1: **Urea export pricing, January 2020-February 2021: f.o.b. benchmarks for Arab Gulf, Egypt, Baltic and China**



Source: ICIS

Fig. 2: **Urea import pricing, January 2020-February 2021: Brazil cfr benchmark with US Gulf cfr price (metric equivalent) included for comparison**



Source: ICIS

Matix urea plant in Panagarh, West Bengal, should come online in April, after a supply of natural gas feedstock was finally secured. The Matix plant has been inoperative for over three years, after starting up for a brief period in October 2017.

Two urea plants in Nigeria – the new world class Dangote plant and Indorama's second urea line – are expected to become operational in mid-2021, although doubts about timings still remain with no official word yet from either producer.

New Russian production capacity, meanwhile, including units at Acron, Metafrax and TogliattiAzot, is also likely to come on-stream between mid-2021 and the year's end.

In Brunei, current shipment capabilities are reportedly inadequate, suggesting significant exports will only begin once port infrastructure has been revamped.

Iran – a special case

The above 2.5-3 million tonnes estimate for extra urea supply in 2021 does *not* include additional production from Iran. It is therefore worth noting that the 1.08 million t/a Lordegan plant in Iran, which started production in late 2020, will ramp-up and achieve full capacity in 2021.

Iran currently has a total urea production capacity of nearly 7.9 million tonnes, with less than half of this quantity being exported. Despite continuing US sanctions, the country has continued shipping to Brazil and Turkey, together with a few cargoes to India via China.

Although there is now the prospect of sanctions being lifted, due to the Biden administration's softer stance on Iran, this could take several months or even be deferred until 2022.

The impacts of supply

Even with the delays and the uncertainty surrounding Iran, 2.5-3 million tonnes of extra urea supply this year is a significant volume for the market to digest. For this to happen, uneconomical or high cost plants in China and Ukraine would need to permanently shut or be regularly shuttered in slower months.

In any case, the Arab Gulf and Egypt will still face a squeeze and increasingly need to look towards Asia to sell their tonnages, as new tonnes from Nigeria have become more competitive in their traditional markets such as Latin America.

"Nigerian cargoes will upset [the urea market in] Brazil and South America as freight advantages are there for them. Some southern European markets and Turkey may be hit too. [That means] Middle Eastern producers and Egypt may now have to look more east than west," one trader told us.

China ended up exporting 5.45 million tonnes of urea in 2020, according to the ICIS supply & demand database, a 10 percent rise on the 4.94 million tonnes exported in 2019. Exports from China are likely to remain limited this year, in our view, given the continuing focus of the Chinese government on national food security and supplying the domestic market.

Rising demand offers some respite

World urea capacity is set increase by 14 million tonnes during 2019-2021 to reach 223 million tonnes, according to the latest International Fertilizer Association (IFA) estimates (*Fertilizer International* 500, p13). Not all of this additional capacity will translate into production though. Indeed, the IFA predicts that urea supply will grow to 197 million tonnes in 2021, while demand will grow by 1.3 percent year-on-year to reach 185 million tonnes. Encouragingly, such an increase in demand would digest a major chunk of the potential 2.5-3 million surplus tonnes of urea anticipated.

Two regions, South Asia and Latin America, are expected to be key drivers of fertilizer use in 2021. However, as always when it comes to the outlook for crop-based fertilizer demand, weather conditions will also be key, especially in the US and India. Currency fluctuations and gas prices, by affecting global demand and production rates, will also be important market factors to look out for.

Keeping a watch on policy and regulation

The impact of new environment regulations in Europe and the UK, which specify the coating of urea with inhibitors, will need to be watched in our view. That is because demand for standard commodity urea may see a drastic decline, if the rest of the region follows Germany's lead and imposes similar regulations. Coating urea with an inhibitor can increase costs to farmers by €40/tonne, without benefiting yield, a rise that could prompt them to make the switch to nitrates instead.

The urea demand outlook for the rest of the world remains positive, however, with the agricultural sector remaining resilient in the face of the coronavirus-related slowdown. Governments are focussed on food security, especially in big markets such as China and India, a stance that bodes well for fertilizer and urea demand in 2021.

AMMONIA

Global demand strongly rebounds after a difficult 2020

Demand for ammonia from international fertilizer and chemicals users bounced back strongly in early 2021. This followed a difficult 2020 in which the Covid-19 pandemic underlined the market's fundamental overcapacity (*Fertilizer International* 499, p4). Producers on both sides of Suez shuttered several ammonia units in 2020, as the economic fallout of the deadly virus hit manufacturers' bottom lines. Cheaper feedstock costs did, however, manage to cushion Covid-19 impacts in certain regions.

While major plant outages and unscheduled shutdowns, by disrupting supply, have acted as catalyst for significant price increases in the first-quarter of 2021, the return of normal production schedules during the year's second-quarter should see those price hikes reversed.

Black Sea exports of ammonia look set to remain higher than in previous years, with a continuation of the 2020 jump in Ukrainian output expected. The restart of Fertial's Algerian plants will also add more tonnes to the merchant ammonia market.

A different picture east and west of Suez

West of Suez, manufacturers in Trinidad have now reversed previous capacity cuts to help meet robust demand from the US agricultural sector. The imposition of import duties on Moroccan and Russian phosphates (*Fertilizer International* 500, p8), meanwhile, is expected to boost domestic MAP and DAP production, and thus Mosaic's ammonia requirements. Buyers in Mexico and Brazil will soak up around half of the remaining Caribbean volume. Another 2020 trend that will continue is the rising number of Trinidadian ammonia cargoes heading across the Atlantic to north Africa and Europe.

East of Suez, Middle Eastern ammonia producers will continue to dominate contract deliveries to buyers on both coasts of India. They will also be eyeing a larger slice of the spot market in South Korea, China and Taiwan too. Rival producers in southeast Asia, despite suffering from higher feedstock costs, will nonetheless be helped by lower freight costs and greater flexibility in delivery dates – due to their closer proximity to the region's key import markets.

Whether more Iranian ammonia cargoes will hit the market in 2021 remains to be seen. The general view is that trade sanctions may ease, given the less hostile policy of the incoming Biden administration. Although Iranian material is only sold into three destinations at present – India, China and Taiwan – the country does have the potential to export more than the current 40,000 tonnes/month.

Chemicals manufacturers in northeast Asia typically schedule their turnarounds during the fourth-quarter. This usually results in an uptick in import demand early in the following year. Significant rebounds in the prices of popular chemicals, such as caprolactam and acrylonitrile, have also boosted current import demand, particularly in China and South Korea.

Green and blue ammonia projects accelerate

On the supply side, 2021 will bring more balance to the global supply and demand equation. This rebalancing follows the overcapacity, and consequent lower prices, created by the investment burst in new projects. While a handful of new ammonia plants are still due to come on-stream during 2021, none will add substantially to export volumes as, being dedicated plants, their ammonia output will be consumed by on-site urea units instead.

Additionally, the recent flurry of green ammonia/hydrogen project announcements is also significant. This demonstrates an acceleration of interest from

A snapshot of the rest of the market

PHOSPHATES

The imposition of import duties on Moroccan and Russian imports by the US Department of Commerce is expected to dominate the phosphates market in 2021. Consequently, phosphates producers in both countries are expected to divert their exports to Latin America and the Indian peninsula instead – the exact volumes depending on the how punitive the finalised duties end up being.

The arrival of import duties will, however, open up opportunities for phosphate producers in other countries to ship product to the US, including Egypt, Mexico, Jordan, Saudi Arabia, Australia and perhaps China.

As well as the shift in trade patterns, the supply/demand balance could be affected by the arrival of new phosphates capacity, with new production plants in Morocco and Egypt expected to come on-stream in 2021.

Also on the supply side, the production shift to higher margin products, at the expense of DAP and MAP, will also continue in 2021, as demand for speciality fertilizers rises globally.

The high phosphates market prices seen at the beginning of this year are expected to ease once Chinese export availability picks up again. By affecting production costs, rising raw material prices are also expected to weigh heavily on the market, as will the rising price of phosphoric acid in India and Morocco.

Russian producers, by focussing on supplying domestic and European farmers during the spring season, could take some tonnages out of the wider market.

SULPHUR

Sentiment is bullish in the global sulphur market. The ongoing supply tightness has shown no signs of easing and downstream demand also remains robust.

The market was active throughout February and prices have climbed to new highs, despite top importer China being absent for the week-long Lunar New Year holidays.

Supply tightness remains a key feature globally, particularly for regions which rely on refinery-produced sulphur. Refineries have lowered their output since 2020, in response to significantly lower fuel oil demand during the coronavirus outbreak. In the short term, the supply situation is not seen as improving, given the pandemic's continuing impact.

In the US, sulphur production from refineries is at a near-decade low. Further supply concerns have also emerged recently after an intense polar storm swept across Gulf Coast states. This resulted in shutdowns and production cuts across a swathe of regional petrochemicals plants and refineries.

POTASH

News of two long-term supply settlements agreed between the Belarus Potash Company (BPC) and a consortium of Chinese buyers and regular customers in India, respectively, is still being digested by the global muriate of potash (MOP) market.

Both annual settlements were agreed at $247/t cfr (cost & freight) – a $27/t increase on the expired 2020 China agreement, and a $17/t increase on BPC's previous settlement with India.

BPC's rival producers have yet to set out their 2021 plans for potash contracts with key importing countries. But speculation remains that some producers may opt to renegotiate their own contracts, or focus on sales to higher-priced destinations, such as Brazil.

"We want to organise all sales around the world and calculate what we can perform," said a source at one European producer. "Crazy times – [we] need to take a pause and evaluate the production and demand." Elsewhere, producers have largely closed their order books for first-quarter sales of granular product into the booming Brazilian market. Producers who are sold out for the first-quarter have been heard asking $300/t cfr for second-quarter loading.

Canadian MOP major Nutrien is keeping an eye on Brazil, thanks to favourable crop economics and firmer MOP pricing, as well as considerable inventory-building in this key market ahead of what should be a strong *Safrinha* corn season. The company closed 2020 on a high note after reporting firmer sales in the year's fourth-quarter. This was despite lower full-year 2020 sales, a sign that the global Covid-19 pandemic has hit the Canadian giant's bottom line.

Finally, demand for sulphate of potash (SOP) in northwest Europe remains firm and pricing stable. However, there is speculation that a price uptick may be imminent, based in part on a shortage of liquid sulphur and sulphuric acid feedstocks for Mannheim production.

The other key concern troubling the SOP industry currently is the lack of shipping containers for product transportation. This confirms that national lockdowns and logistical snags continue to frustrate traders.

investors, as they seek to tap into environmentally-friendly plants likely to attract financial incentives from public bodies and governments. Major fertilizer industry players like Yara, CF Industries and Fertiberia have all pledged to pour huge sums into green ammonia projects (*Fertilizer International* 499, p8) – a trend that can only harden as 2021 progresses.

Similarly, to help the fight against global warming, more blue ammonia projects are also set to be announced, with existing manufacturing sites being adapted and upgraded to capture carbon dioxide.

Efficient marine engines

The race to develop efficient marine engines that run on ammonia, rather than traditional fossil fuels, should provide another boost for ammonia market players. This will open up a new market segment, if and when the technology takes a step closer to the finish line.

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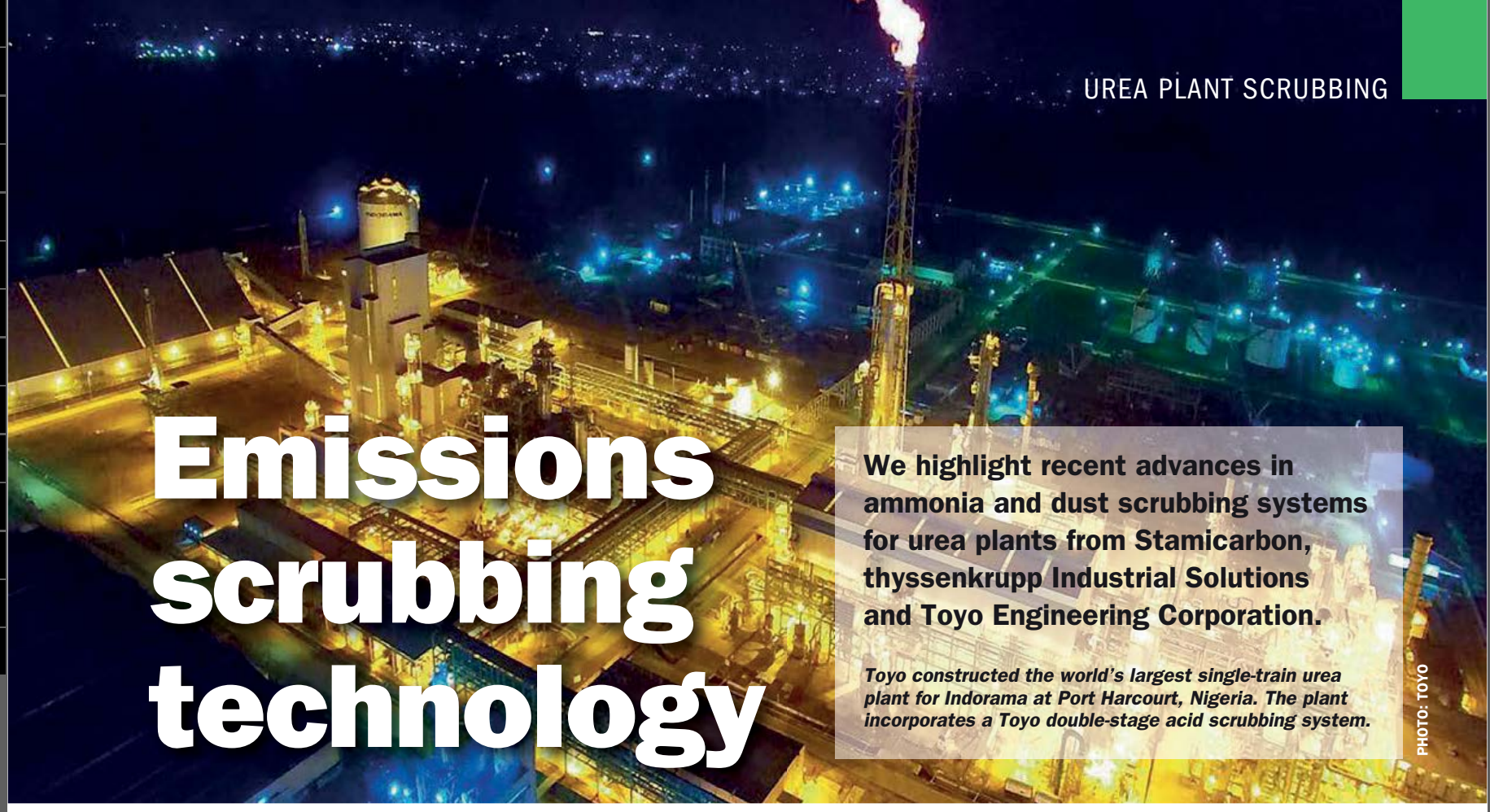


Emissions scrubbing technology

We highlight recent advances in ammonia and dust scrubbing systems for urea plants from Stamicarbon, thyssenkrupp Industrial Solutions and Toyo Engineering Corporation.

Toyo constructed the world's largest single-train urea plant for Indorama at Port Harcourt, Nigeria. The plant incorporates a Toyo double-stage acid scrubbing system.

PHOTO: TOYO

TOYO ENGINEERING CORPORATION

High efficiency urea plant scrubbing systems

Japan's Toyo Engineering Corporation (Toyo) has developed technologies to abate urea and ammonia in emissions and effluents from urea plants since its establishment as a leading urea process licensor in 1961.

The abatement of ammonia emissions is a particularly critical issue, as the recent introduction of stricter regulatory requirements are not achievable by conventional water scrubbing systems alone. Typical emissions guidelines for urea plant finishing section are 50 mg/Nm^3 for urea dust and 50 mg/Nm^3 for ammonia.

Toyo's latest reduction technologies for cutting ammonia and dust emissions at urea plants are described below

Single-stage water scrubber

Toyo offers a water scrubbing system for removing urea dust at the finishing stage in prilling and granulation plants. The system has the ability to reduce the dust in exhaust air from urea finishing sections to less than 30 mg/Nm^3. The system has been adopted at more than 40 prilling towers and granulation plants worldwide and benefits from the following features:

- Low power consumption thanks to its low pressure drop of only 50-150 mm H_2O
- Efficient recovery of urea as a 45 wt-% solution
- Lower construction cost due to a simple structure and the low loading weight of the polypropylene packed bed.

The system is a packed bed type tower with demister (Figure 1). Exhaust air enters the bottom of the scrubber and rises upwards through a packed bed. Urea dust is removed when this exhaust gas comes into contact with a descending stream of water moving downwards in counter-current. Scrubbed air is finally vented to the atmosphere from the top of the scrubber after mist carry-over has been eliminated.

Toyo also offers three acid scrubbing options for removing ammonia emissions:

- A single-stage acid scrubbing system
- A double-stage acid scrubbing system
- An acid scrubbing system without by-product.

Single-stage acid scrubber

This system has the same configuration as the water scrubbing system (Figure 1). However, by injecting acid into the circulation water, ammonia emissions in the exhaust air are reduced to below 20 mg/Nm^3. At the same time – similar to the water scrubbing system – urea dust emissions are also scrubbed to less than 30 mg/Nm^3.

The system removes and recovers ammonia gas as either urea ammonium sulphate (UAS) or urea ammonium nitrate (UAN) solution, depending on the acid injected. With this system, because it combines to form an ammonium salt instead, it is not possible to return captured urea to the urea plant.

Double-stage acid scrubber

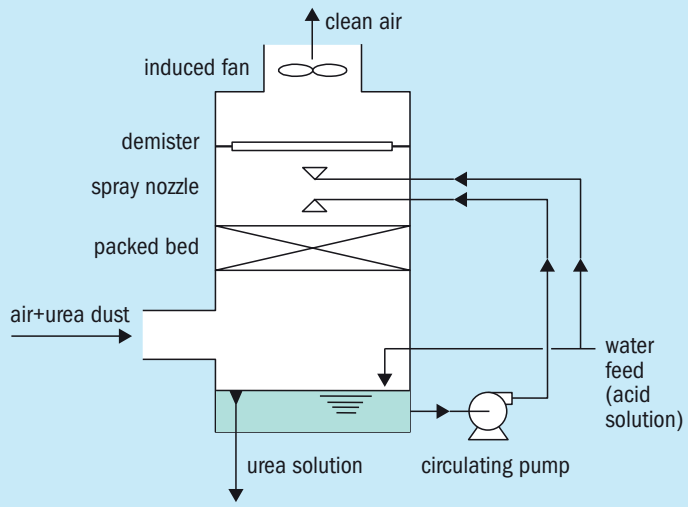
This system combines water scrubbing and acid scrubbing in two separate stages (Figure 2). Urea dust is firstly captured by a packed bed in the lower water scrubbing stage and recovered as 45 wt-% urea solution. Acid scrubbing in the packed bed of the upper stage is then used to absorb and remove ammonia gas. This system option does allow urea to be recovered as a separate product. This scheme is suitable for plants which need to minimise by-product, or instead produce ammonium nitrate (AN) or ammonium sulphate (AS).

Eliminating by-products

Toyo acid scrubbing systems can be configured to eliminate by-products. In this system option, ammonia present in exhaust air is absorbed by sulphuric acid during an acid scrubbing stage and recovered, together with urea dust, as UAS. A small independent evaporator then concentrates the recovered UAS solution. This is sent to the urea finishing section where it is added to the urea feed.

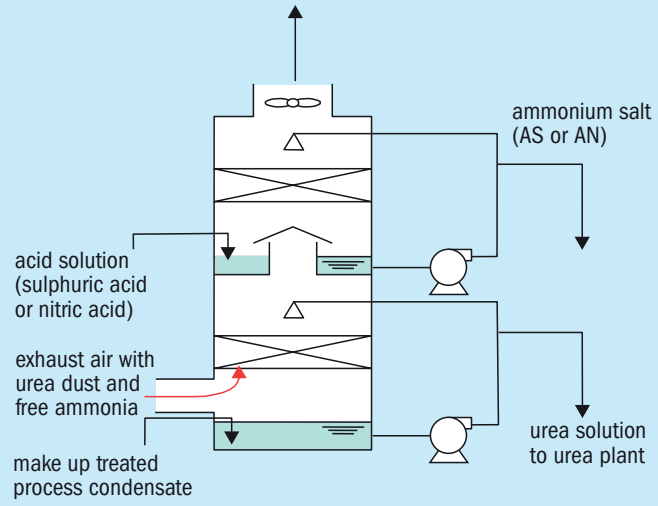
This setup eliminates ammonium sulphate (AS) as a by-product by incorporating it within the urea production process. The final urea product obtained, which contains 0.2-0.3 wt-% AS, contains sulphur as an additional crop nutrient. This system option is suitable for plants producing urea for the agricultural market, particularly when there is no scope for producing by-products other than the main urea product.

Fig. 1: **Dust scrubbing system**



Source: Toyo

Fig. 2: **Double stage acid scrubbing system**

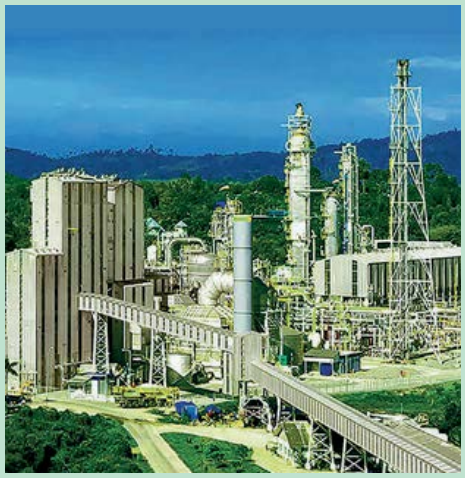


Source: Toyo

World-class scrubbing projects

Toyo was awarded a number of major urea granulation plant contracts in the 2010s. Two notable examples that incorporated Toyo scrubbing systems are the large-scale Kaltim No 5 project (3,500 t/d) in Indonesia for PT Pupuk Kalimantan Timur (Kaltim), and a world-class project (4,000 t/d) for Indorama Eleme Fertilizer and Chemicals Limited (IEFCL) in Nigeria. Brief case studies for both projects are provided below.

Toyo case study 1: Kaltim No 5 project, Bontang, Indonesia



In 2011, Toyo was awarded a contract by PT Pupuk Kalimantan Timur (Kaltim) to construct a 2,500 t/d ammonia plant and 3,500 t/d urea plant (Table 1). Kaltim is a subsidiary of the state-owned PT Pupuk Indonesia Holding Company. The urea plant was designed using Toyo's *ACES21®* urea process and spout-fluid bed granulation. It is one of the largest single-train ammonia/urea complex in Southeast Asia.

Toyo provided engineering, procurement and construction (EPC) for the whole complex on a turn-key, lump sum basis in collaboration with PT Inti Karya Persada Tehnik (IKPT), a Toyo subsidiary company. Urea production at the plant began in early 2015.

A Toyo water-scrubbing system for urea dust was also installed as part of this project. This was acceptable as domestic Indonesian regulations did not specify the need for an acid scrubbing system. A performance test was carried out at the ammonia/urea complex during the first year of production with excellent results (Table 2). Urea dust emissions at the plant were reduced to just 21 mg/Nm^3.

Table 1: **Kaltim No 5 project summary**

Plant owner	PT Pupuk Kalimantan Timur (Kaltim)	
Plant capacity	Ammonia 2,500 t/d / Urea 3,500 t/d (Granular urea)	
Location	Bontang, Indonesia	
Ammonia process	KBR *Purifier*™ Process	
Urea process	Toyo *ACES21®* and Spout-Fluid Bed Granulation	
Project scope	Turn-key lump sum in cooperation with IKPT	
Key milestone	2011 September	Effective Date of Contract
	2014 November	Mechanical Completion
	2015 January	First Production
	2015 August	Commercial Operation

Source: Toyo

Table 2: **Urea plant performance Kaltim No 5 urea plant**

Production capacity, t/d	**3,545**
Product quality	
Total nitrogen content, wt-%	46.2
Biuret content, wt-%	0.9
Moisture content, wt-%	0.3
Granule size, wt-%	
2 to 4.76 mm	97.2
less than 1 mm	0
1 to 2 mm	3
above 4.76 mm	0
Urea dust emission, mg/Nm^3	**21**

Source: Toyo

Toyo case study 2:
Indorama train 1 project, Port Harcourt, Nigeria

In 2013, Indorama Eleme Fertilizer & Chemicals Limited (IEFCL) awarded a contract to Toyo and its consortium partner Daewoo Nigeria Limited to jointly build the world's largest single-train ammonia-urea complex at Port Harcourt in Nigeria. The complex, which has a design capacity of 2,300 t/d for ammonia and 4,000 t/d for granulated urea, became operative in mid-2016 (Table 3). It consumes locally-available natural gas as a feedstock and uses licensed KBR technology for its ammonia process and Toyo's *ACES21*® technology for urea production.

The urea finishing section produces high quality urea granules (Table 4) and incorporates a highly-effective Toyo double-stage acid scrubbing system (Figure 2). This successfully mitigates ammonia emissions, as well as reducing urea dust emissions to the atmosphere to less than 10 mg/Nm³ (Table 4). ■

Table 3: **Indorama ammonia/urea train 1 project summary**

Plant Owner	Indorama Eleme Fertilizer and Chemicals Limited (IEFCL)	
Plant Capacity	Ammonia 2,300 t/d / Urea 4,000 t/d (Granular urea)	
Location	Port Harcourt, Rivers state, Nigeria	
Ammonia process	KBR *Purifier*™ Process	
Urea process	Toyo *ACES21*® and Spout-Fluid Bed Granulation	
Project scope	Turn-key lump sum in cooperation with Daewoo Nigeria Ltd	
Key milestone	2013 April	Effective Date of Contract
	2015 November	Mechanical Completion
	2016 May	First Production
Source: Toyo	2016 June	Commercial Operation

Table 4: **Urea plant performance of IEFCL urea plant**

Production capacity, t/d	**4,003**
Product quality	
Total nitrogen content, wt-%	46.4
Biuret content, wt-%	0.8
Moisture content, wt-%	0.3
between 2 to 4 mm	93
Urea dust emission, mg/Nm³	**7**

Source: Toyo

Conclusions

Urea dust scrubbing: Toyo's water scrubbing system is a proven technology able to reduce urea in exhaust air from the urea finishing section to less than 30 mg/Nm³. By applying a double stage acid scrubbing system, urea dust emissions in exhaust air finishing section can be reduced even further – to less than 10 mg/Nm³.

Ammonia scrubbing: Toyo's highly effective acid scrubbing systems can reduce ammonia emission to less than 20 mg/Nm³. These systems are flexible, being offered in three options: single-stage acid scrubbing, double-stage acid scrubbing, and acid scrubbing without by-product. ■

THYSSENKRUPP INDUSTRIAL SOLUTIONS

Optimising emissions control at urea plants

Low gaseous emission limits, especially for ammonia, require an acidic scrubbing system at urea plants. Besides the urea dust and ammonia vapour emissions typically associated with the granulation unit, gaseous ammonia emitted by the plant's synthesis unit needs to be treated as well.

When required, the ammonia in the off-gas of the synthesis unit is removed by a standalone acidic scrubbing system. These scrubbing systems typically consists of a scrubber installed within the steel structure of the synthesis unit, together with pumps located at ground level plus associated instrumentation and piping. However, this separate dedicated scrubbing system is not necessarily required, if the plant already has a scrubbing system installed at the granulation unit, as explained below.

During the engineering for two urea plants in the United States, thyssenkrupp Industrial Solutions (tkIS) engineered an efficient method to catch the ammonia emissions of the synthesis unit. This employed a more integrated engineering approach.

Traditionally, the synthesis unit and granulation unit of a urea plant are viewed as individual and separate sections. They are built using the licensor's know-how with each unit constrained by their respective battery limits. Yet, when viewed together, a contractor can overcome these constraints by combining both units in one interconnected 'smart' plant.

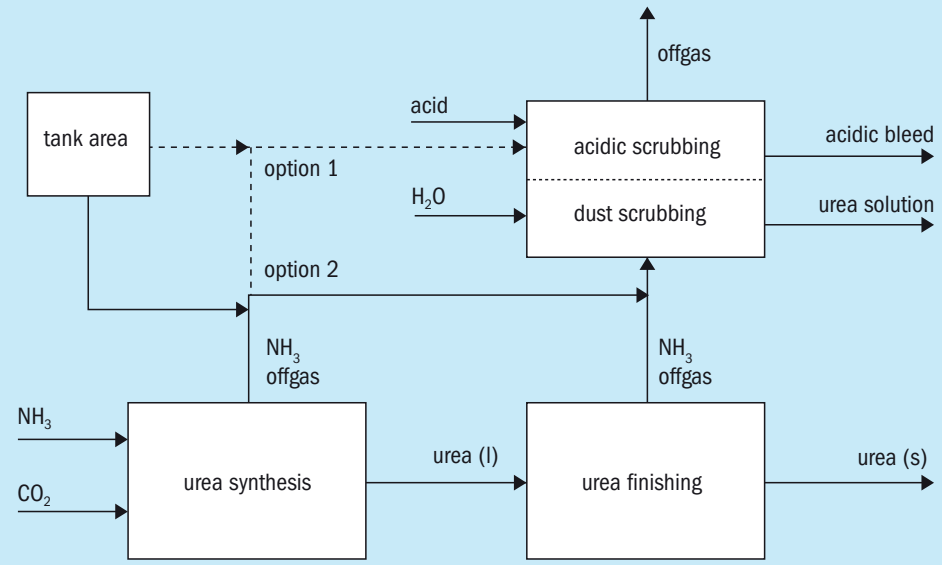
A single integrated scrubbing system

The characteristics of the off-gases of the synthesis unit and granulation unit do differ from one another. The flow rate of the synthesis unit off-gas is much lower than that of the granulation unit while its ammonia concentration is much higher.

Nevertheless, these two off-gas streams can both be routed to the scrubbing system of the granulation unit and be jointly treated in the granulator scrubber. In principle, this also provides the option to treat other ammonia-containing off-gases from the synthesis unit in the granulator scrubber as well, e.g. from the ammonia water tank or the urea solution tank (Figure 1).

Treating the off-gases of both units in the granulation scrubber results in lower operating costs and reduces the amount of electrical equipment in operation. At the same time, emissions are minimised, thereby reducing product losses as well. Less equipment also translates into lower investment costs.

Fig. 1: **Routing of ammonia off gases**



Source: tkIS

Table 1: **Emission limits for urea granulation plants**

Source	Urea dust/particulate matter (mg/Nm³)	Ammonia (mg/Nm³)
World Bank/IFC Pollution Prevention and Abatement Handbook (PPAH), 1998	<50	<50
European Fertilizer manufacturers Association (EFMA) Best Available Technology (BAT) Booklet, 2001	<50	<50
EU Best Available Technology Reference Document (BREF), 2007	<15-55	<3-35
Louisiana, 2012	PM10/PM2.5 <8.3 <20% opacity	<30
Iowa, 2012	PM10/PM2.5 <20.96 No visible emissions	Best available control technology (BACT)

Source: tkIS

Table 2: **Dust and ammonia emissions from new urea granulation plants**

Parameter	Required	Achieved
Dust emission	<8.3 mg/Nm³ *	0.86 mg/Nm³ * 5.6 mg/ Nm³ **
Opacity***	< 20%	average: 3.8 % maximum: 5.8 %

* using EPA 5 method
** using EPA 202 method
*** using EPA 9 method

Source: tkIS

The scrubbing systems built by tkIS for the two US urea plants were of a horizontal cross flow type design with structured internals from Kimre (*Fertilizer International* 485, p25). This can remove dust and ammonia to very low levels, as shown in Tables 1 and 2. With this design, the visibility of the plume can also be reduced by capturing submicron particles with an *AEROSEP*® stage, if required.

A simple, lower-cost alternative?

An alternative to the horizontal cross flow type design are vertical tray type scrubbers. These consist of at least one dust removal stage and one acidic stage. A major advantage of the vertical tray type design is that the distribution and removal of condensate and washing agent are less elaborate. Such scrubbers, because of their round or square shape, do however need to be carefully configured within the plant layout.

A common feature of vertical tray and horizontal cross flow type designs is that both scrubbing systems require either sulphuric acid or nitric acid as a washing agent – which then reacts with ammonia in the scrubber to form an ammonium salt solution.

If ammonium nitrate (AN), calcium ammonium nitrate (CAN) or urea ammonium nitrate (UAN) are also produced on site, the resulting small amount of weak ammonium nitrate solution can be exported to these units and converted into a marketable product.

If the scrubbing is done using sulphuric acid, the ammonium sulphate (AS) generated can either be discharged to battery limits, or returned to the urea granulator feed after treatment – using proprietary Ammonia Convert Technology (ACT) offered by thyssenkrupp Fertilizer Technology (*Fertilizer International* 469, p25). The resulting urea product still fulfils fertilizer-grade urea specifications while, advantageously, containing a minor amount of sulphur as well (0.1% maximum), a beneficial secondary crop nutrient. With sulphur depletion an increasingly common problem in many soils, this is a welcome urea product enhancement. Crops which are sulphur-deficient also pick up less nitrogen. Consequently, sulphur can support plant nitrogen uptake, an important property given the increasing focus on avoiding nitrogen losses.

Tailor-made scrubber design

In general, there are three different sources of emissions a scrubbing system has to deal with:

- Fine dust – Small quantities, good visibility in plume, difficult to remove
- Coarse dust – Large quantities, fair visibility in plume, easy to remove
- Ammonia – Gaseous, easy to remove.

For fine dust removal, the installation of sophisticated internals, or even an *AEROSEP*® stage, is necessary to remove submicron particles. In this regard, horizontal cross flow scrubbers are very effective at delivering the low emission requirements associated with submicron particle removal, while also achieving a very low pressure drop.

Yet many regions of the world do not yet specify extremely low emission levels.

The most commonly applied upper emissions limit for dust and for ammonia is still the World Bank standard of 50 mg/Nm³. In these circumstances, the removal of fine dust is generally not necessary.

This allows simplified scrubbing systems to be developed and installed at many locations. This has operational and cost benefits, given that fine dust removal requires much more effort and is also the main contributor to overall pressure drop. With this in mind, thyssenkrupp Fertilizer Technologies (tkFT) nowadays offers a simplified horizontal scrubbing system (compared to the BACT standard) for less stringent dust and ammonia emission requirements (e.g 50 mg/Nm³). This simpler scrubbing system offers the following operational and cost benefits:

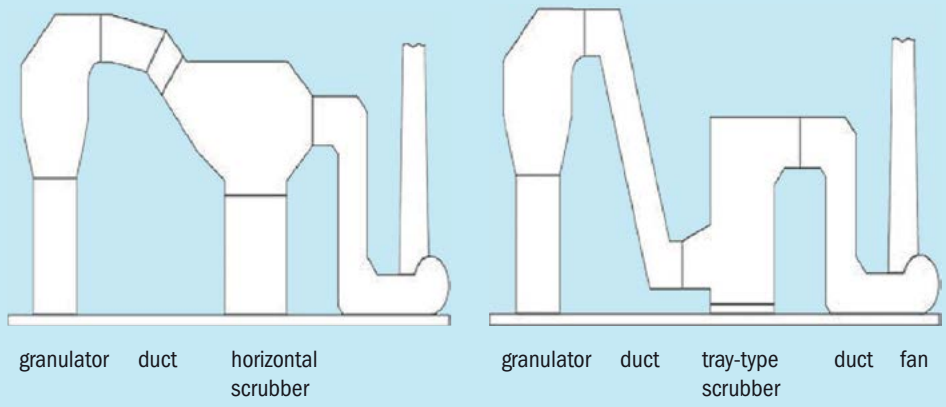
- Reduced number of stages/internals
- Less energy consumption due to lower pressure drop
- Lower equipment cost due to the scrubber's more compact design.

A brief comparison of a conventional tray-type scrubbing system with this new cost-efficient horizontal tkFT scrubber concept, designed for dust and ammonia emission limits of 50 mg/Nm³, revealed the following:

Equipment size: For a 3,600 t/d plant, tkFT's cost efficient horizontal scrubber concept can reduce the cross-sectional area of the cooler scrubber by more than 50 percent, relative to the cross-sectional area of a standard tray-type scrubber for the same size plant. This is possible by adapting the internal configuration and the mechanical design to actual needs. The smaller and simplified design also lowers the overall equipment cost. The pressure drop is far lower than for a comparable tray-type scrubber, even with the resulting higher gas velocity.

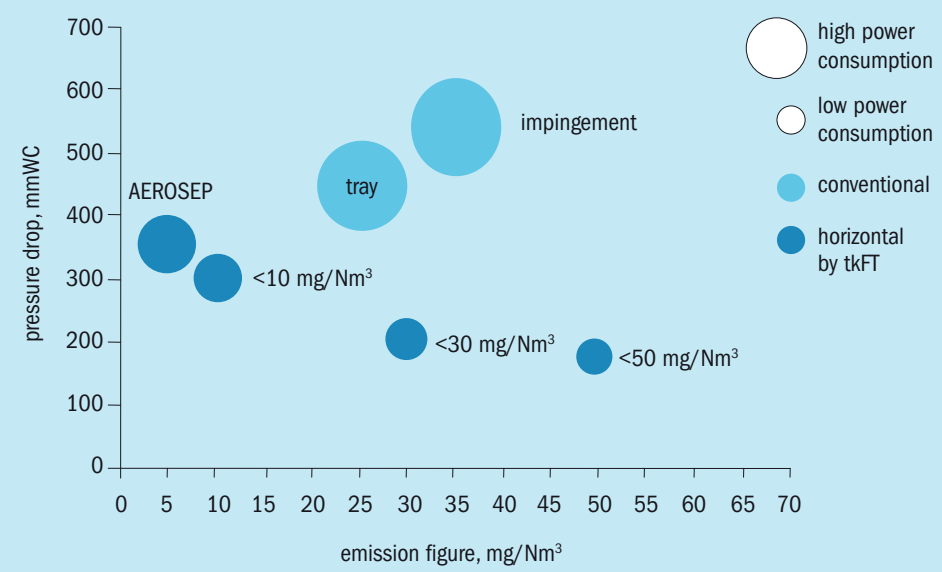
Energy Consumption: The energy consumption of a urea granulation plant is mainly determined by the amount of air used by the scrubber, and the pressure drop associated with both the scrubber and its off-gas ducting (Figure 2). In a horizontal cross-flow type scrubbing system, off-gas routing is straightforward. The off-gas travels from the outlet of the granulator to the scrubber inlet and from the scrubber outlet to the suction side of the scrubber exhaust fan, without any bend or change in direction. For a tray-type scrubber, in contrast, the off-gas needs to be routed down to enter the bottom of the scrubber and then, after leaving the top of scrubber, travels down again to the inlet of the scrubber exhaust fan, causing extra pressure drop. Consequently, the pressure drop within the horizontal cross-flow design is much lower than in a tray-type scrubber: overall, the pressure drop for a horizontal granulator scrubber is around 200 mmWC, versus the considerably higher pressure drop of 400-500 mmWC for a tray-type scrubber. The relationship between achievable emission limits and pressure drop (and therefore power consumption) for different scrubbing systems is shown in Figure 3.

Fig. 2: **Typical duct routing in different scrubbing systems**



Source: tkIS

Fig. 3: **Typical pressure drops associated with dust emission limits**



Source: tkIS

Summary

The range and variety of emission requirements in new-build projects today is greater than in the past. At the same time, even existing operations are being faced with the need to adopt more and more stringent environmental regulations. Fortunately, cost-efficient revamp options are now available to meet these regulatory changes.

Permissible levels of dust and ammonia emissions at urea plants are typically governed by either local regulations or customer-specific limits. The installation of a single integrated scrubbing system for both the synthesis unit and granulation unit – whether for standalone plants or a larger complex – is a more efficient plant concept.

Together, tkIS and tkFT offer high-performance, tailor-made scrubbing systems to urea plant operators. These comply with emission limit requirements while minimising investment and operating costs. These systems are suitable for new plants as well as the revamping of existing production sites. ■

STAMICARBON

Experience with *MicroMist*™ and Jet Venturi Scrubbing systems

It is a well-known fact that granulation plants and prilling towers generate substantial submicron dust in their off-gas. The resulting negative environment effects are equally well-known.

Consequently, governments are introducing increasingly strict fine particulate emissions regulations. Stamicarbon, the innovation and license company of Maire Tecnimont, together with its partner EnviroCare International have, however, found a solution.

The two companies have co-developed the *MicroMist*™ Venturi (MMV) Scrubber for granulation plants and the Jet Venturi Scrubber for prilling towers. Both these innovative, high-performance scrubbers can remove submicron urea dust particles at extremely high efficiencies.

First *MicroMist*™ Venturi (MMV) Scrubber installation in a granulation plant

The first urea granulation plant equipped with innovative *MicroMist*™ Venturi (MMV) scrubbing technology was licensed in 2013. Four more installations have followed since then; two of these are currently in operation and three are under construction. MMV scrubbing technology forms one part of Stamicarbon's overall granulation plant design (Figure 1).

The first ever MMV scrubber was installed as part of a large-scale single-line Stamicarbon urea granulation plant with acidic scrubbing. Ammonium sulphate (AS) is generated by the scrubber from the reaction between the ammonia present in the off-gas and injected sulphuric acid. This is recycled back into the granulator – eliminating any disposal streams.

The water content of the AS salt generated by the scrubbing system (about 55 wt-%) means it cannot be mixed directly

Fig. 1: **Process flow diagram for Stamicarbon's optimised granulation design**

Source: Stamicarbon

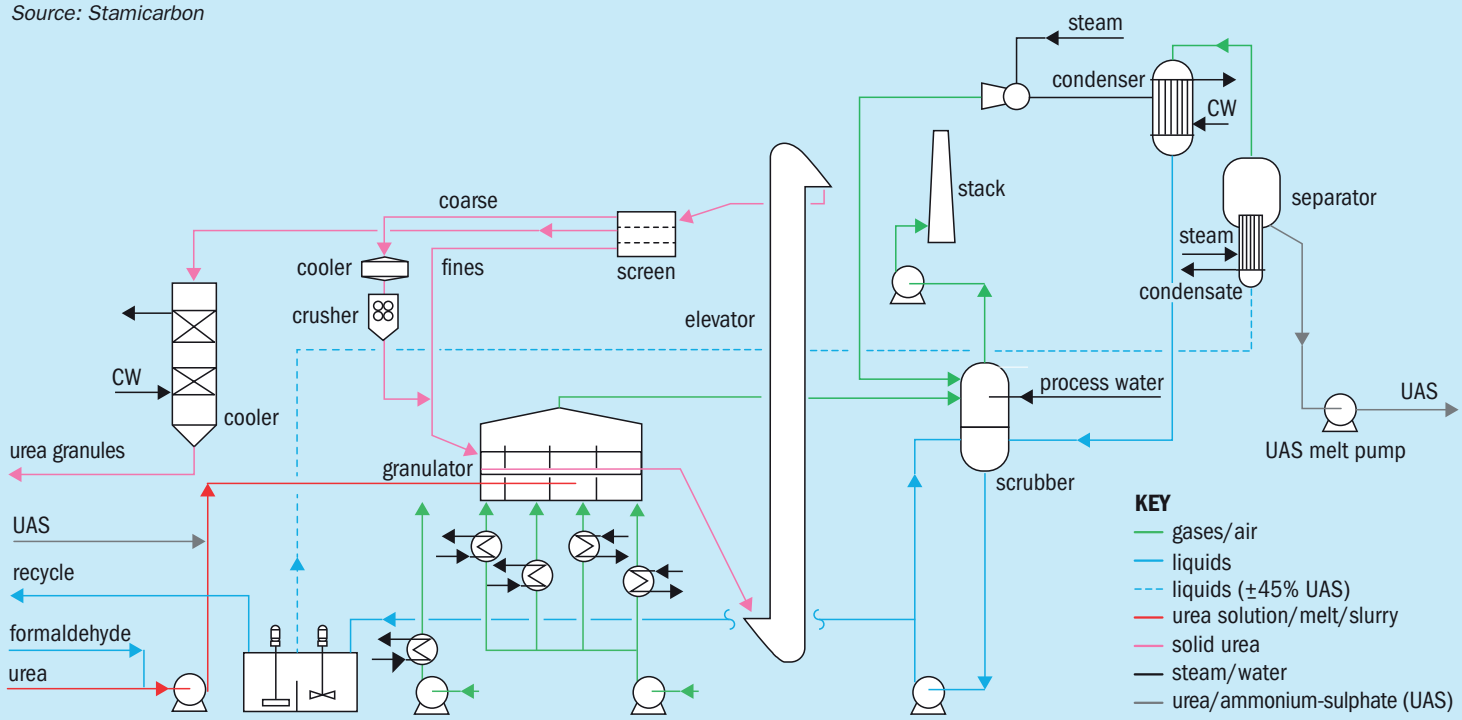
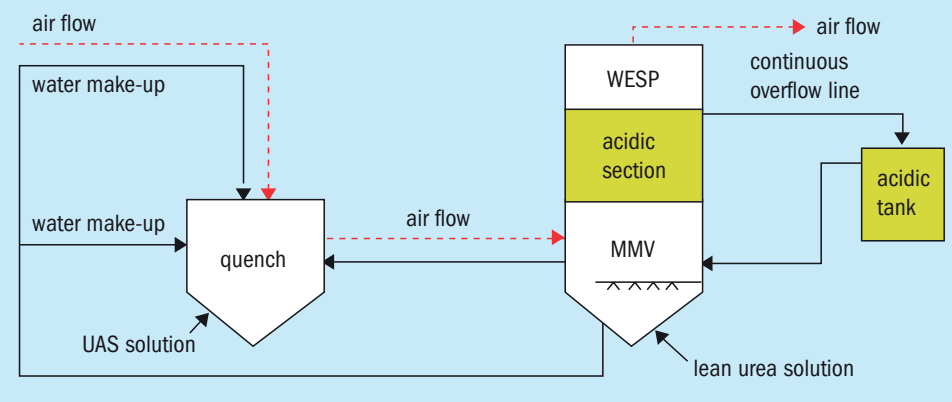
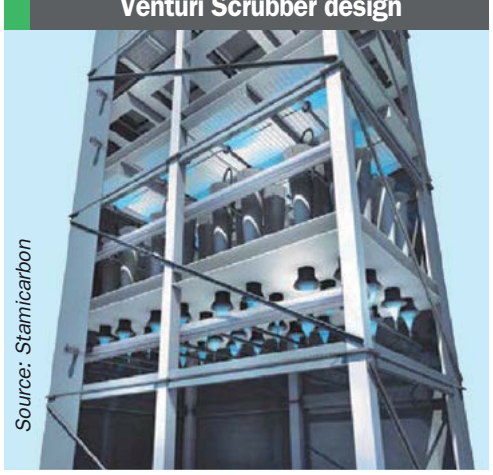


Fig. 2: **Original MicroMist™ Venturi Scrubber design**



Source: Stamicarbon

Fig. 3: **New *MicroMist*™ Venturi Scrubber design**



Source: Stamicarbon

with the main urea melt fed to the plant's granulator via nozzles (water content 1.5 wt-%). Instead, a dedicated evaporation step is used to regulate the water content of the liquid urea ammonium sulphate (UAS) recycled to the granulator.

Original MMV design

The original MMV scrubber design is shown in Figure 2. This incorporates a preliminary quench scrubbing stage. The majority of the dust is separated from the air flow in this quench vessel. The scrubbing process is described below.

Exhaust air from the granulator enters the quench vessel where circulating UAS solution is sprayed into this air flow. The temperature difference between the air flow and the UAS solution promotes the collection of urea dust – with water in the gas flow naturally condensing on top of the dust particles. Within the quench, lean urea solution drawn from the sump of the MMV column is used as make-up water to compensate for evaporation losses.

On leaving the quench vessel, cooled and partly saturated air enters the bottom section of the MMV scrubber, where it is further conditioned by introducing a mist of droplets. These are created by the process condensate make-up sprayer. Lean urea solution is sprayed as a fine mist into the airflow as it enters the MMV stage. This mist collides with the sub-micron dust particles as they first enter and then exit the *MicroMist*™ Venturi. This separates them from the air flow.

On leaving the MMV, the air is introduced into the middle acidic scrubbing section where ammonia is removed. The ammonia reacts with sulphuric acid solution circulating over the acidic scrubber trays to form ammonium sulphate. The resulting ammonium sulphate solution discharges from the trays into the acidic tank. The overflow from this tank flows continuously to the quench scrubber.

After leaving the acidic section, the air flow passes through a mist eliminator (demister). This prevents entrained acidic mist from entering the wet electrostatic precipitator (WESP) and the granulator scrubber fan. The air flow then enters the WESP, the final treatment step. Within the WESP, cooled steam condensate supplied to wash the walls becomes a second source of make-up.

This MMV design incorporates two overflow lines:

- A continuous overflow line: going from the *MicroMist*™ Venturi column into the quench vessel.
- An emergency line to prevent overfilling: going from the quench column into the dissolving tank of the granulation plant.

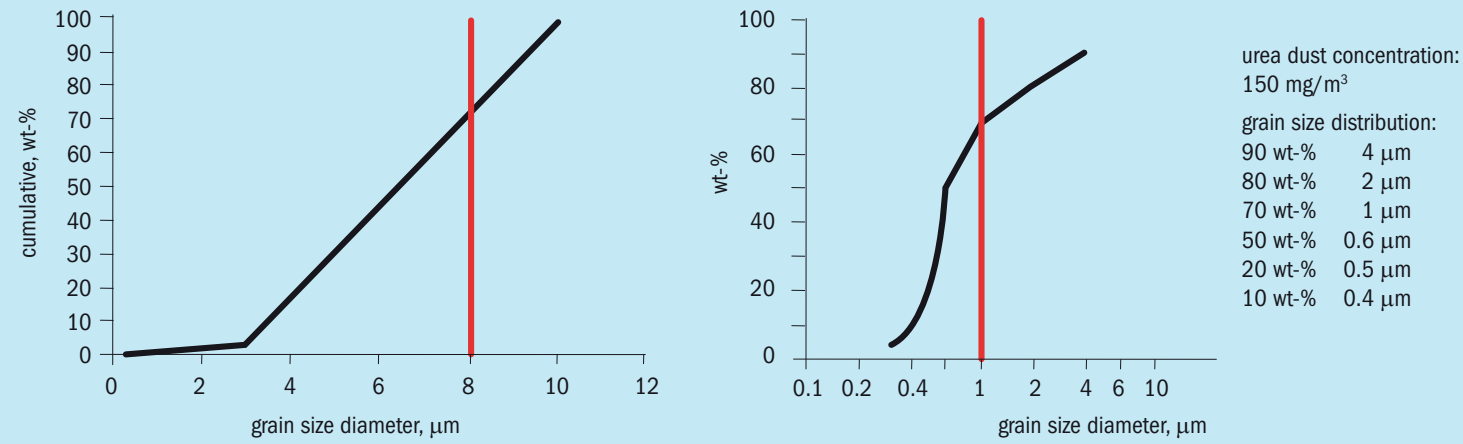
Problem solving during commissioning

Unsurprisingly, some teething issues and design deviations occurred when the scrubbing system initially entered operation. These were resolved as follows:

An air flow with high concentration of entrained urea entered the MMV scrubber system from the quench. This resulted in a significantly concentrated urea solution in the MMV sump instead of a lean solution. As a consequence, no lean urea solution was available to compensate for the evaporation losses in the quench column. This was addressed by maximising the level in the MMV column and then using the overflow as make-up to the quench column. A trench was also installed in the cross-over duct to act as drain catch. The solution from this trench was then used to decrease the urea concentration in the MMV sump down to an acceptable operational level of 30 percent.

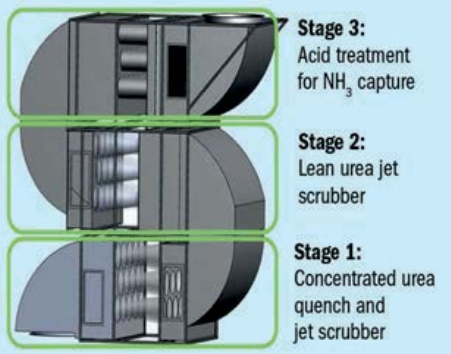
At the same time, an upset of the total water balance was avoided by returning

Fig. 4: **Typical particle-size distributions for dust in the off-gas of granulation (left) and prilling plants (right). The red line shows the particle size at the 70 weight-percent cut-off**



Source: Stamicarbon

Fig. 5: **Scrubber cutaway view with three stages indicated**



Source: Stamicarbon

Fig. 6: **Jet Venturi Scrubber pilot unit after fabrication in ECI's workshop. Numbered boxes and the gas flow directions are marked**

Source: Stamicarbon

urea entrainment to the quench vessel by gravity.

Within the MMV column, urea entrainment went from the MMV section into the acidic section. This happened as a direct consequence of the above deviation. The urea solution level in the MMV sump fell more rapidly than could be matched with fresh make-up water, risking cavitation in the Venturi tubes.

This issue was solved by closing the overflow line from the acidic tank to the quench vessel. This allowed the extra water generated to fall back into the MMV sump and restore its level.

Landmark dust emissions reduction

Once the above commissioning difficulties were overcome, official testing reported urea dust emission levels of less than half the (already stringent) target of <5 mg/Nm³ and a plume opacity of zero percent. These results – by confirming that Stamicarbon's urea granulation plants were able to exceed even the most stringent dust emissions targets – were viewed as a milestone achievement for the urea industry globally.

New MMV scrubber Design

An updated design has now been introduced for all future projects, incorporating the lessons learned to date (Figure 3).

The main upgrades include:

- **An optimised quench sump.** A new reduced capex design optimises the water balance.
- **Using the scrubber as small UAN production unit,** where nitric acid is used as the acidic scrubbing medium. This allows producers to avoid waste generation by directly converting the acid into a UAN-32 final product within the scrubber. This solves two operational issues with one solution – as the scrubber uses acid to reduce ammonia emissions, while producing a finished final product instead of a waste salt.
- **Training.** Operators can now learn to operate the MMV scrubber using Stamicarbon's Operator Training Simulator, as this now includes a specific scrubber training package.

The Jet Venturi Scrubber

The exhaust gas from urea prilling towers contains a very fine dust with an extremely large surface area. Indeed, up to 70 weight-percent of the total dust load can consist of submicron particles. This fine dust creates a highly visible, persistent plume and does not dissipate easily. Consequently, environmental regulations for prilling tower emissions are becoming stricter. Permissible dust emissions levels within Europe are currently 50 mg/Nm³ maximum. Limits are even more stringent in some other regions.

In response to this, Stamicarbon and EnviroCare International have been developing a Jet Venturi Scrubber designed for prilling towers that discharge plumes with a high submicron particle content (Figure 4, right). This scrubbing technology is designed to reach very low emissions levels.

Jet Venturi design

This dust scrubbing technology is suitable for both natural and forced draft prilling towers. The scrubbing unit can be placed at ground level or on top of the prilling tower. A tower top location is generally preferred, though, as this needs much less ducting – so reducing capex and avoiding the associated pressure drop. Advantageously, the Jet Venturi Scrubber does not require the installation of additional fan capacity, as its unique jet effect moves the off-gas without the aid of a fan.

Jet Venturi Scrubbing units can be conveniently mounted on the air exhaust stacks of forced draft prilling towers, with each stack having its own dedicated unit. Each scrubbing unit comprises of three compact stages that progressively treat and clean the off-gas until it is free of dust and ammonia contamination (Figure 5). The three stages are as follows:

1. **Quench and primary Jet Venturi scrubbing stage.** Coarse urea particulates are removed from the gas stream in the quench section by a spray of recirculated urea solution. This is followed by a downstream Jet Venturi section spraying a scrubbing solution.
2. **Secondary Jet Venturi scrubbing stage.** This uses dilute urea solution as a scrubbing liquid.
3. **Optional acidic scrubbing stage.** This is used to reduce ammonia emissions, if necessary.

Experience on prilling towers

Initially, a Jet Venturi Scrubber pilot unit, fabricated by Envirocare International at its US workshop, was transported to Europe for prilling tower tests carried out in cooperation with a Stamicarbon client. During the testing, all measurements were conducted by a certified and independent third party laboratory from the Netherlands.

The pilot unit consisted of two Jet Venturi elements arranged in series which function as primary and secondary scrubbing stages, respectively (see Figure 6). Four boxes were placed at the inlet and outlet of both Jet Venturi elements (numbered 1-4, Figure 6). These boxes contained mist eliminators, atomising nozzles and hold-up reservoirs to collect scrubbing liquid before it is pumped back to the nozzles.

Treated gas extracted from one of the prilling tower stacks entered through the bottom left duct and was then fed through boxes 1 to 4, and in-between the installed Jet Venturi elements, then discharged to the atmosphere via the top left duct. The sampling ports are visible in the middle of the inlet and outlet ducts (see Figure 6).

Pilot test results demonstrated that the Jet Venturi Scrubber can handle the air flow specified in its base design, yet still drastically reduce the dust content of the exhaust gas.

The expected dust emissions from a prilling tower with an installed Jet Venturi Scrubber are less than 15 mg/Nm^3. This is way below the current European emissions limit of 50 mg/Nm^3. Valuably, this scrubber technology can be installed during the debottlenecking of existing prilling towers.

Conclusions

Stamicarbon's innovative scrubbing technologies allows urea plant owners to meet and go beyond the emissions limits of even the most stringent environmental regulations, while simultaneously reducing the associated investment costs. These are rigorous conclusions based on real-plant experiences with *MicroMist*™ Venturi Scrubbers and on-site tests conducted with the Jet Venturi Scrubber. ■

The importance of cooling equipment

Plant operators require effective and efficient equipment for cooling the solid materials generated during fertilizer production. The main options include fluid bed coolers, rotary coolers and bulk flow coolers.

During their manufacture, fertilizer products require additional cooling as a final process step – after granulation, drying and screening but prior to bagging. It is generally necessary to cool fertilizer prills and granules close to ambient temperature to prevent the subsequent degradation of products during storage, with the caking of products in particular needing to be avoided.

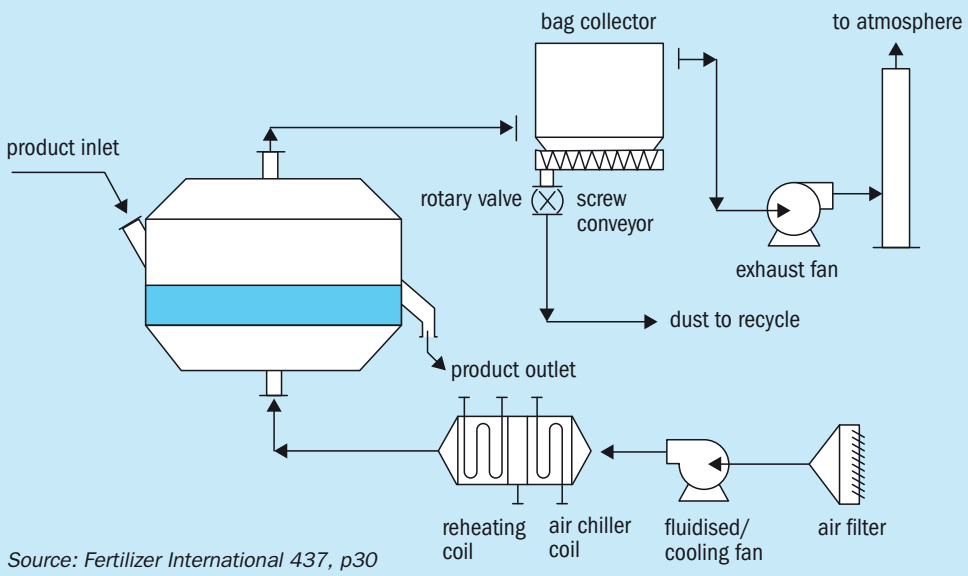
For many years, fluid bed coolers and rotary coolers have been installed at fertilizer production plants worldwide as standard equipment for product cooling. Bulk flow coolers – also known as bulk solids coolers – are another attractive equipment option. These use efficient plate heat exchangers for the indirect cooling of fertilizer prills and granules.

Fluid bed coolers

This type of cooler suspends solid material in a flow of air causing it to behave as a fluid. Such fluid beds offer high cooling efficiency as the entire surface area of the material, while suspended in a fluidised state, is exposed to the flow of air. The gentle handling of materials in fluids beds is another distinct advantage.

Fluid bed coolers typically consist of a perforated horizontal plate (Figure 1). This is made to a proprietary design to ensure an even distribution of cooling air. Granular product moves through the fluid bed until it reaches a discharge weir. This can be lifted or turned to allow the bed to be emptied for cleaning. A bag collector is usually used to collect and remove dust.

Fig. 1: **Fluid bed cooler: typical process configuration**



Source: Fertilizer International 437, p30

The fertilizer product discharged from the granulator usually enters the cooler at between 90-100°C. The product needs to be cooled to the preferred storage temperature – generally about 40°C – to avoid caking. Two cooling stages with primary and secondary fluid bed coolers may be required, or just one single cooling step may be necessary, depending on the process.

France's Comessa and Spanish equipment manufacturer Comspain are both major suppliers of fluid bed coolers to the fertilizer industry (*Fertilizer International* 437, p30). Fluid bed coolers are commonly used in urea granulation. They are a notable feature of the *UFT*® fluid bed granulation process offered by thyssenkrupp Fertilizer Technologies (tkFT), for example, although bulk flow cooling (BFC) can also be a good alternative (see the companion article on p40).

Fluid bed coolers may be a better option – compared to rotary coolers – in situations where physical degradation needs to be specifically avoided.

Rotary coolers

Rotary coolers work by tumbling material in a rotating drum in the presence of chilled or ambient air. The drum is set at a slight angle to so that material moves down its length under gravity. Many rotary coolers, such as the *Cascade Cooler* offered by Barr-Rosin (GEA Group), use a counter-flow of air to cool the cascading solid material as it moves in the opposite direction within the drum. Lifting flights maximize heat transfer by firstly raising and then dropping the material, so improving its contact with the chilled/ambient air as the drum rotates.

Rotary coolers are in widespread use in the fertilizer industry – including production processes for DAP, MAP, NPK and TSP etc. Comessa, Comspain, GEA and FEECO are notable equipment suppliers. Cooling fertilizers within a rotating drum has proved popular within the industry due to the following strengths:

- High throughput
- Ease of handling
- High availability
- Low maintenance requirements
- Flexibility – particularly the ability to cope with a wide range of particle sizes, fluctuations in material properties and the amount of material handled.

Rotary coolers are liked by fertilizer producers due to their high capacity, simplicity, robustness and reliability, according to Wisconsin-based equipment manufacturer

FEECO International (see box).

Although their capital and maintenance costs and thermal efficiency are broadly comparable, rotary coolers have a number advantages and disadvantages versus fluid bed coolers, according to FEECO, including:

- Lower energy requirement
- Larger footprint
- More tolerant to feedstock variation
- Some attrition and degradation
- More easily automated.

Bulk flow coolers

Indirect cooling using heat exchange technology was first introduced several decades ago as an alternative approach to cooling fertilizer granules and prills before storage. Indirect cooling combines together the engineering science of heat transfer with the mass flow of bulk solids.

The heat exchangers used in indirect fertilizer cooling consist of a series of vertical, hollow stainless steel plates. The fertilizer granules fall slowly under gravity between these plates. Cooling water, meanwhile, flows internally through the plates in a counter-current for improved efficiency. A discharge feeder below the base of the cooler controls the outflow of product material.

Such bulk flow coolers – also known as bulk solids coolers – offer the following benefits, compared to other cooler types:

- Mass flow ensures an even temperature
- Little or no product degradation
- Efficient design – large heat transfer area in a compact unit
- Indirect cooling – no contact between cooling water and product
- No cooling air is required, thereby avoiding emissions
- Energy and equipment cost savings, as no fans, scrubbers or baghouses are required.

Canada's Solex Thermal Science is an established major supplier of cooling equipment to the fertilizer industry. The company's proprietary heat exchanger technology offers efficient, indirect cooling of fertilizer granules and prills. The company reports that indirect cooling technology offers dual benefits, by providing fertilizer manufacturers with a better product while also being more environmentally-friendly (see accompanying article on p36).

In certain circumstances, bulk flow coolers also provide an attractive alternative to fluid bed coolers in urea granulation plants, according to tkIS (see separate article on p40). ■

FEECO rotary coolers

The ability to properly cool fertilizers is directly linked to the bottom line – minimising losses to caking and attrition, preventing mould growth during storage or transport, and ultimately preserving product value. Incorporating a cooler into the production line also allows products to be immediately bagged, handled, stored, or shipped, without risk to equipment or employees.

Rotary coolers remain the fertilizer industry's preferred option when it comes to cooling. They offer high throughput, simple operation and ease of maintenance and – when properly designed – a long and reliable lifetime of product cooling.

Fertilizer producers around the world have relied on FEECO for the design and manufacture of rotary coolers since 1951. Indeed, since the advent of modern granulation systems, FEECO's rotary coolers have been the industry standard for efficiently cooling fertilizer products while maximising product integrity.

As well as being built to stringent quality standards, the design and specifications of FEECO coolers are customised according to the unique characteristics of the material to be processed. This can require:

- Upgraded construction materials to improve protection against corrosion and abrasion
- Customized flight (lifter) designs for optimized heat transfer
- A lined inlet for resistance to incoming hot materials.

For peace of mind, FEECO coolers can be provided with process and mechanical warranties, and are backed by an extensive parts and service programme. Maintenance services are available for every aspect of the cooler, including laser alignment and tire grinding. The main constituent parts of the cooler are described below.

The drum

FEECO rotary coolers are available in a wide scope of sizes to match production needs. Drum diameters can range from 3' to 15' (1-4.6m) and can accommodate capacities ranging anywhere from 1-200 short tons per hour (1-181 metric tonnes per hour). Entire drum shells, as well as shell sections, are available in various construction materials.

The tire mounting assembly

FEECO utilises a floating tire assembly to provide optimal support to the cooler. This extends drive life by allowing for thermal expansion and reducing stress on mechanical components. Neither the tire nor flotation blocks (steel pads) are fixed to the drum, being held in place by keeper blocks instead. A graphite block provides lubrication to the tire as it moves over the steel pads. This design is easy to adjust to compensate for excessive wear or creep.

The drive assembly

Each cooler is equipped with a unitised drive base. This houses all the drive components in a unique design – making installation quicker and maintenance easier and less time-consuming. Several drive assembly options are available to suit the customer's individual size and horsepower requirements.

Chain and sprocket and gear and pinion type assemblies are the most commonly used drive types for fertilizer coolers – although friction drive and direct drive assemblies are also available. The chain and sprocket assembly is the preferred option for smaller drums running up to 75 horsepower (55 kW), while the gear and pinion drive is ideal for heavy-duty applications involving larger drums with higher horsepower requirements.

Add-ons

Rotary coolers can be customised with additional components to optimise performance and improve longevity. Common add-ons include:

Trommel screens: Also known as grizzlies, these are used for breaking up clumps as material exits the cooler. They are also used for screening off-specification product.

Knockers: When working with materials prone to sticking, such as phosphates, knockers can be added to the cooler to discourage the caking of materials on flights and cooler walls. By knocking the drum against a wear band or plate during rotation, these dislodge accumulated material without affecting the shell's integrity. ■

Greener cooling makes better products

An industry-wide push for greater environmentally accountability is driving the need for improved fertilizer cooling methods. Not only is indirect cooling technology more environmentally-friendly, says **Igor Makarenko** of Solex Thermal Science, it also provides fertilizer manufacturers with a better product.

Plate-based vertical heat exchanger cooling installation at a fertilizer plant.

PHOTO: SOLEX THERMAL SCIENCE

With environmental, social and corporate governance (ESG) rising up the business agenda, the fertilizer industry is taking an increasingly holistic approach to product stewardship. Creating more efficient fertilizer production processes that support sustainable food systems and mitigate climate change have become a particular priority.

The International Fertilizer Association's first-ever Global Stewardship Conference in New York in 2020 demonstrated how sustainability has become a major priority and business imperative (*Fertilizer International* 495, p10). Attended by the industry's top flight from around the world, last year's IFA event placed ESG centre stage. In particular, the conference emphasised the need for fertilizer producers to innovate by embracing energy and water efficiency, low-carbon production methods and emissions-reduction technologies.

Such sentiments were echoed in a recent IFA member survey. More than 75 percent of respondents said growing environmental regulation will have some impact on their businesses – with the highest concerns coming from North America, West Asia and Europe.

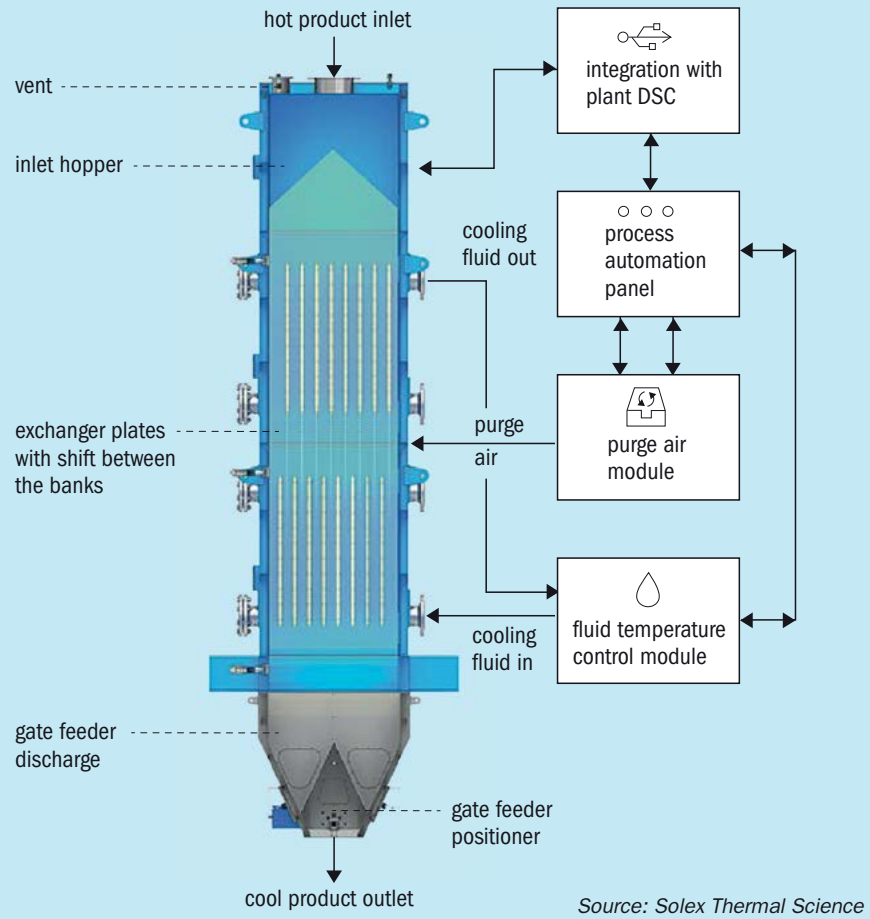
A focus on cooling

With growing awareness of environmental responsibilities and the need to optimise processes, the industry is focused on four entwined issues:

- Emissions reduction
- Improving operational practices and efficiency
- Revamping/reconfiguration of existing plants to maximise production output
- Maintaining product quality.

Inevitably, this has also shone the spotlight on the cooling stage of fertilizer production – an essential process step and key precursor to fertilizer storage and transport. However, traditional cooling equipment, such as rotary drums or fluid beds, have

Fig. 1: **Schematic of a Solex plate-based, vertical heat exchanger**



Source: Solex Thermal Science

been hampered by their need for high volumes of air. These large air flows subsequently require the use of costly scrubbing equipment and incur considerable energy and maintenance costs. Traditional cooling equipment installations are also accompanied by other challenges such as product quality concerns (e.g. attrition) and limited throughputs (e.g. planned rate reductions).

Plate-based vertical heat exchangers (Figure 1), in contrast, have emerged as a valued mainstay within the fertilizer industry. The technology offers a way to improve production and product quality, at lower capital and operating costs, while also reducing the environmental footprint of production plants.

Plate-based vertical heat exchangers are a form of indirect cooling technology. Their design harnesses the science of mass flow and combines this with high thermal efficiency. First deployed more than 30 years ago, this type of equipment has been successfully used to cool the full spectrum of currently-produced fertilizers. That includes different size products – from fine crystalline to granulated and prilled products – as well as different fertilizers types such as urea, ammonium nitrate and calcium ammonium nitrate (AN and CAN), diammonium phosphate and monoammonium phosphate (DAP and MAP), NPKs, ammonium sulphate (AS) and potash.

In the following discussion we've broken down indirect cooling technology into four categories:

- Overcoming water quality and water usage challenges
- Operational cost reductions – particularly for energy
- Installation cost savings
- Product quality improvements.

This provides a better understanding of how the technology works and, importantly, how it helps deliver on the industry's current need to reduce its collective environmental footprint while simultaneously improving operational efficiency.

Addressing the water quality and usage challenge

Unlike traditional direct-contact types of cooling equipment, such as fluid beds and rotary drums, plate-based vertical heat exchange technology (Figure 1) relies on water to cool the fertilizer instead of air.

In simple terms, the technology functions as follows:

- The fertilizer flows under gravity through vertical banks of stainless-steel plates, while cooling water passes through the plates to cool the material by conduction.
- Water is circulated through the plates in counter-flow for enhanced thermal efficiency.
- This absorbs the heat from the fertilizer by cooling granular solid matter as it moves slowly down through the tower.

The benefits of utilising water instead of air as a fertilizer cooling medium are highlighted in the sections below. Yet sourcing that water – and doing so economically – can still pose challenges for many fertilizer producers around the world.

Industry concerns around water scarcity and quality were revealed by IFA's most recent member survey. An overwhelming majority of respondents (87%) specified that water scarcity will have a severe impact on the fertilizer industry moving forward, while nearly three-quarters (74%) said deteriorating water quality is a further concern.

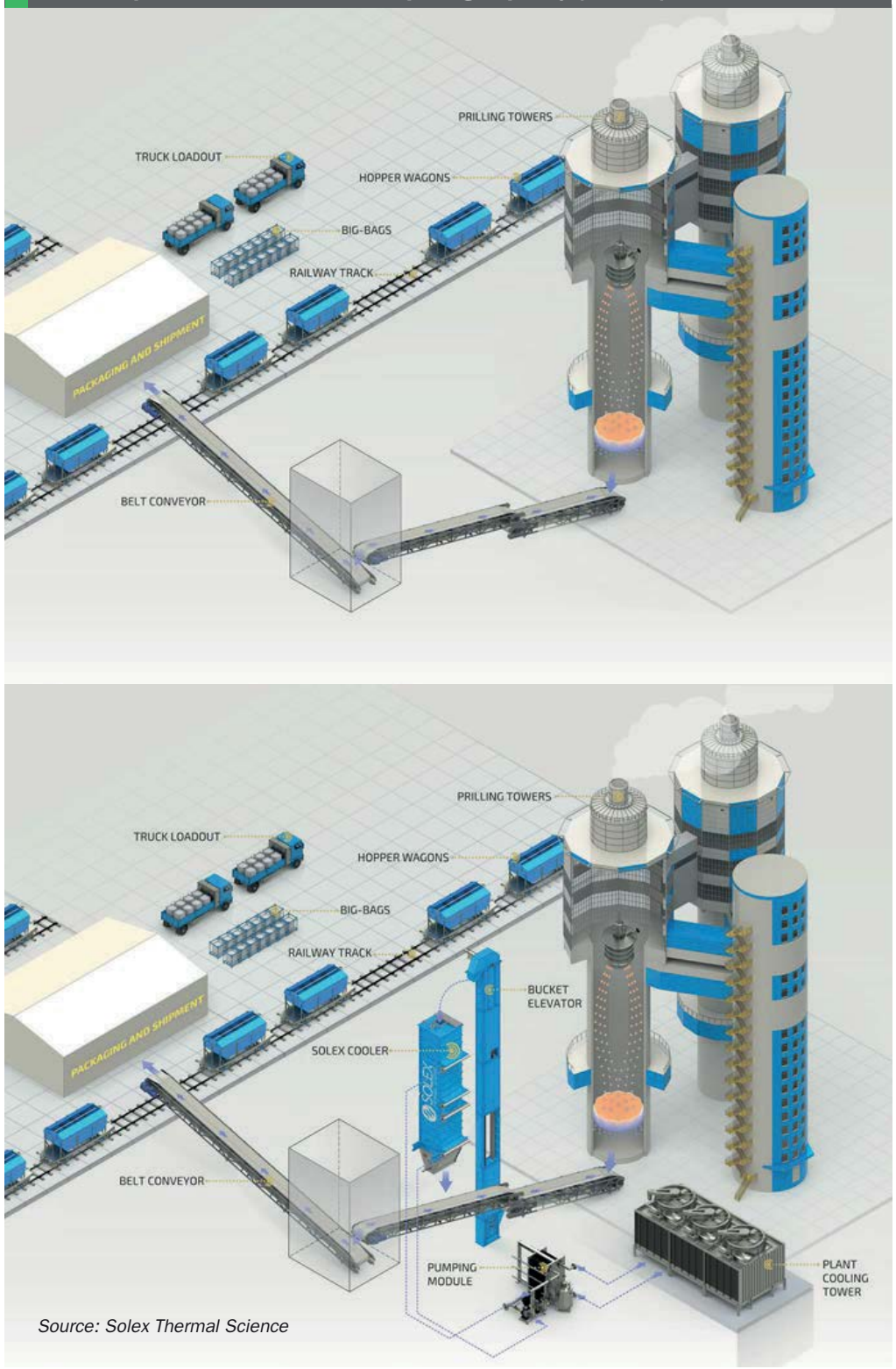
The adoption of cooling equipment that incorporates closed-loop water systems is one way of addressing these challenges. That's because in open-loop water cooling systems, while water might be available in the required volume, it can present quality challenges, e.g. high-chloride content or general cleanliness. If water quality becomes compromised in such systems, it will damage or foul the heat transfer equipment over time. To prevent this happening, plant operators need to factor-in the operating costs of treating water prior to introducing it into the fertilizer cooling process.

In other operational circumstances, the volume of water required for open cooling systems might not be available on-site or is too far away or too costly to bring in. Costs can be prohibitive, for example, if plant operators need to install costly pipe bridges, insulation and even heat tracing to supply the water to the heat exchanger.

In open-loop systems, the return of water from fertilizer cooling equipment to the plant's main water circuit is another issue. This adds extra load on cooling towers and, by reducing their capacity, can compromise process performance elsewhere in the plant.

Generally, accessing water for open-loop cooling systems can be difficult due

Fig. 2: **Cooling capacity within urea prilling plants. This is limited by the prilling tower's original design (top). An additional fertilizer cooler is therefore required to handle increased prilling capacity (bottom).**



Source: Solex Thermal Science

to the quality and cost considerations described above. It is not surprising, therefore, that many plant operators are moving to closed-loop water cooling systems instead, especially when these offer other advantages such as improved operational sustainability.

This is true of plate-based vertical heat exchange technology which, notably, incorporates standalone and self-contained closed-loop water systems. These operate as secondary water circuits, thereby isolating the plate exchangers from the plant's primary cooling water supply.

Beneficially, these separate closed-loop circuits also allow fertilizer plant operators to regulate water quality and temperature before allowing it into the cooling exchangers. In doing so, the system maintains a steady water temperature profile without being affected by other operating conditions in the plant. A consistent cooling profile in the plate heat exchanger, in turn, helps ensure consistent fertilizer quality.

Closed-loop water modules operate on a standalone basis. This means fertilizer plant operators have access to completely independent systems that do not require any additional plant instrumentation. Importantly, such systems do not take water from other plant circuits. Neither do they load cooling towers with returning warm water. Instead, the heat load of returning cooling water is removed via one or more standalone cooler units. Meanwhile, the water is consistently clean and doesn't require make-up supply.

In cases where the process requirements for the finished product temperature are close to ambient, plant operators can also include chillers in their water temperature control modules. The circulation of output water through the chillers provides a boost to cooling capacity, when needed, helping to maintain circulating water temperature. The cooled water, once it reaches the regulated temperature, is then sent back into the module and eventually the exchanger.

Chillers offer plant operators two benefits: they eliminate the need to supply additional cooling water and avoid placing extra heat load on the plant's cooling towers. Everything is instead maintained within the closed-loop system.

Additionally, these combined systems are both flexible and efficient. Chillers only operate when needed – during the summer months, for example. This allows systems to operate using the existing plant-supplied water during the rest of the year, thereby saving on energy costs.

Closed-loop systems, due to their zero losses, can also run with the same circulation water for years.

Operational & energy cost savings

The energy required to operate plate-based vertical heat exchangers is significantly less than that of traditional fertilizer cooling equipment. Fluid beds, for example, typically require two powerful large horsepower fans: a forced draft fan to supply air to the cooler; and an induced draft fan following the scrubber. The air chiller and air pre-heater in fluid bed systems also draw additional energy.

With plate-based vertical heat exchangers, in contrast, the cooler itself places only a small additional energy load on the plant's existing cooling water system. The

associated cooling water pump, bucket elevator and purge air system, meanwhile, all have low horsepower requirements.

Compared to a fluid bed system, plate-based vertical heat exchangers operate at high thermal efficiency with a large capacity of up to 150 tonnes/hour in a single cooler. This reduces energy costs by 90 percent and typically saves 4-5 kWh/tonne.

The above calculation is based on typical operational power requirements of 1,040 kW for a fluid bed cooler for a 3,600 t/d urea plant on the US Gulf Coast. That compares with an equivalent 85 kW requirement for a Solex cooler. (The load for the fluid bed cooler is an average based on mean monthly day and night ambient conditions.)

The operating costs of plate-based vertical heat exchangers are further reduced due to the ease of cleaning and the simplicity of system maintenance. Large hinged doors on the back of the cooler give full access to the plate banks. These are configured to enable easy access for inspection and cleaning.

Cleaning is carried out by washing with water and drying with a counter-current of warm air. The exchanger can typically be washed and dried within an eight-hour period, easily fitting within a normal plant maintenance schedule.

Their design also makes it possible for single plates to be isolated or replaced, if required. Overall, operating such a simple system with so few moving parts generally minimises maintenance requirements.

Installation cost reduction

Capital costs associated with the installation of plate-based vertical heat exchangers are also lower as they eliminate the need for air-handling equipment such as fans, air conditioning units (cooling and heating), and scrubbers, as well as ancillary equipment – particularly the large-diameter ducting used to accommodate the high volume air flows necessary with other cooler types. The cooling water circulating skid that is required is relatively small and not particularly costly.

Usefully, because of their vertical configuration, plate-based heat exchangers are both compact and modular in design. This makes them easy to integrate into existing plants, and therefore ideal for revamp projects and plant de-bottlenecking/capacity increases. Furthermore, this modular design allows additional heat exchanger plates to be added easily to the existing stack, if and when increased cooling capacity is required in future.

While the final capital cost of any project is subject to many variables, several case studies have demonstrated that, in general, the installation costs of plate-based indirect cooling systems are at least 30 percent lower than those of fluid-bed cooler installations.

Maintaining product quality

It is important to ensure, whenever production output is raised, that product quality also remains high. Plate-based vertical heat exchanger technology, compared with conventional rotary drum and fluid-bed fertilizer coolers, offers several advantages in this respect – as they can help improve product quality while also reducing plant emissions.

Ensuring that products are stored and packaged at the correct temperature is an essential part of successful fertilizer production. In particular, elevated temperatures need to be avoided as, given the hygroscopic nature of fertilizers, they can quickly translate into caking during subsequent storage, packaging and bulk transportation. Caking, by compromising product quality, ultimately results in lower sales price and dissatisfied customers because of the associated product breakage and handling difficulties.

Ensuring sufficient cooling in the fertilizer plant and the proper control of product temperature can require the installation of additional coolers at granulation plants, or the inclusion of cooler units at prilling plants.

Urea prilling plants operating at their original design capacity rely on the original prilling tower design, for example, rather than a separate cooler, to cool prills to an acceptable storage temperature. That situation can change, however, when plant capacity is increased. That's because the built-in cooling capacity of the prill tower is essentially fixed by the original design (e.g. height of the tower). An additional fertilizer cooler is therefore required to deal with the increased capacity (Figure 2).

Conventional fertilizer cooling technologies present a number of challenges when retrofitting an existing plant to increase production. Typical fluid bed or rotary drum cooler types, for example, employ large volumes of air blown directly through or across the product, as touched on earlier.

Plate-based heat transfer technology, in contrast, being based on indirect cooling, eliminates the need for large volumes of process air and therefore subsequent costly cleaning by scrubbing systems. Instead, the fertilizer flows under gravity through the cooler at the most suitable velocity, as determined using customised thermal modeling software. This ensures that the fertilizer's residence time within the cooler – typically 10-15 minutes – is sufficient and provides even cooling.

Based on process requirements, sophisticated modelling software calculates the correct product velocity and residence time from a range of parameters including the fertilizer's bulk density, specific heat, thermal conductivity, input temperature and flow rate. The modeling also accurately predicts how long prills or granules need to stay within the fertilizer cooler, and determines the plate spacing required to reach the desired discharge temperature.

The product's flow rate through the exchanger is controlled using a mass flow discharge device. Fertilizer solids move through the cooler in a laminar flow pattern. The absence of any mechanical handling of particles makes the cooler ideal for soft and friable fertilizer grades.

Test results have shown that no measurable quantities of fines are generated by the product as it flows through the cooler. Indeed, the slow movement of material and gentle product handling avoids product degradation, abrasion and dust formation – the end result being the delivery of a high-quality final product.

The uniform flow of solid materials as they pass through a plate-based vertical heat exchanger, when combined with residence times, ensures an even product temperature profile at the discharge. It is these advantageous design characteristics that enable Solex fertilizer coolers to guarantee remarkably stable and uniform final product temperatures. ■

About the author

Igor Makarenko is Global Director, Fertilizer, with Solex Thermal Science, a Canadian-headquartered pioneer in bulk solids thermal exchange. Over the past 30 years, the company has installed more than 600 advanced heat exchangers in more than 50 countries worldwide with applications such as fertilizer, oilseeds, sugar and industrial materials.

Cooling concepts for urea granules

Globally, thyssenkrupp Industrial solution (tkIS) has engineered and built nine urea granulation plants during the last 10 years. Based on this experience, **Benedict Jass, Marc Wieschalla** and **Ivo Mueller** of tkIS describe two different cooling concepts for urea granules – fluid bed cooling and bulk flow cooling – and their contrasting advantages and disadvantages.

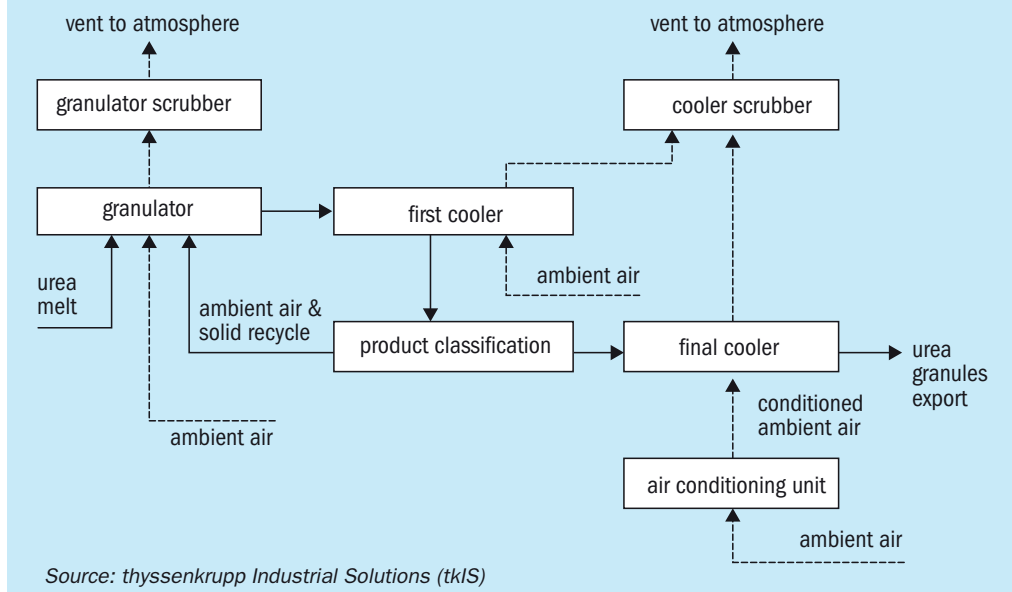
Urea granulation generally consists of four main process steps: granulation, cooling, product classification (screening) and off-gas scrubbing, as illustrated by the standard set-up in Figure 1.

The urea granules produced leave the granulator at temperatures slightly below 100°C. In the first cooling step, these are cooled down to an intermediate temperature to allow the granules to be properly handled – by bucket elevators or during screening, for example. As a next step, the granules are then classified, generating three size fractions: a fine fraction, the product fraction and a coarse fraction. The latter is crushed and recycled together with the fine fraction back to the granulator as seed material.

The product fraction contains those urea granules with the correct particle-size distribution. These are cooled down further in the final cooler to a temperature (e.g. 45-50°C) that allows stable and safe storage of the final product in a bulk hall.

The licensor thyssenkrupp Fertilizer Technologies (tkFT) offers the well-established and market leading *UFT*® fluid bed urea granulation process. Product cooling can be achieved as part of this process using different concepts, each having their own advantages and disadvantages. In standard set-ups, however, both cooling steps (Figure 1) are generally performed by fluid bed coolers, as described below.

Fig. 1: **The *UFT*® fluid bed urea granulation process, standard setup**



Source: thyssenkrupp Industrial Solutions (tkIS)

Fluid bed coolers

Advantageously, for small- and medium-capacity plants, the first cooling step can be directly integrated into the granulator – delivering significant investment savings. Integration of the first cooler is not, however, recommended at higher production capacities, as this would lead to equipment transport difficulties and installation problems due to the granulator's larger size. A separate first cooler is therefore still required in high-capacity urea plants.

The final fluid bed cooler has to be operated with dry air to avoid caking and lump formation in the cooler itself and during subsequent product handling and storage. Air drying is achieved using an air conditioning unit, with the evaporation of liquid ammonia within this unit providing the chilling necessary.

Bulk flow coolers

The bulk flow cooler (BFC) is an alternative cooling concept that can – in certain circumstances – replace the fluid bed as the final cooler. Essentially, the BFC is a plate heat exchanger, with cooling water on one side and free flowing urea granules on the other side. It functions as follows:

- The cooling water flows along enclosed channels in-between pairs of plates
- Evenly distributed urea granules are introduced at the top of the BFC.
- These flow vertically through gaps between the pairs of plates before being discharged at its base.

One of the main advantages of a BFC is that it operates by indirect cooling and, as a consequence, requires almost no maintenance and much less cleaning than a fluid bed cooler.

Operational experience

During the first five months operating a BFC at a urea granulation plant in Iowa in the United States, tkIS did not find it necessary

to open the cooler for cleaning, despite several start-ups and shut-downs. Because of this, unlike other equipment (e.g. the urea granulator), washing is not foreseen as a regular procedure for this BFC installation. Nonetheless, if cleaning is eventually required, maintenance doors on the side of the BFC offer easy access. This enables heat exchanger plates to be pulled out for very simple cleaning or inspection during turnaround of the plant.

From a purely technical point of view, it should be possible to install BFCs widely at urea plants, as they are capable of providing sufficient cooling at all production capacities and scales. However, in practice, the successful installation and operation of this type of indirect cooling equipment will depend on various factors, as described below.

While BFCs require cooling water to operate – which is generally available at urea plants – they do not require a chiller unit to function, unlike fluid bed coolers (see Figure 1). The ability of BFCs to operate without an ammonia chiller is advantageous, as it eliminates the use of a potentially hazardous fluid at the urea granulation plant. Additionally, substituting a BFC for a fluid bed cooler, in the granulation plant's final cooling step, eliminates other equipment items such as the final cooler fluidisation fan, as well as the air conditioning unit.

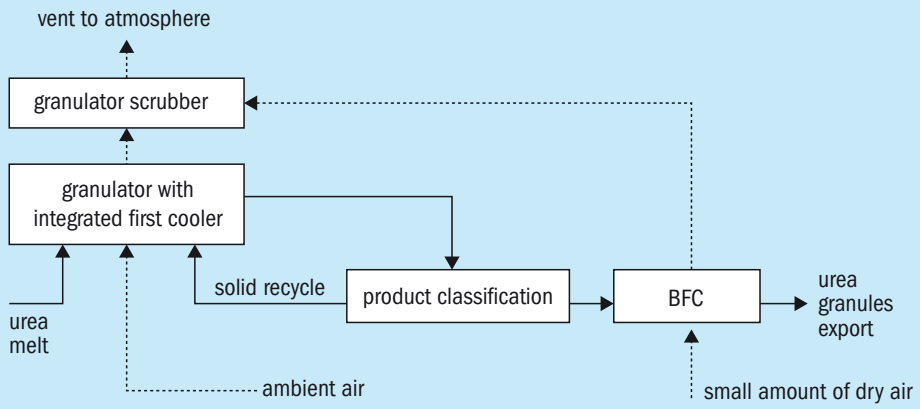
Advantages of BFCs for small- and medium-capacity plants

For the *UFT*® process, the greatest advantage of adopting bulk flow cooling can be achieved at small- and medium-capacity urea granulation plants (Figure 2).

In the process setup for plants of this size, the first cooler is incorporated into the urea granulator by extending the cooling area. This avoids the installation of the first fluid bed cooler and the corresponding fluidisation fan. Air used in this first cooling step is cleaned in the granulator scrubber alongside granulator off-gases.

In this configuration, replacing the second fluid bed cooler with a BFC eliminates the whole cooler scrubbing system – a cooler scrubber and a cooler scrubber exhaust fan – so reducing equipment and saving energy. The omission of the blowers alone cuts the electrical energy consumption of the granulation plant by around 3.5 percent. In addition, the absence of the air conditioning unit also reduces energy consumption by eliminating the power consumed in ammonia recompression.

Fig. 2: ***UFT*® fluid bed urea granulation process incorporating an integrated first cooler and bulk flow cooler (BFC)**



Source: thyssenkrupp Industrial Solutions (tkIS)

Utilities: cooling water and purge air

The cooling water side of the BFC is operated as a circulating loop. Control of the cooling water inlet temperature is used to prevent the condensation of humidity on the surface of plates on the process side. Condensation can also be an issue during start-up and filling of the BFC. A heat exchanger is therefore used to bring the cooling water loop to the desired operating temperature before start-up of the BFC.

Although normally operated open, the cooling water loop is typically designed closed at high chloride concentrations. This is because the presence of chlorides in cooling water can lead to corrosion, particularly crevice corrosion and pitting, due to the elevated operating temperature on the cooling water side.

On the process side, purging is used to ensure the urea product flows freely though the inside of the cooler. The injection of purge air into the BFC helps prevent plugging and bridge building resulting from the adhesion of fine urea particles. As urea is a hygroscopic compound, it is important to prevent water, particularly humidity, from entering the BFC, as this can result in blockage of the cooler. This is achieved by controlling the dew point temperature of the purge air. This is effective at preventing both moisture condensation on the plates and moisture pick-up by the urea product.

In many regions, the ambient air is dry enough to be directly applied as purge air for much of the time. Where this is the case, the most economical option is to draw purge air directly from the existing granulator fluidisation fan. Because the ambient air was sufficiently dry, this was the solution chosen by tkIS for the BFC installed at the granulation plant in Iowa in the United States.

For time periods when – or geographic locations where – the moisture content of the ambient air is too high, the dew point can be lowered by mixing in an additional source of dried air, e.g. instrument or process air. Automatic mixing to control purge air dew point is even possible using ambient air temperature and humidity measurements to calculate the required flow rates.

The process air compressor of an ammonia plant can be used as a permanent supply of dry purge air in very humid or warm locations. Energy consumption can be kept to a minimum by taking air dry enough for use in the BFC at the lowest permissible discharge pressure. In contrast, using instrument air as a dry air source for the BFC will inevitably increase power consumption, as it generally needs to be dried to a much lower dew point.

Installation and layout requirements

From an installation point of view, while the BFC occupies a smaller footprint area than a fluid bed cooler, it is both taller and significantly heavier (Figure 3). That can make the installation of a BFC cooler within the plant more challenging. On-site structural restrictions and operational requirements both need to be considered when assessing whether the dimensions of the cooler can be accommodated.

Cooler doors also need to be accessible so they can be opened to allow the exchange of cooler plates. The height of BFCs means elevated platforms are

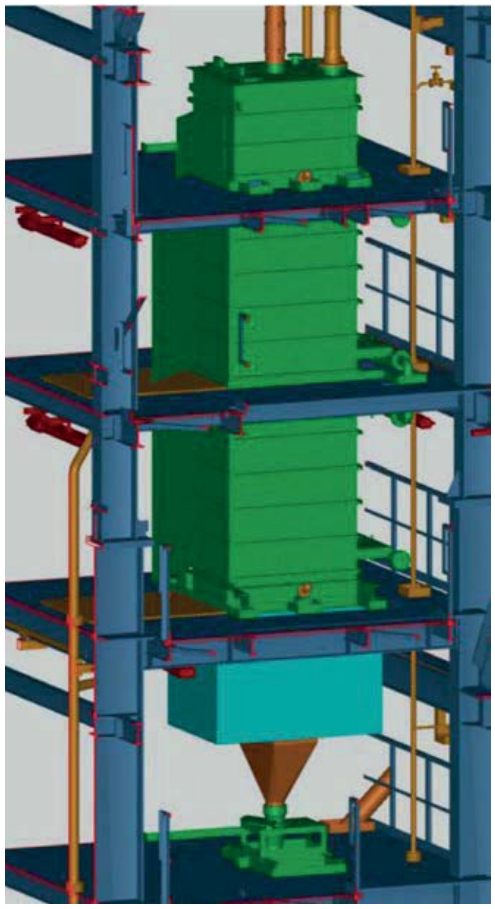
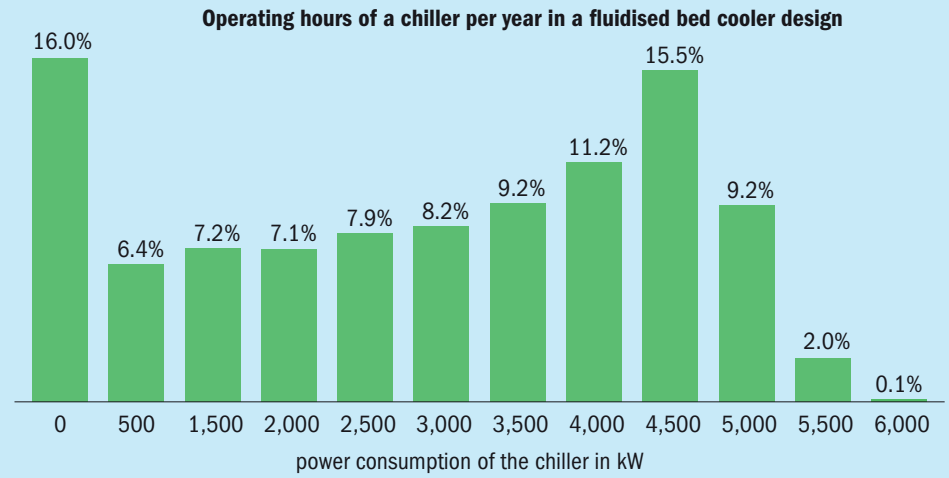


IMAGE: THYSSENKRUPP INDUSTRIAL SOLUTIONS

Figure 3: Schematic of a BFC designed to meet all layout requirements.

Fig. 4: **Annual operating hours (y-axis, percent) of a fluid bed chiller against power demand (x-axis, kW) for a fictitious US Gulf Coast production site**



Source: thyssenkrupp Industrial Solutions (tkIS)

required to enable single modules to be reached. Should blocking of the BFC occur on the process side, the upper part of the cooler also needs to be accessible for flushing by water hose. A washing area at each plate bank (indicated in brown in Figure 3) is therefore needed for cleaning purposes.

In circumstances where only a small BFC design is necessary, e.g. for urea plant revamps, the cooling water can be actively cooled (chilled).

Effect on product characteristics

During the granulation process, both the classification of the product and transport under gravity result in the formation of dust which then adheres to urea granules. Fluid bed coolers, in addition to their cooling function, also have a valuable de-dusting effect on urea granules. Hence, products generated by a plant configured with a fluid bed as a final cooler will tend to be less 'dusty'.

Using a BFC as the final cooler instead of a fluid bed type could, therefore, potentially lead to a change in product characteristics. But experience gained during commissioning has demonstrated that bulk flow cooling does not, in fact, have any measurable negative effects on product quality. Indeed, the perceived problem of higher dust adhesion to urea granules can be addressed by good ventilation and installing sufficient de-dusting spots during material handling.

Energy consumption case study

Which of the two cooling concepts, the fluid bed cooler or the BFC, is the most suitable type for the final cooling of urea granules is subject to much debate. The answer clearly depends on which parameters are used to measure their relative performance. Any assessment must also involve detailed monitoring. One comparison, for example, could be based on their relative operating costs, which is linked in turn to power consumption.

As already stated, the fluidising air for the fluid bed cooler must be dry so that the urea does not pick up humidity. Application of cooled dry air also ensures an economical design. The air conditioning (drying and cooling) is done using an air chiller unit supplied by ammonia sourced from the ammonia plant. But how much energy is consumed by a chiller unit during the course of a year? That depends on factors such as the production site's temperature profile.

Figure 4 shows the annual operating hours of a fluid bed chiller in percent (y-axis) against power demand in kW (x-axis) for a fictitious US Gulf Coast site with a capacity of 3,500 t/d. This chart shows that the fluid bed chiller is only operated at full load (6,000 kW) on a few days, while for the majority of the year the chiller operates using only a fraction of its total cooling capacity.

Overall, we calculate that the fluid bed cooler concept requires approximately 950 kW, including the required chilling duty and fan power. In comparison, for an otherwise similar plant, using a BFC for cooling would result in an average energy consumption of approximately 140 kW, assuming the BFC is supplied purely with dry air. This calculation takes into consideration the production of dry purge air and cooling water pumping. Therefore, by comparing power consumption alone, the BFC clearly wins the race in this case study.

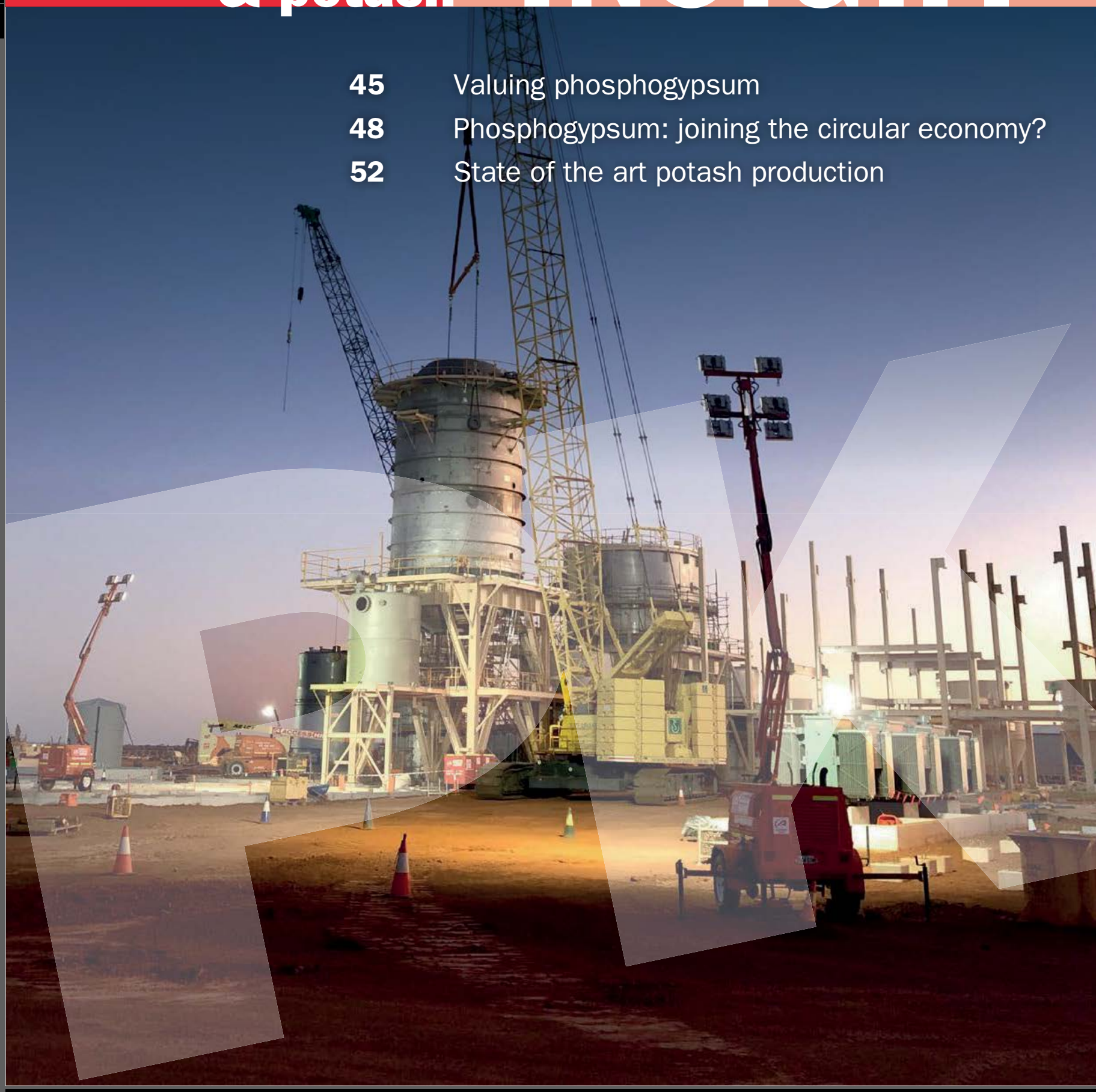
Conclusions

The use of a bulk flow cooler instead of a fluid bed cooler can provide a good alternative in the final cooling of urea granules. Nevertheless, many parameters require evaluation before deciding which solution best fits the client's specific requirements.

In our view, implementing bulk flow cooling as part of the granulation process also requires an experienced engineering contractor. thyssenkrupp Industrial Solutions has valuable experience of using bulk flow coolers, at both new-build urea plants and during urea plant revamps. tkIS also has long-term experience in cooperating with the urea granulation licensor tkFT. Together, these capabilities ensure that, for each individual urea granulation plant, the best cooling concept is selected and implemented. ■

March-April 2021

phosphates & potash INSIGHT



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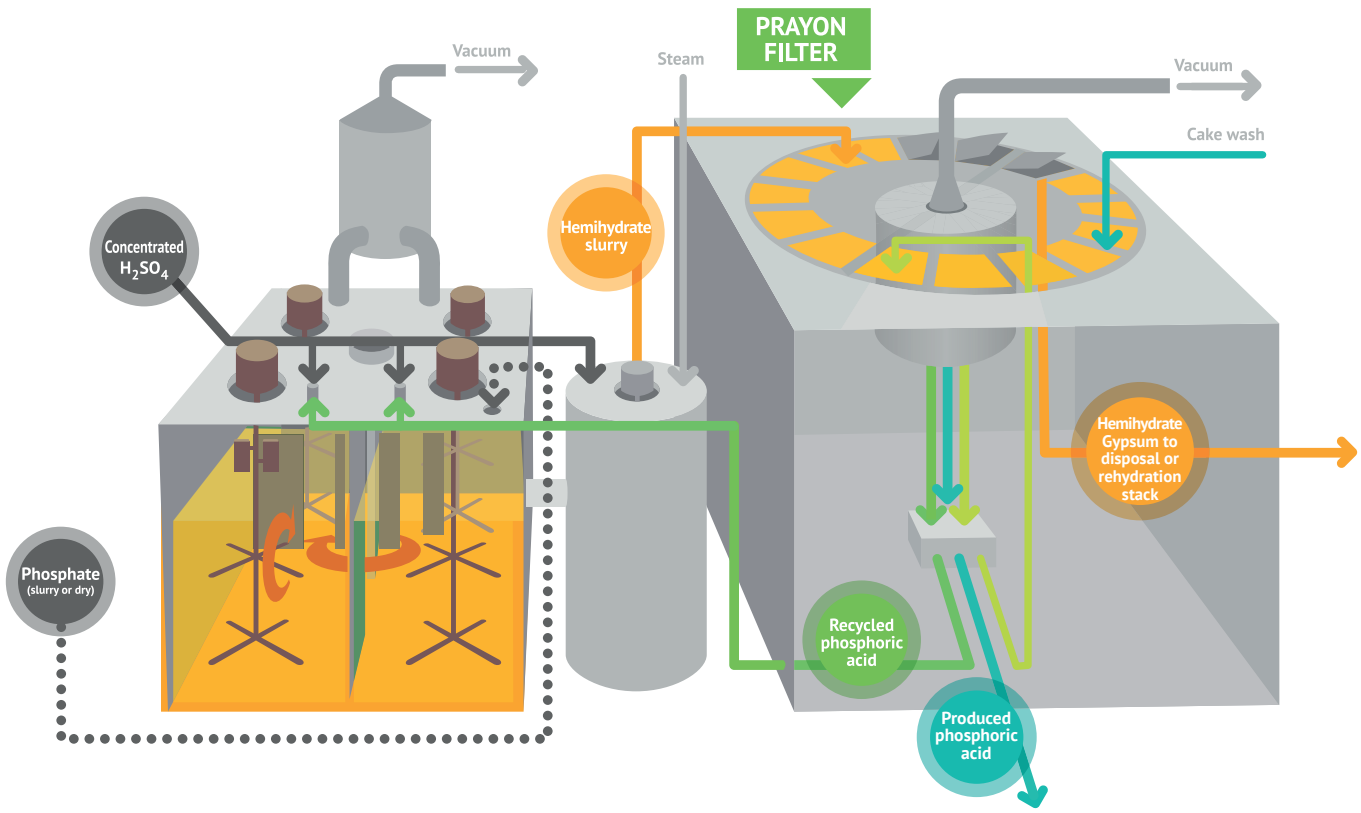

DA-HF Process - New Process for Improved Phosphoric Acid Production*

PHOSPHORIC ACID PROCESS ROUTES

- **New** DA-HF*
- Dihydrate (DH)
- Hemihydrate (HH)
- Central Prayon (CPP)
- Hemi-dihydrate (HDH)

OTHER PROCESSES LICENSING

- **New** DCP Production from low-grade phosphates
- Phosphoric acid treatment (F, As, S, Mg, Fe, Al, Cd)
- Fluorine recovery
- Gas scrubbing
- Gypsum treatment

CONSULTING

- **New** Long-term collaborative program for assistance (P_2gether)
- Plant operation simulator tool

*Dihydrate Attack-Hemihydrate Filtration

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Valuing phosphogypsum

PHOTO: NUTRIEN

Phosphogypsum is finding increasing use in plaster and cement manufacture, roadbed construction and afforestation. We look at how previously unwanted solid waste generated by the phosphate industry is being turned into a valued resource.

Left: Produce grown by Nutrien staff on a fertile man-made soil created using phosphogypsum.

Greater commercialisation

As it expands globally, phosphate fertilizer manufacturing is generating ever larger volumes of phosphogypsum waste. Billions of tonnes of this material are currently being managed at great cost within giant waste stacks.

Nevertheless, phosphogypsum is finding increasing use as a co-product in agricultural, building and construction applications, particularly outside of the United States. This is a sign that the previously unwanted solid waste generated by the phosphates industry is becoming a valued resource (*Fertilizer International* 478, p58).

In recent years, there has been a clear shift away from desk studies and R&D towards commercialisation. Indeed, it is estimated that some 50-60 million tonnes of phosphogypsum is now being utilised worldwide[1]. Notable examples of commercial phosphogypsum (PG) use include:

- **Belgium** (Prayon): sells high-quality PG for the cement and plaster market.
- **Brazil**: most PG now goes to agriculture (5 million t/a) following its reclassification.
- **Canada** (Nutrien): PG for agriculture and, working with forestry service, afforestation using man-made 'anthrosols' – PG mixed with soil in a 9:1 ratio.
- **China** (Wengfu Group): more than half of PG output is used in agriculture and construction, or recycled as ammonium sulphate/calcium carbonate.
- **Kazakhstan** (UN): large-scale remediation of saline/sodic soils.
- **India**: PG reclassified as a co-product, not waste, in 2008. Widely sold for construction, agriculture, soil additive, cement and as bagged fertilizer. Examples include afforestation for green energy (Coromandel) and road construction (Paradeep).
- **Russia** (PhosAgro): use of PG in agriculture, construction and road building
- **Tunisia** (GCT): remediation and return of land to productive use in Sfax, brick-making, road construction and housing.

The phosphate industry globally has also benefitted from a growing evidence base on phosphogypsum usage. The International Fertilizer Association (IFA), through its PG Working Group, has played a leading role in promoting phosphogypsum reuse. The association published a comprehensive landmark report on the sustainable management and use of phosphogypsum in 2016[2]. This was followed last year by a compilation of peer-reviewed case studies written by IFA member companies on the use of phosphogypsum in agriculture/forestry, construction and road building[3]. The 10 diverse case studies presented, together with four national overviews, were global in scope, covering developments in Belgium, Brazil, Canada, India, Morocco and Russia.

The impressive evidence assembled in IFA's latest report provides examples of current best practice, together with core principles for phosphogypsum management and use. Three exemplary case studies illustrating the value of phosphogypsum in agricultural/forestry, construction and road building are provided below.

Construction: Prayon leads the way

Prayon provides a leading example of a successful circular economy approach to phosphogypsum use. The leading technology licensor, phosphates producer and equipment manufacturer has actually been selling gypsum as a co-product for more than forty years[4].

The company sells virtually all of the phosphogypsum it produces at its phosphoric acid plant in Engis, Belgium, compared with 80-90 percent 4-5 years ago[3]. In 2018, for example, Prayon sold 708,000 tonnes of phosphogypsum for plaster and cement manufacture, with a further 60,000 tonnes sold for agronomic use, from output totalling 790,000 tonnes.

When it comes to selling phosphogypsum, Prayon attributes its successful track record to several factors: notably the quality of its product, which in turn is attributable to the Central Prayon Process (CPP) used at its Engis plant, and the company's long-term partnerships with its gypsum customers[4].

The CPP, with its double crystallisation process and two filtration steps, is exceptionally efficient (*Fertilizer International* 481, p49). The process is, however, only responsible for about one percent of total phosphoric acid production globally. Key feature of the CPP include:

- **Flexibility**: process can accommodate a wide range of phosphate rock types.

- **High recovery**: reduces phosphate rock consumption and generates a saleable gypsum co-product.
- **High P_2O_5 content in the filtered acid**: reduces steam and therefore energy consumption.
- **Self-drying gypsum**: phosphogypsum from the CPP process naturally cures from wet hemihydrate (HH) to dry dihydrate (DH), meaning less fuel oil is required to process gypsum.
- **Environmentally-friendly interim storage**: neutralised phosphogypsum with a low P_2O_5 content is stored as a temporary 'gypsum quarry' not as a waste stack.

Prayon's commercial end-customer Knauf established a plaster production plant close to Engis in Belgium on the opposite bank of the River Meuse. Phosphogypsum from Prayon's production plant is transported by conveyor belt across the river to a discharge point where it is temporarily stored.

Over a period of several weeks, the phosphogypsum cures naturally in-situ, reverting from wet hemihydrate (HH) cake (18% free water, 6% crystalline water) to rehydrated dry dihydrate (DH, 5% free water, 19% crystalline water). The resulting gypsum product requires no further treatment prior to its shipment down river by barge to Knauf's stucco plaster factory.

In 2018, some 90 percent of phosphogypsum generated by Prayon at Engis met Knauf's HH feedstock specifications, while eight percent was used in agriculture, leaving just a minor volume in the interim storage area.

Prayon is currently collaborating with the British company Carbon Cycle on the innovative *PureGYP* process[4]. This novel purification technology is designed to clean phosphogypsum so that it can be sold, rather than stacked, and offers the following advantages:

- Extracts fluoride and phosphate making phosphogypsum suitable for cement and plasterboard manufacture
- Typically removes 96 percent fluoride and 99 percent phosphate
- Widens the range of usable phosphate rock sources
- Has the potential to convert phosphogypsum stacks into valuable raw material quarries.

Roadbuilding: examples from Russia

Roadbed phosphogypsum (RBPG) is an innovative material for road construction produced by the Balakovo Branch of Apatit, a wholly-owned PhosAgro subsidiary[3].

The product's specifications were approved by Russia's Federal Road Agency in 2018 for three years. This authorises the use of RBPG in road construction and repair. To date, the total area of roads constructed using RBPG, including experimental pilot stretches, is around 180,000 m^2, these having a service life of between two and 11 years.

Notably, a 2,500 m^2 stretch of the Syzran–Saratov motorway (83rd kilometre) was built in 2017 using RBPG, with the approval of local federal authorities in Povolzhupravtodor. This was part of seven road stretches constructed in Russia using RBPG between 2008 and 2017 (Table 1).

RBPG combines large volume availability, affordability, simplicity and safe handling with high operational performance and environmental safety. Its key advantages include:

- Tensile strength up to 10 times higher than required benchmarks
- Elasticity modulus up to two times higher than required benchmarks
- Eliminates the need for a sand drainage layer in road construction
- Road performance maintained in marshy terrain
- Low propensity to heave during winter (freeze-thaw)
- An operational warranty as a road base of not less than 12 years
- No detectable negative environmental impacts.

Overall, RBPG has proven economically viable as a secondary resource for road construction due to its ability to substitute for primary raw materials without compromising roadway performance. Indeed, cost-benefit analysis suggests that replacing conventional materials with RBPG in road construction could deliver cost savings of 21-35 percent[3].

Technology: helping phosphogypsum join the circular economy

Technology has a key role to play in generating commercially valuable and saleable 'clean' gypsum as a co-product of phosphoric acid manufacture. Germany's **thyssenkrupp Industrial Solutions**, for example, is developing a viable treatment process for phosphogypsum, based on the OSW-Krupp method (see accompanying article on p48).

The dihydrate (DH) process from **Technip Energies** also generates good quality phosphogypsum suitable for industrial reuse. In our forthcoming May/June issue, Philippe Malsan, the company's Fertilizer Consulting & Technology Manager, will present industrial cases studies from Senegal and Austria – to show how phosphogypsum from this process has been successfully recycled on a large scale for cement, plaster and other end uses.

Table 1: **Inventory of road stretches built with RBPG in Russia, 2008-2017**

Facility name	Area	(M2) built
Stretch of Motorway Village of Bykov Otrog – Household Garbage Ground	900	2008
Stretch of Motorway leading to the Rolled Section Plant, Balakovo Severstal Publicly Traded Company	59,000	2013
Motorway Stretch Village of Kormezhka	9,000	2015
Motorway Stretch Village of Mayanga	2,000	2016
Pilot and Operating Stretches in the territory of the Balakovo Branch of Apatity JSC	20,000	2008-2019
Regional Motorway Balakovo – Ershov	80,000	2014
Federal Motorway Syzran – Saratov, 83-rd km – process exit ramp for heavy duty vehicles	2,500	2017
Total: In operation for 2-11years	**180,000m²**	

Source: Hilton (2020)

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Using phosphogypsum to create soil and combat climate change

The conventional way of reclaiming phosphogypsum (PG) stacks is to cover their surface with a thick layer of soil. When Nutrien began researching alternative methods of PG stack reclamation in Alberta, Canada, in 2005, the company discovered that reclamation could be improved by mixing small amounts of soil directly into weathered PG. This created a man-made soil known as an 'anthrosol'. Nutrien's **Connie Nichol** explains more about this highly beneficial discovery.

Creating healthy soils for trees

"It was found that any amount of soil mixed into weathered PG grew larger, healthier biomass than plants grown in soil alone. Nutrien then investigated the possibility of growing trees in the PG mix to reduce long term maintenance costs and increase sustainability – while also creating value and sequestering carbon.

"Approximately a thousand hybrid poplar (*Populus* spp) and hybrid willow (*Salix* spp) cuttings were planted into a PG/soil mix in 2015 and found to grow extremely well. Based on this success, approximately twenty hectares of PG stacks were reclaimed and planted to high yield afforestation plantations in 2016 and 2017 following the protocols developed by the Canadian Wood Fiber Center, Natural Resources Canada."

Rapid tree growth

"These trees are growing very quickly. As an example, between 2016 and 2017, the hybrid poplar cultivar Tristis grew from an average height of 85 cm to 280 cm, a height gain of almost two metres in a single year. Crown closure has been observed in some species after less than three years. This inhibits vegetation growth beneath the trees, with the site essentially left in a free-to-grow state without any need for maintenance.

"Trees are observed to be growing much faster on the gypsum stacks than the same trees growing on regular soil. This is likely because the PG has excellent water holding capacity and some residual plant nutrients."

Carbon sequestration and biomass for energy

"The tree plantations established at Nutrien are predicted to sequester 30 tonnes CO_2 equivalents per hectare per year. Thus, in 20 years, the gypsum stack area reclaimed to date will sequester 12,000 tonnes of CO_2 equivalents. This same area is also predicted to produce 10 oven dry tonnes/ha/year of above ground woody biomass.

"It is therefore estimated that 4,000 green tonnes will be produced in this area over the next 20 years. These numbers will continue to increase as Nutrien continues to reclaim and establish concentrated woody plantations on their PG stacks."

Myriad environmental benefits

"Establishing a forest on top of PG stacks has many positive impacts on the environment. The afforestation approach to PG stack reclamation will increase carbon sequestration and generate carbon dioxide offsets as well as produce biomass for energy production. Trees are also capable of phytoremediation of any excess nutrients and water within their rooting zone, thereby improving long term groundwater quality.

PHOTO: NUTRIEN

Poplars planted on a phosphogypsum stack in 2016 have grown extremely well.

"University research indicates that there is little or no water infiltration into the gypsum stack under the concentrated tree plantations in the semi-arid climate of the Canadian prairies. Incorporating trees into the reclamation plan will also improve the long term sustainability and ecological diversity while also reducing long term maintenance costs. Increased wildlife such as deer, rabbits, foxes, small rodents and many birds have been observed in the forested areas."

Food production

"The phosphogypsum/soil (anthrosol) can also be used to grow many other types of high value crops. Nutrien has established a small research garden on top of the PG stack and has tested various flowers, fruits and vegetables such as raspberries, potatoes, tomatoes and pumpkins (see photo).

"Analytical results indicate that the quality of the vegetables are the same or better than plants grown on regular soil. Future research will include expanding pollinator habitats and working with local beekeepers to investigate other opportunities to create value *in situ*."

Phosphogypsum: joining the circular economy?

The economic conversion of phosphogypsum waste into a valuable product has been pursued for decades. Results of intensive research by thyssenkrupp Industrial Solutions (tkIS) in this area are presented by **Peter Stockhoff, Dirk Koester, Stefan Helmle** and **Carsten Fabian**. The approach developed by tkIS shows great potential as a controlled treatment process for phosphogypsum.

Large volumes of phosphogypsum (PG) are generated during the production of phosphoric acid from natural phosphate rock using sulphuric acid. About 4-6 tonnes of PG are generated as a waste by-product for every tonne of phosphoric acid produced. This corresponds to annual PG production of around 250 million tonnes globally – roughly equivalent in weight to 1.25 million family houses.

Although gypsum is the main constituent of PG, a range of other impurities can also be present, including residual phosphate, fluoride, organic matter, iron, aluminium, heavy metals and radionuclides (*Fertilizer International* 478, p58). Certain countries have placed legal restrictions on the disposal and use of PG due to the presence of these impurities.

PG is often stored indefinitely above ground as a wet slurry in engineered containments known as 'stacks'. Stockpiling in wet stacks is common industry practice. More than one billion tonnes of PG is stacked in Florida, for example, the main centre of US phosphate production. Large phosphate operations may need to open one or more PG stacks during their lifetime (*Fertilizer International* 478, p58).

PG stacks typically occupy large areas of land near phosphoric acid plants. They are usually designed and operated according to strict regulations, making them costly to construct and maintain. As a consequence, their safe management is a major cost burden and environmental challenge for phosphate plant operators.

Although industry attitudes are changing fast, PG is still generally disposed of and stored as waste. Currently, just 15 percent of the vast amounts of PG generated globally goes on to be used in some form. Nevertheless, common end-uses include:

- In agricultural as a fertilizer
- Land reclamation
- Soil remediation and conditioning
- Building materials – particularly the cement and plaster market
- Road construction.

The OSW-Krupp process

The OSW-Krupp phosphogypsum process was responsible for some promising early examples of commercial PG use. This process combined phosphogypsum with additional clay, sand, coke and natural gypsum to generate equal amounts of sulphuric acid and Portland cement.

A number of OSW-Krupp plants were built between 1956 and 1980 in South Africa, Poland, Austria and Germany. Although their main purpose was to recover sulphuric acid from PG via thermal decomposition, valuable clinker for

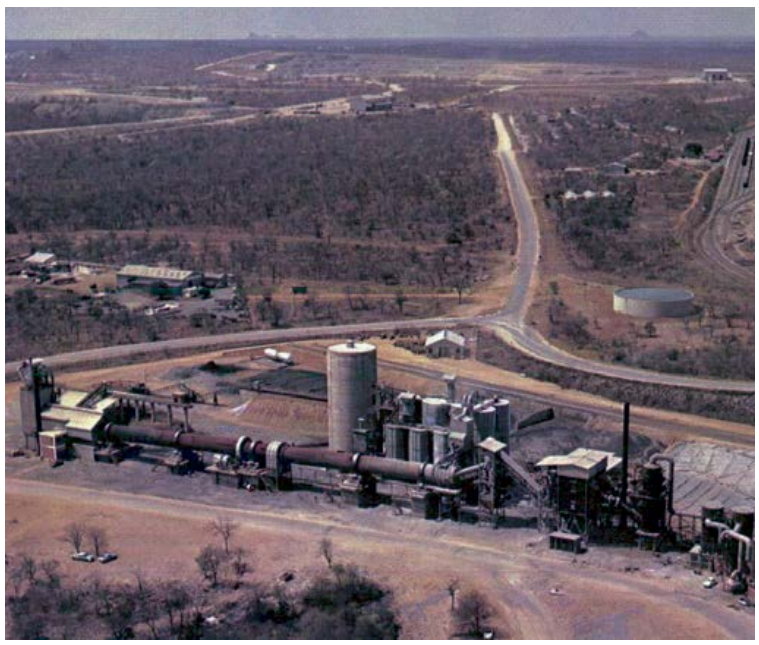
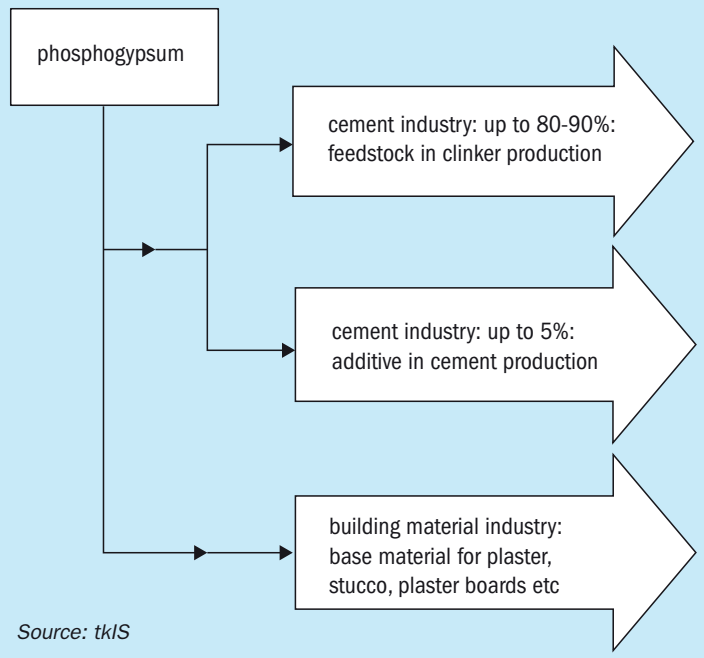


PHOTO: TKIS

Fig. 1: The Phalaborwa OSW-Krupp conversion plant in South Africa. Operating between 1972 and 1987, this had the capacity to produce 105,000 tonnes of both sulphuric acid and cement annually.

Fig. 2: **Potential large-scale markets for phosphogypsum**



Source: tkIS

Table 1: **Major and minor element composition of PG from four different phosphoric acid plants (PG1-PG4) by XRF analysis***

	PG 1	PG 2	PG 3	PG 4
% LOI**	20.42	21.43	20.6	20.29
% SiO_2	0.89	2.86	4.18	2.61
% Al_2O_3	0.13	0.11	0.13	0.07
% Fe_2O_3	0.15	0.02	0.18	0.44
% CaO	31.07	30.79	30.43	31.56
% MgO	0.04	0.01	0.01	0.03
% SO_3	44.56	44.22	42.45	44.07
% P_2O_5	0.52	0.56	1.6	1.22
% F	0.57	0.55	1.63	0.96

** Trace elements (Ti, Mn, alkalis, Cl) have been omitted for simplicity. **Loss on ignition. Source: tkIS*

Table 2: **Clinker chemistry for four different PG 'raw meal' compositions**

Raw meal composition		**A**	**A1**	**A2**
Remark	**Reference PG 1**	**Based on untreated PG 1**	**Based on untreated PG 1**	**Based on treated PG 1**
% PG	100	84.58	50.39	84.58
% Limestone	-	-	35.00	-
% Clay	-	12.63	-	12.63
% Bauxite	-	-	4.09	-
% Iron ore	-	0.68	0.76	0.68
% Sand	-	2.11	9.76	2.11
Clinker chemistry				
% LOI*	20.42	0	0	0
% SiO_2	0.89	21.58	21.94	21.91
% Al_2O_3	0.13	5.14	5.27	5.22
% Fe_2O_3	0.15	3.04	3.11	3.08
% CaO	31.07	65.25	66.34	66.24
% MgO	0.04	0.63	0.64	0.64
% SO_3	44.56	0.02	0.49	0.02
% P_2O_5	0.52	1.07	0.53	0.52
% F	0.57	1.14	0.56	0.20

**Loss on ignition* *Source: tkIS*

the cement industry was also produced. Cement clinker is an intermediary in the manufacture of Portland cement, and is conventionally produced by sintering limestone and clay in a cement kiln.

The OSW-Krupp plant in Phalaborwa, South Africa, is a typical example (Figure 1). This conversion plant, which had a design capacity of 105,000 t/a each for sulphuric acid and cement, was commissioned in 1972 and subsequently operated for 15 years.

The OSW-Krupp plants were eventually closed for economic reasons – with access to lower cost sulphuric acid being a deciding factor – although meeting cement quality and environmental standards were also both issues.

Targeting potential phosphogypsum use

Because of the large amounts of PG produced and available worldwide, research at tkIS has focused on large-scale end-markets that are capable of consuming PG in major quantities. The clinker/cement and building materials industries were identified as the two most promising target markets for PG (Figure 2).

Due to its scale, there should be sufficient demand in the international cement market for additional supply of clinker/cement products derived from PG. Furthermore, PG also has potential as an alternative, carbon-neutral source of calcium to replace the limestone currently used in cement manufacture.

The gypsum supplied to the building materials industry is mainly sourced from natural gypsum and gypsum from downstream flue gas desulphurisation (FGD) at coal power plants. Production of FGD gypsum is, however, set to decline in future as a result of the global phase-out of coal power. This opens up a market opportunity for PG due to its potential as a raw material for plaster, stucco and plasterboard.

The cement industry and some plasterboard manufacturers have already identified PG as valuable raw material source – although, despite this, its use in these industries is still limited. However, the combination of carbon reduction goals, the emergence of the circular economy, and technology developments, have once again brought the economic potential of phosphogypsum back into focus.

PG quality – knowing what we're dealing with

PG is generated as a by-product of high-quality phosphoric acid production. Yet each individual production plant generates PG with distinctly different quality characteristics. This is largely due to the different types of phosphoric acid manufacturing process used, and the natural compositional variability of phosphate rock feed. Table 1, for example, shows the compositional differences (major and minor elements) in PG generated by four different phosphoric acid plants.

Clinker quality requirements

The suitability and potential utilisation of PG depends on a number of quality considerations. Very low values for P_2O_5 and fluorine are required by both the clinker and cement industry, for example, as their presence is known to lower the development of strength in cement. Consequently, the final specification for clinker demands P_2O_5 and fluorine contents of less than 0.5 percent and 0.2 percent, respectively.

The levels of silica, aluminium and certain other elements in clinker also regulate its behaviour and are therefore important to quality. It is typically necessary to add-in several materials (e.g. clay, bauxite, iron ore, sand) to the main PG feed to obtain clinker with the desired composition. This feed mixture for a clinker plant (PG plus additives) is called the 'raw meal'.

Examples of the difference in clinker chemistry resulting from four different raw meal compositions are shown in Table 2. Trace elements (Ti, Mn, alkalis, Cl) have been omitted for simplicity.

The clinker chemistry obtained for a raw meal containing untreated PG is shown in column A of Table 2. This raw meal composition contains sufficient additives (clay, iron ore and sand) to meet the desired silica, aluminium and iron levels in clinker. However, it is clear that using untreated PG (up to 85%) does not meet the required P_2O_5 and fluorine criteria.

One way to achieve the required P_2O_5 content in the clinker would be to replace around 35 percent of the untreated PG with limestone (see column A1, table 2). However, the fluorine content (0.56%) would still remain too high. In any case, replacing untreated PG by limestone in this way would be uneconomical and undesirable for PG producers. Instead, the best way to achieve the target quality in the clinker (see column A2, table 2) would be to selectively treat the PG to reach a P_2O_5 content of 0.24 percent and a fluorine content of 0.1 percent. This clearly shows how reducing the P_2O_5 and fluorine contents of PG upstream of a clinker plant is both an achievable and viable option.

Building material requirements

The usage of PG in the building materials industry, particularly in Europe, is limited by the strict quality criteria for recycled gypsum in this market[1]. The fluorine limit for gypsum used in plaster is set below 0.02 percent, for example. Because of the exacting standards, only a few PG producers worldwide are able to meet construction industry requirements without additional treatment.

PG also contains levels of the naturally-occurring radionuclide decay products of uranium-238 and thorium-232 which were originally present in phosphate rock (*Fertilizer International* 478, p58). Approximately 90 percent of the original radium content of phosphate rock remains in the PG after digestion with sulphuric acid. This considerably limits its use as a building material.

Most countries use an activity concentration index (ACI) to assess building material suitability based on radioactivity. This is defined as follows according to RP 112 of the European Commission[2]:

$$I = \frac{C_{Ra-226}}{300\ Bq\ kg^{-1}} + \frac{C_{Th-232}}{200\ Bq\ kg^{-1}} + \frac{C_{K-40}}{3000\ Bq\ kg^{-1}}$$

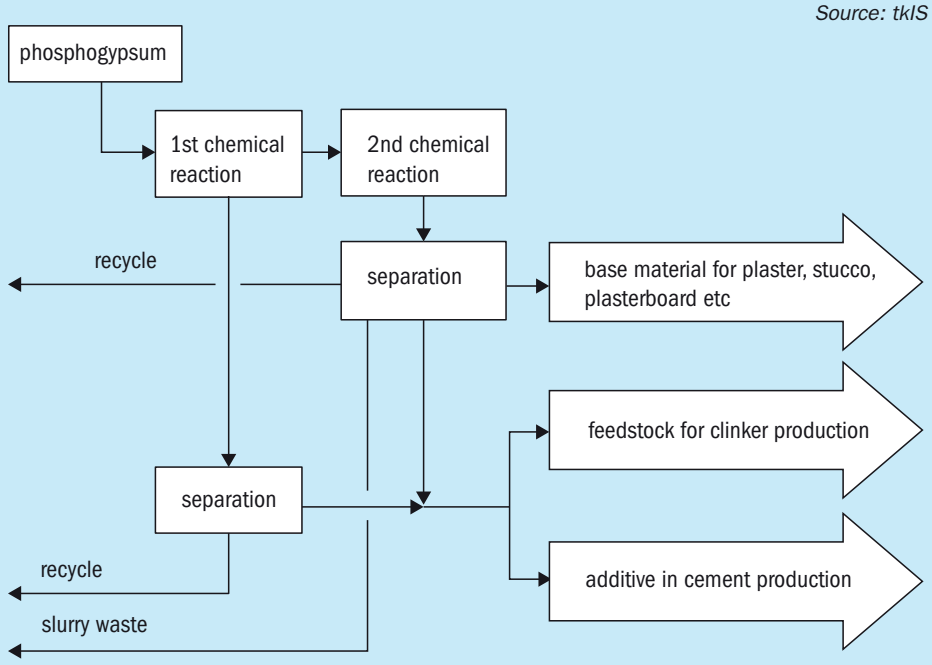
In principle, it is possible to use a bulk material with an ACI ≤ 0.5 for direct use without restrictions, being equivalent to an annual radioactive dose criterion of 0.3 mSv. Generally, the ACI for building materials must not exceed I = 1, which corresponds to an annual dose of 1 mSv. For gypsum plasterboard with restricted use, the ACI must be below either 2 or 6 to meet dose criterion of 0.3 or 1 mSv a^{-1}, respectively.

Typical activity concentrations for PG (390 Bq kg^{-1} for Ra-226, 20 Bq kg^{-1} for Th-232 and 60 Bq kg^{-1} for K-40), as given in RP 112, would lead to an ACI of approximately 1.4. The usage of PG as a clinker raw material would therefore undoubtedly increase its ACI. However, the fact that clinker only makes up a proportion of cement, and an even smaller fraction in concrete, should limit the overall rise in ACI.

The above discussion demonstrates that the activity concentration index does need to be examined in detail when assessing PG for individual building material applications.

Fig. 3: **tkIS PG treatment flow sheet**

Source: tkIS



tkIS phosphogypsum treatment process

The latest PG treatment process from tkIS is based on the original conversion process for the OSW-Krupp plants. An investigation of the performance of these plants revealed that pre-treatment is required before PG is suitable for downstream production of high-quality clinker/cement or other building materials. The literature on other approaches to PG treatment was also reviewed[3,4].

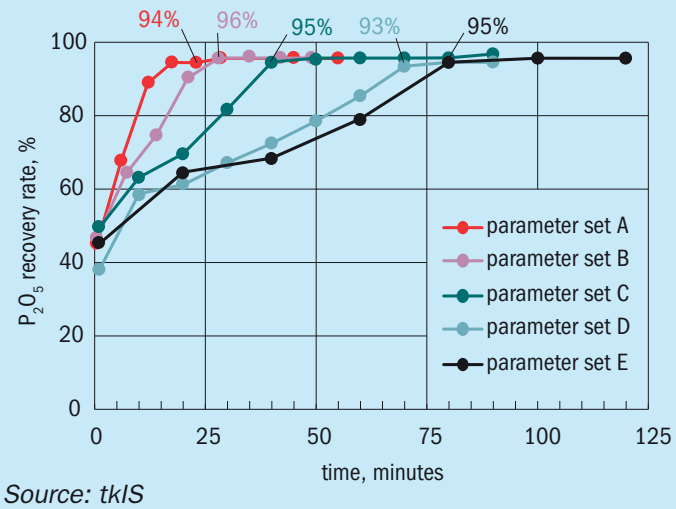
PG from various phosphoric acid plants was chemically and mineralogically analysed prior to developing the treatment process. Additionally, information was also gathered on the specifications and quality requirements for cement and other building raw materials. Once this data had been collated, a laboratory-scale PG treatment process was developed and tested using a step-by-step approach.

Once the laboratory tests were completed, results were transferred into a kinetic process model. This model was then used to predict the treatment process parameters needed to achieve the necessary PG quality. In this way, only a few laboratory tests are required to confirm a suitable process design for the new PG treatment method.

Treatment process results

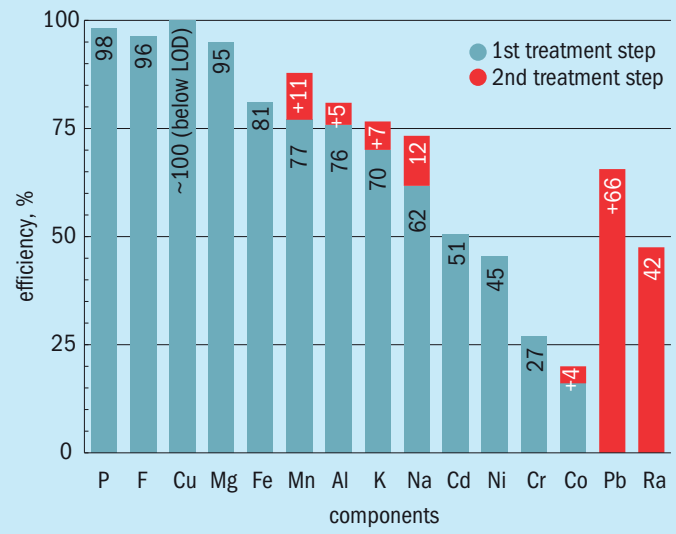
The new PG treatment process consists of two main steps in sequence. Each step involves a chemical reaction followed by liquid-solid separation (Figure 3).

Fig. 4: **Impurity removal performance during the first PG treatment step: P_2O_5 recovery rate vs time under five different process parameter regimes (A-E)**



Source: tkIS

Fig. 5: **Reduction efficiency for components from PG**



Source: tkIS

In the first treatment step, chemical impurities (P_2O_5, fluorides and others) are separated from the PG and removed in the liquid phase. This can, if required, be recycled to the phosphoric acid plant. After this step, the quality of the treated PG obtained should meet clinker/cement production requirements.

The aim of the second treatment step is to reduce radioactive components, especially radium, so the quality of the resulting PG meets building materials requirements. This treatment step is optional, depending on the composition and quality of the untreated PG.

The first treatment step performs well, being very effective at P_2O_5 reduction (see four examples shown Figure 4). A typical recovery rate of significantly more than 90% of P_2O_5 is possible, the exact reduction depending on the process regime. Importantly, the liquid phase containing the dissolved P_2O_5 is fully reusable in the phosphoric acid plant – and therefore contributes to the overall P_2O_5 efficiency of the production complex. The first treatment step has also been shown to be equally effective at reducing the fluoride content of PG.

Generally, understanding the reaction kinetics of P_2O_5 recovery is critical, as this holds the key to optimising the whole process (Figure 4). Reaction conditions have a large impact on the recovery rate, with harsh reaction conditions, for example, typically leading to shorter release periods compared to mild conditions.

The overall reduction in PG impurities achieved by both treatment steps is shown in Figure 5 (first treatment step in blue, second treatment step in red).

In the first treatment step (Figure 5, blue colour), P_2O_5 and fluoride are removed at efficiencies of up to 98 percent and 96 percent, respectively. In parallel with this, significant reductions in other elements (Cu, Mg, Fe, Mn etc.) are also achieved. This is highly beneficial for the potential use of PG as a plaster industry raw material. The efficacy of this first treatment step has also been tested and confirmed on PG generated by both sedimentary and igneous phosphate rock types.

The main aim of the second treatment step is radium removal (Figure 5, red colour). Treatment was found to reduce radium activity by approximately 40 percent, down from 570 Bq/kg originally to an eventual value of 330 Bq /kg. Typically, this would be expected to reduce the ACI of PG from 1.4 to 0.9 approximately. Further studies are nevertheless underway to improve and optimise the removal of radioactive elements, particularly for more radioactive types of PG.

With regard to radioactivity, and despite what is achievable technically, decisions on the ultimate usage of treated PG will still require discussions between manufacturers, users and authorities.

Summary and outlook

thyssenkrupp Industrial Solutions (tkIS) has conducted intensive research with the aim of developing a technology to convert phosphogypsum (PG) into a valuable product for the circular economy. A two-step treatment process for the controlled reduction of impurities in PG has been devised and tested at laboratory-scale. This has shown that treatment can successfully achieve reduction rates of more than 95 percent for both P_2O_5 and fluoride. Promisingly, the radium activity of PG was also reduced by more than 40 percent in initial tests – with higher reduction rates expected in future.

Building on these positive lab-scale results, the next step of process development will scale-up capacity and optimise energy consumption. A strategy for achieving full integration of the PG treatment process within existing production plants will also be pursued. The opportunities for plant integration will be evaluated in cooperation and partnership with interested phosphate producers. ■

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We report on the latest potash mining and processing technology from Andritz, Ebner, Köppern, K+S and Veolia. Recent case studies for potash projects globally are also provided.

State of the art potash production

Erection and installation of a SOP crystallisation plant at Lake Way, Western Australia.

PHOTO: SALT LAKE POTASH

EBNER TECHNOLOGIES

Family-owned crystallisation and evaporation specialist

Germany's Ebner GmbH & Co KG is a family-owned specialist designer and manufacturer of evaporation and crystallisation plants. The company develops tailor-made plants completely in-house, from the customer's first enquiry to final delivery, having expertise that encompasses plant design, fabrication, erection, and start-up. Ebner has extensive experience in the design and manufacture of evaporators and crystallisers for the potash industry. Two recent case studies are provided below.

German technology for Australian SOP project

In October 2019, Ebner and K-UTEC Salt Technologies were jointly awarded a potash engineering contract by the Australian, ASX-listed mining company Kalium Lakes Limited (KLL).

The contract covered the engineering, supply, erection, supervision and start-up of a 90,000 t/a capacity production plant for KLL's flagship Beyondie SOP (sulphate of potash) project. Ebner and K-UTEC joined together to form a special consortium, EBTEC, to deliver this contract.

Kalium Lakes' vision was clear from the moment it first contacted K-UTEC in 2015. It wanted to be the first Australian company to bring domestically-produced SOP to market. Because all the SOP currently consumed in Australia is 100 percent imported, there was a unique, ground-

PHOTO: EBNER

Construction at the Beyondie SOP project in Pilbara, Western Australia.

PHOTO: EBNER

Fabrication of a condenser in Germany for the Nezhinsky potash project in Belarus.

breaking opportunity for a local producer to supply the domestic agricultural industry with SOP for the first time.

The proposed Beyondie SOP plant was located in the remote Pilbara region of Western Australia, about 1,400 kilometres north of Perth and 240 kilometres by road from the nearest town. The plant was designed to produce high-purity SOP by selectively precipitating salts present in a saline brine. This was to be extracted from nearby salt lakes and underground aquifers using a network of trenches and wells.

K-UTEC's main project expertise is in geophysical exploration, process development, design engineering and basic engineering. This includes the technical and economic assessment of full-scale industrial plants and the piloting of complete process routes. The company developed a suitable SOP production process for the Beyondie project in 2018. This involved initial test drilling, preliminary studies, feasibility studies and practical test work – to demonstrate the most commercially-viable production route. In the production process selected for the SOP project by K-UTEC, salt is firstly generated by concentrating a brine solution in large solar evaporation ponds, each with a surface area of around 400 hectares. This salt is then refined in a processing plant to obtain a high-purity SOP fertilizer product.

The Beyondie project reached financial close in December 2019. The financing included AUD 102 million of senior debt funding from KfW IPEX-Bank, with approximately half of this amount supported by a guarantee from Euler Hermes, the German government's export credit agency. Once project finance had been secured, EBTEC went ahead and designed and delivered the processing plant.

The EBTEC consortium was able to ship the main equipment, including dissolution, flotation and crystallisation apparatus, to Australia on schedule, despite Covid-19 restrictions. Backed by 50 years of plant manufacturing experience, Ebner was able to handle everything in-house, including the fabrication of individual components in its own workshops and the overall completion of the plant. The company's engineering know-how, capabilities and experience were vital for the successful completion of the contract.

The Beyondie SOP project is currently in the assembly phase. This is being carried out by an Australian co ntractor under the joint supervision of EBTEC and Kalium Lakes. Site infrastructure has already been completed and the process plant is in the process of being built. SOP production is scheduled to start-up in September 2021.

Large-scale MOP crystallisation plant for Slavkaliy

In February 2020, Famako Anlagenexport GmbH, with Ebner as subcontractor, were awarded a major engineering contract by Slavkaliy for its Nezhinsky potash project in Belarus. The contract encompassed complete project design, manufacturing, delivery and start-up of a large-scale crystallisation plant for the production of MOP (muriate of potash).

In the Nezhinsky processing plant, potassium chloride will be obtained from hot-saturated brine by vacuum cooling crystallisation using the classic hot leaching process. In total, two production lines at the plant will produce around two million tonnes of MOP annually. Both lines are designed to operate as independent seven-stage vacuum crystallisation plants.

For Slavkaliy, the design and delivery of the crystallisation plant will be critical for the overall success of the Nezhinsky mining and production complex.

To ensure the vacuum crystallisation plant operates efficiently, vapour generated during the expansion of the hot solution will be used to reheat the cold circulation-brine obtained from the salt separation. This minimises steam consumption requirements during hot leaching. At the same time, this process configuation also reduces the plant's cooling water consumption to the lowest level possible.

Most of the individual components of the crystallisation plant were made of high-quality special materials. Due to their size, these were prefabricated in Germany for onward transport to Belarus (see photo). The project's schedule necessitated just-in-time delivery and the careful choreography of logistics for such a large plant. Ensuring individual components were available on time and ready for transport was a particular challenge, especially against the backdrop of a global pandemic.

As a contractor, Famako is responsible for project financing, coordination with suppliers and project logistics. The company, which is active in the former Soviet Union (FSU), specialises in the planning, delivery and commissioning of conveyors and other systems for processing fertilizers and other bulk materials. Ebner, meanwhile, provides project know-how and is responsible for plant design. This expertise is delivered by in-house staff, from the initial design computations through to the final design specification.

Thanks to the relevant experience of both companies, and closely coordinated project management, the project remains on-track with the processing plant scheduled to be fully assembled in 2023. Ebner and Famako are proud to have successfully completed their project work for Slavkaliy, given the challenging global conditions currently, especially as the contract with Slavkaliy is the largest ever undertaken by both companies in financial terms. ■

ANDRITZ

Process automation

With over 90 years of experience, Andritz is a market-leading supplier of liquid/solid separation equipment to the potash industry. The company installed its first potash centrifuge in 1926. Since that time, Andritz-manufactured equipment has been adopted by many large-scale potash producers globally, including conical screen bowl decanters, large-diameter disc filters and proprietary fluidised bed systems.

Indeed, Andritz is the brand behind some of the mining industry's best-known separation equipment suppliers – including dryer, centrifuge, filter and fluidised bed manufacturers such as Bird, KHD Humboldt Wedag, Krauss Maffei and Escher Wyss.

Andritz has a total of around 600 potash references around the world, including:

- 425 centrifuges
- 100 fluidised bed systems
- Dozens of filters, plate dryers and thickeners.

Impressively, these have been installed on five continents in every major potash-producing region. In recent years, large-diameter Andritz disc filters have a been adopted by potash operators in Belarus, Russia, and South America, while its innovative conical screen bowl decanters have entered operation in North America.

The installation of a high-capacity, energy-saving Andritz dewatering system in Belarus, for example, has delivered major operational improvements at Belaruskali's Plant No 1. These included a 10 percent increase in production capacity, 15 percent lower energy costs and a 30 percent reduction in residual product moisture (*Fertilizer International* 484, p64).

Control system for Compass Minerals

Andritz also has expertise in automated production systems for the potash industry, having notably supplied a complete control system to Compass Minerals. This was part of a 2016 project to commission and integrate a new crystalliser and compaction plant at the company's Ogden, Utah, sulphate of potash (SOP) production site in the United States.

Andritz was tasked with:

- Validating the process design
- Designing and supplying the control system
- Supplying the proprietary *BrainWave* advanced controller for the SOP crystalliser
- Supplying power distribution and motor control equipment
- Developing a simulation-based operator training programme.

Virtual plant to predict behaviour

Compass Minerals wanted to reduce the project's implementation costs, minimise start-up risks, and predict how the new project would affect its existing operations. To help deliver on these objectives, Andritz modelled the new compaction process, and used its dynamic *IDEAS* process simulator – essentially a 'virtual plant' – to accurately predict the behaviour of the new SOP crystalliser. The benefits of the complete automation package delivered by Andritz included:

- Reduced errors, risks, costs, and project uncertainty
- Optimisation of the SOP process
- Successful plant start-up and then ramp-up to full production
- Completion of simulation-based operator training before start-up
- Only minimal project impact on existing operations.

The overall outcome was that, from the very first day of start-up, Compass Minerals had access to a fully-functioning and integrated SOP production control system that was already up and running. ■

KÖPPERN

Potash compaction-granulation

Köppern, a family-run business founded in Hattingen, Germany, has been manufacturing briquetting, compaction and comminution machinery since 1898. The company has been supplying compaction and granulation equipment and plants to the fertilizer industry for more than 70 years. Its sales include several hundred roller presses in over 60 countries.

Granular potash is produced almost exclusively by a compaction-granulation process. Fine-grained potash feed is generally compacted on roller presses to produce flakes with a density close to that (>95%) of natural potash. These flakes are then crushed and screened to produce a closely-sized (often 2-4 mm) granular product.

Three key components

A typical compaction-granulation plant for MOP (muriate of potash) consist of three key components – roller presses (compactors), crushers and screens – configured in closed-circuit. The feed is firstly compacted at an elevated temperature. Köppern typically installs compactors with a 1,150 mm diameter and 1,000 mm working width. Multiple compactors are often installed within one potash plant. These presses have a maximum flake throughput of approximately 140 t/h and a gross granular potash capacity of 40-50 t/h. After compaction, impact and roller mills, working in a closed-loop cycle with multi-deck screens, crush the flakes into granulate with an approximate density of 1.9-1.95 g/cm^3.

Since the 1990s, the preferred flake capacity of potash compactors has increased to 110-130 t/h. The majority of new compactor investments made by potash producers in recent years have been in designs of at least 100 t/h flake.

Design innovation

Köppern has introduced a number of innovations and design changes to ensure compactors of this size are safe, reliable to operate and deliver excellent flake quality. This has involved the modification of various sub-assemblies, including the frame, feeder, roll design, roll drive and the hydraulic systems.

PHOTO: KÖPPERN

Köppern roller press.

Vibrations are a particular operational problem when de-aerating and compacting potash – as they can result in severe juddering that damages equipment. The risk of

this can be reduced by lowering roll speed and/or feed rate. However, changing the compactor drive design to increase mechanical stiffness is a preferable way of solving this problem at source. This approach also maintains throughput, and is therefore less of a compromise for customers.

For many years, Köppern has stiffened the drive train of large roller presses by manufacturing these with planetary gear reducers mounted directly onto the roll shafts. The company delivered its first large potash compactor (130 t/h) with this drive technology to Germany in 1998. Since then, compactors with this drive design have been widely-adopted worldwide. For example, Köppern's fertilizer compaction customers in Brazil, Canada, China, Croatia. Hungary, Jordan, Italy, Russia, Serbia and Spain have either modified or ordered new roller presses fitted with this type of main drive.

All large potash compactors supplied by Köppern since the early 1990s have also been supplied with a hinged frame. This allows quick access to rollers for assembly or maintenance. Rollers can be picked up easily without dismantling any part of the frame or feeder.

The feeder is an important component of the compactor. It needs to transport large volumes of material, de-aerate this effectively and distribute it evenly over the entire working width of the roller. The ability to independently adjust screw speeds also prevents misalignment by controlling the gap between rollers. Meeting these requirements prompted Köppern to develop a special double-screw feeder design. This design was first introduced into the potash industry in the mid-1990s in roller press upgrades in Germany and Belarus. The newly developed double-screw feeder was subsequently supplied to K+S in Germany and further clients in Canada, Chile and Belarus.

It is also economically advantageous to provide the roller body with exchangeable tyres, as this allows refurbishment of the tyre profile after wear.

Most of the above improvements and new design features, developed by Köppern over the years, can be found in many compactors used today by the potash industry globally. ■

K+S GROUP

Kainite crystallization flotation (KCF) unit

Werra, K+S Group's biggest potash plant, is a large-scale complex spread across four sites in two German states: Hattorf and Wintershall in Hesse, and Unterbreizbach and Merkers in Thuringia. The plant produces fertilizers alongside numerous technical and industrial products. These have a wide-range of uses, including pharmaceuticals, foodstuffs and animal feed.

Major investment in the Werra site

K+S has invested heavily in new production technology at Werra in recent years. In particular, the commissioning of the kainite crystallization flotation (KCF) unit at the Hattorf site in 2018 has allowed the company to dramatically cut the volume of wastewater discharged into nearby rivers. This major investment was also designed to safeguard the future of Werra as K+S's largest potash operation in Germany.

The new €180 million KCF unit recycles saline solutions generated by ore processing operations at the Hattorf and Unterbreizbach sites. Valuably, it improves operational efficiency by extracting more saleable product from process water, using new technology developed in-house by K+S.

Improving efficiency, reducing wastewater

The implementation of kainite crystallisation downstream of ore processing has delivered two main benefits. Firstly, the KCF has cut the volume of saline water generated by production annually by fifty percent. Secondly, the new unit recovers large amounts of reusable product materials annually, by recycling saline solution from upstream processes at both the Hattorf site in Hesse and the Unterbreizbach site in Thuringia.

The KCF operates via four main process steps:

1. **Partial capture of process and wastewater streams:** The KCF captures over two-fifths of the wastewater at the Werra plant and recycles this to reclaim economically-valuable materials.
2. **Evaporation step:** A salt mixture, made up of kainite ($MgSO_4 \cdot KCl \cdot 3H_2O$), sylvite (KCl) and halite (NaCl), is firstly obtained by an evaporation step using process steam from the Hattorf site's power plant.
3. **Crystallisation and flotation step:** The recyclable components are then separated from this salt mixture and further processed to produce sulphate of potash (SOP, K_2SO_4) fertilizer.
4. **Cutting saline wastewater discharge:** The KCF reduces the volume of saline wastewater discharged to the Werra river, or disposed of underground, from 7.0 million m^3 to 5.5 million m^3. The unit also reduces the salt load present in wastewater discharges by more than 500,000 t/a.

> **"K+S has invested heavily in new production technology at Werra in recent years.**

Mammoth construction project

Construction of the KCF was a mammoth project, due to the scale of the new €180 million processing unit (74 metres-long, 20-metres wide and 58 metres-high). The structure required around 5,500 tonnes of steel, for example, enough to build the Berlin Radio Tower nine times over. The need to excavate 36,000 cubic metres of soil during earth moving for the project further illustrates the massive scale of this undertaking. Constructing the KCF also required:

- More than 1,000 valves
- 180 kilometres of cabling
- 86 pumps
- 82 items of equipment and machinery
- 35 kilometres of piping.

The KCF's heaviest single component is the heat exchanger which weighs 110 tonnes – about 90 times the weight of a typical family car. The largest item, the V1200 evaporator, is 16 metres long, has a diameter of seven metres, and weighs 82 tonnes when empty. To manufacture and install specialised items of this size and weight, K+S awarded contracts to a number of German manufacturing and engineering companies including Ebner. ■

VEOLIA WATER TECHNOLOGIES

Lake Way potash project

The speciality fertilizer SOP (sulphate of potash, K_2SO_4) is a premium source of potassium with a rapidly growing global market demand. The product is favoured by many higher value crops, many of which are chloride-intolerant. That makes chloride-free SOP an increasingly popular fertilizer of choice for these crops. In regions such as Asia-Pacific and South America, demand for premium fertilizers such as SOP is thriving – thanks to the expansion of micro-irrigation and greenhouse-based horticulture.

Pioneering the production of SOP in Australia is Salt Lake Potash Ltd, the developer of the Lake Way potash project. This sustainable mining project is aiming to produce up to 245,000 tonnes of premium SOP annually. Suitable for use in organic farming, this will be extracted and refined from dry salt lake deposits in the Northern Goldfields region of Western Australia.

PHOTO: SALT LAKE POTASH

Erection and installation of a SOP crystallisation plant at Lake Way, Western Australia.

Process description

The Salt Lake Potash production plant is designed to produce SOP using a natural potassium-bearing source as a feedstock. The process involves recovering SOP from hypersaline brine extracted from salt lakes. Initially, potassium-rich salts are harvested by concentrating and transporting these brines through a series of solar ponds.

Veolia Water Technologies is supporting the project by designing and supplying the crystalliser technology packages. These are capable of converting the harvested salts (schoenite) into premium-grade SOP. Veolia's proprietary *HPD*® SOP crystalliser will grow and purify potassium sulphate crystals. A second crystalliser, meanwhile, will recover secondary schoenite salts [$K_2Mg(SO_4)_2 \bullet 6(H_2O)$] from recycled SOP mother liquor. To maximize SOP yield, these recovered secondary schoenite salts are combined with primary schoenite salts in the feed to the primary SOP crystalliser.

Operational flexibility allows potassium chloride (KCl) to be added to the crystallisation system. This can increase SOP production capacity by up to 32 tonnes/hour (245,000 t/a).

More performance, less risk

To support the development of the Lake Way potash project, continuous bench-scale crystallisation testing was carried out at Veolia's Phillip J Stewart Technology center in Plainfield, Illinois. Tests were performed on actual harvested salts from on-site pilot evaporation ponds, together with process water from the site, and KCl sourced from the Dead Sea. The crystallisation of both SOP and secondary schoenite was tested under various conditions. The results obtained were then used to design the optimal process flowsheet and the full-scale commercial crystallisation equipment.

By validating the feed chemistry, simulating the optimal flowsheet design, and confirming process performance projections, the test work also helped to de-risk the project.

Basic engineering and bench-scale testing were both staged simultaneously – to further accelerate this fast-track project and deliver the client's objectives on schedule. This approach, as well as helping optimise capital costs, also kept operating costs low, as the system design ensured that fouling and cleaning requirements were minimised.

The project packages were delivered to the Lake Way site ahead of schedule, ready for erection and installation by contractors GR Engineering Services. Plant commissioning is expected to begin in March, with first production and sales of SOP expected in the second-quarter of 2021.

Approximately 90 percent of Lake Way's SOP production output is destined to be exported to customers globally. This includes volumes supplied to Helm, WeGrow, Unifert, Fertisur, Mitsui & Co and Indagro under long-term offtake agreements. The remaining balance of production will be reserved for the domestic market.

Salt Lake Potash has control of a portfolio of salt lake resources within the Northern Goldfields. The company's ultimate ambition is to develop an entire SOP province through a series of lake expansions. ■

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