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FERTILIZER INTERNATIONAL
ISSUE 492
SEPTEMBER-OCTOBER 2019

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Best of times, worst of times

2018 was a good year for the 'big three' US fertilizer producers. Factors such as higher selling prices, record sales volumes and lower production costs delivered bumper rises in earnings.

Nutrien's much improved 2018 company results exemplified the overall upswing in financial fortunes. Revenues at the Canadian fertilizer giant increased by eight percent last year to $19.6 billion, while earnings rose 32 percent to $3.9 billion.

The Mosaic Company also prospered in 2018. Full-year revenues at the Florida-headquartered potash and phosphate producer rose 29 percent to $9.6 billion. Earnings grew by an even more impressive 68 percent year-on-year to reach $2.0 billion.

Illinois-headquartered nitrogen producer CF Industries was another of 2018's strong performers. Its full-year revenues rose seven percent to $4.4 billion, while 2018 earnings of $1.4 billion were up 45 percent on 2017.

Chaucer said all things must end and, after 2018's stellar performance, this year did not start well for the big three. The skies didn't just rain on their parade – they unleashed a non-stop torrent.

Nutrien infamously described spring 2019 as "the worst US planting season in history". It noted that record rainfall in the first six months of the year prevented the planting of a massive 10 million acres – a new US record. "US weather in the first half was so severe it nearly eliminated global demand growth for crop inputs," commented Chuck Magro, Nutrien's president and CEO.

Unsurprisingly, second-quarter results this year were mixed, as commodity research company CRU noted: "Nutrien and CF both outperformed expectations, while Mosaic was still licking the wounds suffered from the recent unprecedentedly wet spring season. Saturated soils, persistent rainfall and flooding rivers interrupted the movement and application of fertilizers throughout the country."

In August, Chris Lawson, CRU's fertilizer research manager, in an excellent piece of analysis*, gave a cautious thumbs-up to North American market prospects for 2020. Chris identified fertilizer prices, affordability and inventory levels as three key factors to watch, alongside corn plantings.

The story on US fertilizer prices varies from mixed to decidedly downbeat. "Phosphate prices have plunged since October 2018. Midwest potash prices have been extraordinarily resilient, while urea prices have been volatile," reports CRU.

Urea prices notably surged in early summer. Distributors became desperate for product as flooding along the length of the Mississippi disrupted transport. Faced with adversity, suppliers did, however, prove adept at eventually getting stranded product out to farmers.

Phosphate prices have fallen particularly sharply since last autumn. The bad spring application conditions and US distribution difficulties have been exacerbated by a build-up of large import volumes. This has resulted in phosphate prices falling to their lowest levels in three years.

The good news is that low prices stimulate demand by improving affordability. Encouragingly, CRU and Mosaic are reporting that average fertilizer affordability in the US is the best it has been in 10 years. This is due to a combination of higher futures prices for corn and lower fertilizer prices, particularly for phosphates and ammonia.

In a round of bullish second-quarter earnings calls, Nutrien, Mosaic and CF all shone the spotlight on the likely increase in 2020 corn plantings. All three predicted US corn plantings of 95 million acres plus – a fundamental that should be supportive of fertilizer demand next year.

Those are two positives. But should US fertilizer producers expect any more rain on their parade?

The carry-over of inventory remains one concern, especially for phosphates. "With a poor fall season and then a disappointing spring season, probably about 800,000 tons of demand was lost. At the same time, we had one million tons more imports into the US, exacerbating the problem along with the flooding along the river," Mosaic commented in July.

The other wild card is, of course, the growing US-China trade war. This zero-sum game of international brinkmanship is undoubtedly hitting business confidence.

In early August, the Chinese government told state enterprises to stop buying US agricultural goods. Although largely priced into the market already, the move has still injected "a heavy dose of negative sentiment" into agricultural commodity markets, suggests CRU, highlighting one potential downside.

Nevertheless, if spring 2019 was the worst of times, North America's big three fertilizer producers – striking a resolutely positive tone – are looking forward to better times ahead. ■

"Nutrien called spring 2019 the worst US planting season in history. Record rainfall in the first six months of the year prevented the planting of a massive 10 million acres – a new US record.

*Lawson, C., 2019. North America's 'Fertilizer Three' set optimistic tone for 2020… but caution is urged. *CRU Insight*. 7 August 2019. London

Simon Inglethorpe, Editor

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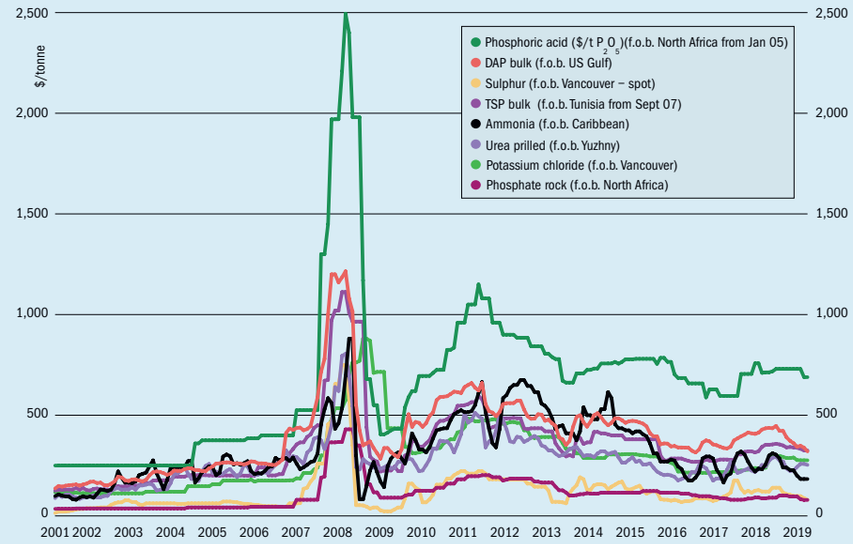
Market Insight

Historical price trends $/tonne



Source: BCInsight

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: Prices fell during the third-quarter, dropping to around $260/t f.o.b. Middle East and $250/t f.o.b. Egypt in late August. Baltic prilled urea also traded as low as $230-235/t f.o.b. Prices have weakened on low demand and a resurgence in Chinese exports. China's January-July urea exports, at two million tonnes, were up by nearly 150 percent year-on-year. July demand was generally lower. A rise in prices in June was one factor, as this caused buyers to step back in anticipation of falling prices.

Phosphates: International prices continued to slide during August, with a fundamental lack of demand in key buying regions pushing these lower. The Argus DAP index – a basket of f.o.b. price levels from the five largest DAP-exporting nations – has dropped by over 23 points since the start of this year. Against the general trend, Pakistan DAP demand did pick up marginally at the end of August, as importers moved to secure product for the peak October-November season. In India, high stock levels (around 2 million tonnes excluding port stocks), and importers angling for lower prices, pushed the DAP price below $340/t cfr at the end of August. Prices have been depressed West of Suez too. Nola MAP barges traded at $281/st f.o.b. at the end of August, its lowest level since 2012.

Potash: MOP prices are still declining. After showing strong improvements from mid-2016 onwards, prices began to level off last November and have been dipping steadily ever since. Lower-than-expected demand in most major potash-buying regions has left too much MOP on the market. Prices have dropped in many regions this year as a consequence. Granular prices in Brazil have fallen to $320-330/t cfr, down from $350-360/t cfr in January. Standard MOP prices have fallen to $285-305/t cfr in Southeast Asia, down from $300-320/t cfr. In the US, granular MOP barge prices are at $248-250/st f.o.b., down from $285-290/st f.o.b. at the start of the year.

Sulphur: Prices are still softening, having now lost 46-61 percent of their value since late October last year, when prices first started to slide. Weak sentiment in the finished fertilizer market, together with consistent contract volumes to key end-users in China, Brazil and north Africa, have depressed spot market demand. Strategic spot market purchases by key end-users have been enough to cover demand well into the fourth-quarter.

MARKET OUTLOOK

Urea: The market bottomed out in late August with prices in some regions starting to firm – notably in North Africa due to seasonally-strong buying for the European market. Buying from several major markets is expected to prompt a rise in prices for October shipment. An Indian tender, due for September-October shipment, should support Asian prices. Spot demand for the US should also emerge in September, while Brazil's peak season for shipments is October-November.

Market price summary $/tonne – Mid-August 2019

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	175-190	-	f.o.b. E. Europe 112-125	f.o.b. US Gulf	313-326	-	-
f.o.b. Yuzhny	195-215	245-260	-	f.o.b. N. Africa	330-360	310-340	635-740
f.o.b. Middle East	190-205	256-270**	-	c.fr India	347-350	-	655*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	252-300	-	c.fr US Gulf	80-110	f.o.b. Vancouver	75-85	-
f.o.b. Middle East	260-313	-	-	-	f.o.b. Arab Gulf	75-85	-
f.o.b. Western Europe	-	500-535	-	-	c.fr N. Africa	80-100	-
f.o.b. Baltic	236-311	-	-	-	c.fr India	96-100+	-

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.*

Phosphates: The lack of significant demand on the Indian subcontinent is underscored by large DAP stocks. Although Pakistan DAP buying is likely to pick up, imports looks set to be less than half the two million tonnes bought last year. Chinese phosphate producers will also be looking to load vessels for Australia from September onwards. Demand in Latin America is quiet. Brazil's safra soybean crop has now been sown, and political uncertainties abound in Argentina.

Potash: The MOP market is in a period of oversupply. This is concerning producers, given that there are no signs of key annual contracts from India or China – which combined buy around 11 million t/a out of an annual 67 million tonne market. New capacity being brought on-stream by EuroChem and K+S Canada will need to capture market share somewhere – although the delay to EuroChem's VolgaKaliy mine ramp-up means this will have less impact than first thought.

Sulphur: A reverse to the current 10 month trend of softening prices is unlikely, as long as the finished fertilizer market remains weak and Chinese port inventories remain at six-year highs. Some market participants are, however, hoping for a brief reprieve from the downward price trend in October. By that point, fourth-quarter contract negotiations will have been concluded, and sulphur consumers are likely to step into the spot market to secure their remaining demand for the year.

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UNITED STATES

Threat of 100 percent tariffs on EU nitrogen products

The US is considering tariffs of up to 100 percent on imports of EU nitrogen products.

These would encompass calcium ammonium nitrate, sulphur-urea and automotive grade urea (AGU) – a transport sector product used in diesel exhaust fluid (DEF, *AdBlue*).

The threatened tariffs are part of a larger US-EU dispute about aircraft subsidies.

The impact of tariffs on DEF trade could be particularly significant. Norwegian producer Yara, for example, supplies the US market with around 60 million gallons (230 million litres) of DEF-equivalent annually, according to commodity analysts Argus.

The tariffs were reviewed by the United States Trade Representative (USTR) at a public hearing on 5th August. The USTR is weighing up the available options – under World Trade Organisation (WTO) rules – for sanctions on a range of EU goods.

These potential trade measures are in response to US government claims that Airbus has received a total of $22 billion in unlawful EU subsidies. A preliminary list of products published by USTR in April 2019 covered EU imports worth $21 billion. Nitrogen products were subsequently added as part a supplementary $4 billion list of goods published in July.

US imports of EU nitrogen fertilizers are relatively low, both in terms of volume and value. The US imported a total 700,000 tonnes of the listed nitrogen products from the EU last year, says Argus. These were valued at $99 million. AGU import volumes (186,000 short tons) are particularly significant, making up almost one-quarter of the EU nitrogen products sold into the US market. AGU imports are shipped as a liquid but are equivalent to around to 89,000 short tons of solid urea.

Yara is Europe's sole AGU exporter to the US market, with an AGU market share of around 15 percent. Although some of this AGU supply is sourced within North America, most volumes are imported from EU urea plants. Argus estimates that the 60 million gallons of DEF exported to the US by Yara in 2018 represents around seven percent of the total US market for DEF.

The USTR is also weighing up tariffs – again of up to 100 percent – on EU ammonium sulphate (AS) imports, as part of the same trade dispute. The EU is major North American supplier, providing around 50 percent of AS imports entering the US in 2018. EU imports satisfy around one-third of total US consumption. Notable EU suppliers include Fibrant and OCI in the Netherlands and Belgium's Lanxess.

EU imports have grown in recent years, following the imposition of tariffs of more than 200 percent on Chinese AS imports. These were introduced as an anti-dumping measure by the US Department of Commerce in 2017.

Canada, by increasing its supply of AS to the United States, could be the main beneficiary, suggests Argus, if the USTR imposed tariffs high enough to lock out EU imports. The country already supplies around one-third of US imports of AS. Extra supply could partly come from Nutrien's Redwater, Alberta, plant. The conversion of the MAP unit at Redwater is expected to double its AS production capacity to 700,000 t/a. ■

Tigur-Sul to sell Sulphur Mills products

Tiger-Sul has secured exclusive North American rights to distribute and sell Sulphur Mills' *Techno-S*® and *Techno-Z*® sulphur- and zinc-based products.

The new sales agreement, announced in early August, links-up Tiger-Sul Products, the world's largest sulphur-bentonite producer, with Sulphur Mills Limited (SML), the world's largest manufacturer of water-dispersible granules (WDGs).

SML uses a patented process to manufacture 2-4 micron-size sulphur and zinc granules with excellent water dispersion properties. Its WDG products are used to supply sulphur and zinc to deficient crops via low-dose fertigation.

Techno-S® is a 90 percent sulphur fertilizer, while *Techno-Z*® combines 15 percent zinc with 70 percent sulphur. Both products undergo extremely quick oxidation, rapidly providing S and Zn in plant-available form.

Tiger-Sul Products was founded more than 50 years ago and is a global leader in sulphur-bentonite production, as well as marketing a range of other well-established crop nutrient products.

"Our vast distribution network throughout the United States and Canada, makes Tiger-Sul the perfect partner to get *Techno-S*® and *Techno-Z*® into the hands of farmers," said Mark Hochgesang, Tiger-Sul's director of business development. "The outstanding performance that we have seen in global trials, assures us that this will be a very rewarding venture for both companies. We are very excited about this opportunity."

Mumbai-based Sulphur Mills currently supplies products to over 80 countries. Its chief operating officer, Bimal Shah, said: "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."

Murat Kamisli, SML's general manager for its international crop nutrition 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."

AUSTRALIA

Rural purchase approved

Australia's Competition and Consumer Commission (ACCC) has approved Nutrien's acquisition of agricultural retailer Ruralco Holdings.

The Ruralco purchase, now that it's been confirmed, adds to Nutrien's existing Landmark retail network in Australia, bringing with it a further 157 farm outlets across the country.

"We are very pleased with [this] decision. We continue to believe the combination of our Landmark operations with Ruralco in Australia will provide significant strategic and financial benefits," said Chuck Magro, Nutrien's president and CEO. "This combination is good for Australian farmers, bringing a greater choice of products, services and technologies to Ruralco's customer base."

Rob Clayton, the head of Landmark, added: "With this ACCC decision, we are one step closer to a combined Ruralco and Landmark, which we believe will create enormous value for Australian farmers. By leveraging the global reach of Nutrien, our people – who live and work in rural and regional Australia – will deliver enhanced solutions and services, products and innovation to Australian growers."

Nutrien expects the purchase to be completed by the end of September, subject to approval from the Australian Foreign Investment Review Board (FIRB) and Ruralco's shareholders.

PHOTO: YARA

Jon-André Løkke, CEO of Nel Hydrogen (left) and Tove Andersen, Yara's Production EVP (right), at the signing ceremony.

GHANA

West Africa's largest blending plant opens

Ghana's vice president Mahamudu Bawumia officially opened a $4.5 million fertilizer blending plant in August.

The 840,000 t/a capacity plant is said to be the largest in West Africa. It is wholly-owned by Ghanaian company Glofert Limited, and located at Asuboi, Ayensuano District, in the country's Eastern Region. It employs around 220 people, directly and indirectly, with most of these coming from the local community.

The new plant has the flexibility to produce liquid and solid fertilizer blends such as NPK 15-15-15 and urea and ammonium sulphate.

Speaking at the inauguration ceremony, vice president Bawumia welcomed Glofert's entry into fertilizer production. He said this was an opportune time to supply farmers with fertilizers that can increase yields by meeting their specific soil and crop needs. He noted that agriculture was the nerve centre of the Ghanaian economy, and said that the government was committed to helping private investors thrive in the sector and create jobs.

Dr Gyiele Nurah, Ghana's food and agriculture minister, who was also present, said the government has increased fertilizer supply to Ghanaian farmers from 134,000 tonnes in 2017 to 290,000 tonnes by the end of last year, since the launch of its Planting for Food and Jobs (PFJ) programme. Dr Nurah revealed that the government was currently supplying 335,000 tonnes of fertilizers domestically, and was planning to supply at least a million of the country's farmers with fertilizers by the end of this year.

NORWAY

Yara to pilot green production technology

Yara International is teaming up with Nel Hydrogen to pilot water electrolysis technology at its Porsgrunn ammonia plant in Norway.

The two Norwegian companies will collaborate on the installation of a five megawatt capacity electrolyser at the Porsgrunn plant by 2022. This is expected to contribute around one percent to Porsgrunn's hydrogen output.

Nel's next-generation water electrolyser technology will be tested by Yara under real operating conditions as part a collaborative project unveiled in August. The goal is to produce hydrogen commercially using renewable electricity. This in turn will be used for either sustainable fertilizer production or the production of 'green' ammonia.

The project is supported by Norway's Research Council, Innovation Norway and Enova through the PILOT-E programme. This is a funding scheme that aims to speed-up the development and implementation of green energy technology.

Yara views the link-up with Nel as an important step towards it ambition to become carbon neutral by 2050.

"We're excited to formally launch the partnership with Nel and work towards developing green ammonia and low carbon fertilizer. We have already removed about half of our direct GHG emissions in the past few decades, and we're working towards carbon neutrality by 2050. Producing fertilizer with carbon-free hydrogen will be a very important step towards that goal," said Yara's Tove Andersen, its executive vice president for production.

"We are very pleased with the partnership with Nel. Our ammonia plant will make the first small step towards carbon-free fertilizer production. When further developed, Yara Porsgrunn will be in a unique position also due to the low carbon footprint from our nitric acid plants," added Jon Sletten, the Porsgrunn plant's manager.

Yara says its ultimate goal is to be a "market shaper" for green ammonia and low-carbon fertilizer production.

Green ammonia is a hot industry topic currently, particularly in Europe. Another low-carbon energy collaboration, this time in the Netherlands, was announced between Proton Ventures and Duiker Combustion Engineers in July. The strategic link-up will turn green ammonia – generated by Proton's mini ammonia plants from renewable electricity – into high temperature heat using Duiker CE's stoichiometry controlled oxidation (SCO) technology.

Hans Vrijenhoef, CEO Proton Ventures, said: "The SCO technology of Duiker CE opens new possibilities in applying local ammonia production… such as the conversion of power plants to cleaner fuels."

GERMANY

K+S ramps-up speciality production

K+S Group has increased its magnesium sulphate production capacity after successfully commissioning a new €34 million unit at the Wintershall site of the Werra plant near Heringen. The specialist product is used in fertigation and industrial markets.

The new unit was commissioned in July following three years of investment. It increases the company's production capacity

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for anhydrous magnesium sulphate by more than 50 percent. This extra capacity will help K+S meet high demand and improve its European market position for what is an increasingly important speciality product.

Anhydrous magnesium sulphate has a range of applications. In Agriculture, it is used both in fertigation and as a granulation aid in the manufacture of compound fertilizers. Volumes are also consumed by the pulp industry for stabilising and bleaching paper fibres.

"With the significantly higher product availability, we will now be in a much better position to meet the customer needs in industry and agriculture and win new customers," says Alexa Hergenröther, CEO of K+S's Operating Unit Europe+. "In addition, we are strengthening our portfolio of high-quality specialty products with the enhanced supply."

The new unit is more water efficient, consuming less freshwater and generating less wastewater, compared to the previous production process. It will also produce the animal feed product *KaSa Mag 98* as well as magnesium sulphate.

POLAND

Tecnimont to build granulation unit for Anwil

Italy's Maire Tecnimont has secured an engineering, procurement and construction (EPC) contract from Anwil for a new granulation unit.

The EPC contract is part of a larger $350 million fertilizer production expansion by Anwil, part of Poland's Orlen Group, at its Włocławek complex. The new 1,500 t/d capacity unit will granulate a variety of different fertilizer types. These include ammonium nitrate, calcium ammonium nitrate and ammonium sulphate/ammonium nitrate mixtures

Tecnimont will fully execute the project to construct and commission the granulation plant. The scope of its work includes engineering, equipment supply, construction, performance tests and staff training.

Pierroberto Folgiero, Maire Tecnimont Group's CEO, said: "Carrying out a technological project in the fertilizer sector enables us to further strengthen our footprint in Poland, supporting a prominent client in unlocking greater value [from] natural resources. Moreover, this award represents a new milestone in the Group's strategy of expanding into innovative fertilizers technologies adjacent to urea and ammonia."

Anwil's new granulation unit is due to be completed by mid-2022.

UKRAINE

OPZ set to restart nitrogen production

Ukraine's PJSC Odesa Port-Side Chemical Plant (OPZ) is said to be close to resuming ammonia and urea production for the first time this year.

The site has been idle for more than 12 months due to an interruption in its supply of natural gas feedstock. OPZ owes more than $60 million to Ukraine's state-owned natural gas monopoly Naftogaz.

But work to restart nitrogen production is said to be "in the finishing straight", according to the plant's deputy director Mykola Schurikov. Agro Gas Trading has apparently agreed to supply the plant with 60 million m^3 of natural gas feedstock per month, on a tolling basis, until at least the start of December, and potentially beyond this.

Ukraine's government has tried but failed several times to find a buyer for the troubled plant – even at the knockdown price of $54 million.

The plant is contracted to pay-off its large debt to Naftogaz through a profit sharing arrangement. Some of the profits OPZ receives from Agro Gas Trading for providing processing services ($1.50/tonne of urea and $1.00/tonne of ammonia) will go towards settling the tens of millions owed to Naftogaz.

ERITREA

$200 million for Colluli potash project

Danakali has secured credit approval for $200 million as part of a funding package to develop and construct the Colluli potash project in Eritrea's Danakil region.

The Africa Finance Corporation (AFC) and African Export Import Bank (Afreximbank) formally confirmed that the credit had been granted in early August. This provides the Colluli Mining Share Company (CMSC) with access to a $200 million senior debt facility to fund the construction and execution of the Colluli project. CMSC – a 50:50 joint venture between Danakali and the Eritrean National Mining Corporation (ENAMCO) – is the Colluli project's sole owner.

CMSC staff at the Colluli project site, Danakil, Eritrea.

Afreximbank and AFC are experienced finance institutions with a track record of funding successful projects across Africa. The credit approval is the culmination of an extensive due diligence exercise by lenders. It also a major achievement for Danakali and CMSC and a significant step towards the development of the Colluli project.

Colluli is one of the most advanced and economically-attractive sulphate of potash (SOP) mining projects globally. The venture benefits from shallow, easily accessible ore reserves of more than 1.1 billion tonnes.

CMSC plans to develop the Colluli project in two stages. Module 1 will produce 472,000 t/a of SOP, while Module 2 will ramp-up production to 944,000 t/a. Bringing the project into production is expected to take around two years, once funding is secured. The Colluli mine, once built, is expected to have a 200 year life.

Danakali's CEO, Niels Wage, said: "Final credit approval from leading development finance institutions AFC and Afreximbank for $200M of senior debt represents outstanding progress and a significant de-risking milestone for the Colluli project financing. The Facility is set to provide the majority of the funding required for construction and project execution. I am very pleased to achieve credit approval as it represents one of the last remaining milestones prior to project execution."

Confidence has been building in the Colluli project. The credit approval follows the completion of a front end engineering design (FEED) study, and the appointment of DRA Global as the project's engineering, procurement and construction management (EPCM) contractor.

Danakali also signed an offtake agreement with major producer EuroChem last year. This guarantees cash flow for the project from future production. EuroChem will take-or-pay for up to 100 percent of the production from Module 1 for ten years, with an option to extend for a further three years.

Danakali also became listed on the London Stock Exchange in July 2018. ■

People

Pablo Barrera Lopez is Yara International's new Strategy & Business Development executive. The new responsibility is extra to his current role as Yara's executive vice president (EVP) Supply Chain. In a coordinated move, **Terje Tollefsen** also becomes Yara's IPO lead and senior vice president (SVP) for Strategy & Business Development.

Yara announced in June that it is looking at an initial public offering (IPO) – a type of stock market launch – for its industrial nitrogen business. The potential IPO is part of Yara's strategy to focus on crop nutrition as a core activity. A final decision on whether to proceed with the IPO is expected early next year. "These changes represent a natural step in our journey to become a focused crop nutrition company, and will strengthen our execution of the ongoing IPO evaluation," said Svein Tore Holsether, Yara's president and CEO.

Following the announcement, Yara's executive management team now comprises:

- Svein Tore Holsether, president and CEO
- Tove Andersen, EVP Production
- Pablo Barrera Lopez, EVP Strategy and Supply Chain
- Lair Hanzen, EVP Yara Brazil
- Terje Knutsen, EVP Sales & Marketing
- Kristine Ryssdal, EVP General Counsel
- Lars Røsæg, EVP Chief Financial Officer
- Lene Trollnes, EVP People & Global Functions

After 30 years with the company, **Joel Barker** will retire as JR Simplot's chief financial officer (CFO) and treasurer at the start of next year.

"I am grateful to Joel for his contributions to Simplot and his leadership over the years," said Garrett Lofto, Simplot's president and CEO. "He has been an asset to our company with his professionalism, extensive financial acumen and keen understanding of how to navigate our diverse business. We will miss all he brought to the organization."

Barker has supervised a number of important acquisitions and held a variety of roles during his career at Simplot. He was vice president and controller of the company's AgriBusiness Group before becoming CFO. Prior to that, he held general manager roles at the company's Simplot Turf, Horticulture and Jacklin Seed business units.

Simplot has begun an immediate search for a new CFO and treasurer. This will enable Barker to assist his newly-appointed successor during a handover period.

Compass Minerals announced several executive-level changes in July. The company has appointed the former Peabody executive **George Schuller** to the newly-created position of chief operations officer (COO). He will join the company in early September. Mr Schuller will be responsible for managing all global operations across the company's Salt and Plant Nutrition businesses. In his new role as COO, he will be tasked with improving operational excellence throughout the company's mining and production operations. His objective will be to maximise the value of these assets, as well as ensure safe and reliable production.

Mr Schuller comes to Compass Minerals with more than three decades of mining industry experience at Peabody, having held senior management roles in both surface and underground mining.

The company also named **Brad Griffith** as chief commercial officer (CCO), another newly-created position, with immediate effect. Mr Griffith will manage all global commercial aspects of the company's Salt and Plant Nutrition businesses in his new role. His wide-ranging responsibilities include sales and marketing, innovation, logistics and customer service. Mr Griffith joined Compass Minerals in August 2016 as SVP, Plant Nutrition, where he successfully helped drive business growth throughout North and South America.

"With this new functional organizational structure, I am confident Compass Minerals is positioned better than ever to build on our recent investments, harness our strengths and chart a clear path forward for greater success and value creation," said Kevin Crutchfield, Compass Minerals president and CEO. "The addition of such a highly skilled operational leader as George combined with a strong commercial leader in Brad, should enable us to deliver improved operational results, grow our sales, and double down on our customer focus."

Compass Minerals also announced that **Anthony Sepich**, SVP, Salt, and **Diana Toman**, SVP, general counsel and corporate secretary, have left the business with immediate effect. The company is currently searching for a new general counsel.

CEO **Chris Jahn** has announced that he will leave The Fertilizer Institute (TFI) at the end of October. Chris is leaving TFI to take up a new role as president and CEO of the American Chemistry Council (ACC). TFI has set up a search committee to find a replacement CEO. This will be led by board chairman Tony Will, who said: "On behalf of TFI's board of directors, I extend my thanks to Chris for his work on our industry's behalf." Chris provided TFI's executive committee with advance notice of his departure in June. This should ensure a smooth transition. ■

Calendar 2019

SEPTEMBER

22-24
TFI World Fertilizer Conference,
CHICAGO, Illinois, USA
Contact: Valerie Sutton
Fax: (202)-962-0577
Email: vsutton@tfi.org

24-26
10th GPCA Fertilizer Convention,
MUSCAT, Oman
Contact: Ammara Shahiryar
Tel: +9714 4510666, Ext. 102
Email: ammara@gpca.org.ae

OCTOBER

1-3
Africa Fertilizer Agribusiness Conference 2019, CAPE TOWN, South Africa
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

7-9
SYMPHOS 2019, 5th International Symposium on Innovation in the Phosphate Industry, BENGUERIR, Morocco
Contact: SYMPHOS committee
Email: info@symphos.com or symposiumocp@ocpgroup.ma

27-29
Nitrogen+Syngas Middle East,
MUSCAT, Oman
Contact: CRU Events
Chancery House,
53-64 Chancery Lane,
London WC2A 1QS, UK
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

NOVEMBER

4-7
CRU Sulphur and Sulphuric Acid 2019 Conference, HOUSTON, Texas, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2167
Email: conferences@crugroup.com

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50 YEARS ANNIVERSARY 1969-2019

THEN&NOW

Köppern

Fertilizer International is 50 this year. The continuing success of the magazine is built on mutually beneficial partnerships forged over five decades. So, in celebrating our 50th anniversary this year, we will also be profiling a much-appreciated commercial supporter in every issue. This month it's the turn of the leading compaction equipment manufacturer **Köppern**, a valued long-term advertiser. This fourth generation family-run business, one with a global reach, operates out of Hattingen, Germany, and celebrated its 120th anniversary last year.

Company Profile

Friedhelm Westermann.

Köppern, founded in 1898, has been selling roller presses and plants with roller press technology since the beginning of the 20th century, writes Friedhelm Westermann, Köppern's potash project manager (left). Today, the company is one of the leading manufacturers of roller presses for briquetting and compacting materials in the chemical, fertilizer and metallurgical industries. The company's high pressure grinding roller presses are also widely used in the comminution of cement clinker, ores and minerals. To date, Köppern has supplied more than 900 roller presses to more than 50 countries globally.

Köppern machines and technology have also proved to be very successful in the fertilizer industry. During the last 10 years, the company's combined orders for potash and NPK compactors have exceeded an impressive 28 million t/a of flake capacity. Fertilizer sector clients are located in Belarus, Brazil, Chile, China, Canada, Germany, Hungary, Russia, Serbia and Montenegro, Italy and Jordan. In most cases, NPK and potash compaction granulation orders now include basic engineering as well as the supply of key equipment.

Latest developments

Köppern continues to extend the range of its customer applications, through innovation and by fine-tuning its existing product range. The company's head office in Hattingen provides thorough customer support. This ensures that the 'Made by Köppern' stamp on every machine supplied by the company continues to be a sign of quality on which customers in the worldwide fertilizer industry can rely. Nevertheless, Köppern has established several subsidiary business divisions across the globe in recent years. These offer enhanced customer service to clients in the United States, India, Australia, Canada and Russia.

In response to industry demand, Köppern is also expanding its engineering offering, providing more customers with basic and detail engineering services as well as the supply of compaction equipment. ■

Köppern's manufacturing plant in Hattingen, Germany.

1957
- First supply of a potash compactor in Germany.

1960s
- Supply of more compactors to Germany and Canada.

1970s
- Growth in worldwide fertilizer business, with supply of several compactors to Canada, Germany, France, etc.
- Development and supply of the first NPK compaction plant in Switzerland (still in operation in 2019).

1980s
- In a market first, Russia requests German potash compaction technology and know-how.
- Further supply of NPK compactors to Guatemala and the Philippines.
- Basic/detail engineering and equipment supply for a 30 t/h NPK compaction plant in Turkey.

1990s
- Increase in potash sector demand, with the supply of 14 compactors to German and several other producers worldwide.
- Basic/detail engineering and equipment supply for a 20 t/h NPK compaction plant in Turkey.

2000s
- North and South America increase potash production. Supply of 38 compactors to the potash market, 15 of them to Canada.
- The flake capacity of a single machine increases to 130 t/h.
- Supply of six compactors, basic engineering and key equipment to NPK granulation plants in Hungary, China, Germany, Serbia, Croatia and Italy.

2010s
- Achieve 50 t/h granulation plant capacity for a single compaction and crushing/screening cycle.
- Completion of equipment supply and basic and detail engineering for a Canadian potash compaction plant.
- Supply of a further 50 potash compactors worldwide, mainly to Canada and Russia.
- Modifications to NPK compaction increase capacity and granulate quality.
- Supply of 20 t/h ammonium sulphate compaction plants to Russia, including equipment supply and basic engineering.
- Completion of equipment supply and basic/detail engineering for a Russian potash compaction plant.
- First compactor sold for K99 animal feed.
- Completion of equipment supply and basic/detail engineering for an Australian SOP compaction plant.

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Australia's fertilizer market

PHOTO: SAM BIANCHINI/SHUTTERSTOCK.COM

Left: Fertilization of pasture for cattle and sheep grazing accounts for one-fifth of Australian fertilizer use.

Australia is hosting IFA's Crossroads Asia-Pacific conference in October. The country is home to fertilizer manufacturers such as CSBP, Incitec Pivot, Orica and Yara Australia.

Australia is a vast and diverse country. Covering 7.6 million square kilometres and three time zones, it is the largest nation in Oceania and the world's sixth largest country overall. With a population of 25 million, it remains relatively sparsely populated. The country is also said to be the oldest, flattest and driest inhabited continent on earth – possessing some of the planet's least fertile and most highly weathered soils.

Australia is the fourteenth largest economy globally and a member of the OECD, with strengths in mining, telecommunications, banking and manufacturing. Yet – contrary to its economic status and enormous land area – the country remains a relatively small player in the global fertilizer market. Its fertilizer requirements, according to trade body Fertilizer Australia, represent just one percent of global consumption. Although heavily dependent on overseas supply, Australia's fertilizer imports also account for less than two percent of world fertilizer trade.

Nevertheless, Australia's advanced and mature agricultural sector is served by a sophisticated, modern domestic fertilizer industry. It also remains a major global market for a range of imported fertilizer products and raw materials, including urea, phosphate rock, monoammonium phosphate (MAP) and potash. The country also produces and exports large volumes of diammonium phosphate (DAP) to Asia and the Middle East

Boasting world-class ammonia production plants, Australia has also emerged as a major regional ammonia exporter in recent years, supplying countries such as Korea and Indonesia. Encouragingly, long held ambitions to develop large-scale potash and phosphate reserves located deep in Australia's interior are finally edging closer to fruition. That raises the prospect of Australia eventually becoming a major fertilizer exporter, particularly for potash.

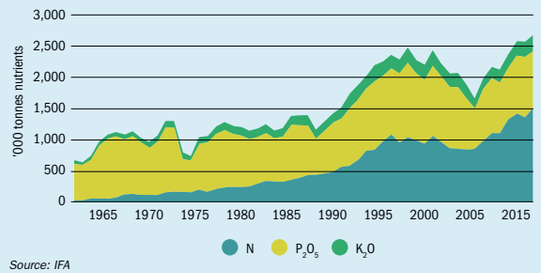
Fertilizer consumption

Australia's nutrient consumption ($N + P_2O_5 + K_2O$) has risen by more than 30 percent over the last two decades, reaching 2.7 million tonnes in 2016 (Figure 1). That translates to the purchase of 5.4 million tonnes of fertilizer products each year, according to Fertilizer Australia, based on average national sales between 2002 and 2017. However, this impression of stability and long-term growth masks what can be a volatile and weather-dependent fertilizer market.

Australia has a large natural rainfall variability, being strongly influenced by El Niño, making the country's agriculture and fertilizer consumption highly sensitive to rainfall. In 2018, Incitec Pivot's fertilizer earnings fell by $19.8 million year-on-year, for example, due to the negative impact of dry weather conditions in New South Wales and Southern Queensland on fertilizer sales.

Australian fertilizer consumption was hit particularly hard by the country's 'millennium drought' – the prolonged dry conditions that affected much of southern Australia from late 1996 to mid-2010. This drought was especially acute in the country's more populous southeast and southwest, having consequences for the Murray-Darling Basin and virtually all of Australia's southern crop zones. As a result, Australian fertilizer consumption fell for five consecutive years between 2004 and 2009 – dropping by 32 percent from 2.4 million to 1.6 million nutrient tonnes – taking fertilizer use back to levels not seen since the early 1990s. Consumption has subsequently recovered, however, reaching a record high in 2015/16 (Figure 1).

Fig. 1: **Australia's nutrient consumption, 1961-2016**



Source: IFA

Another unusual feature of Australia's fertilizer market has been the historical preference for phosphorus as a nutrient over nitrogen. This was partly a reflection of the prevalence of grassland fertilization and the corresponding availability of domestically-produced products such as single superphosphate (SSP) and diammonium phosphate (DAP). Indeed, phosphate consumption exceeded that of nitrogen throughout the 1960s, 70s, 80s and 90s. Australia's potash use is also relatively low. This is due to the naturally high potassium status of many Australian soils, reports IPNI[1], with the exception of those in Western Australia.

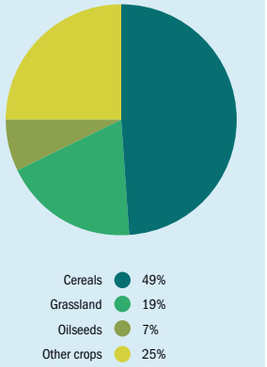
It is only in the last decade that Australian nitrogen fertilizer use has finally exceeded phosphate consumption. In fact, the rise in nitrogen fertilizer purchases has been the main factor driving overall growth in the Australian fertilizer market – given that P_2O_5 consumption peaked in in the early 2000s, and potassium consumption has remaining largely unchanged over the last twenty years.

Fertilizer use by crop

Australia devotes around 23 million hectares of land to crops and pasture. Western Australia (8 million hectares) has the largest land area for crops and pasture cultivation, followed closely by New South Wales (6 million hectares). Fertilizer use by crop is shown in Figure 2.

Cereals, particularly wheat, have been a strong driver of nitrogen fertilizer use and account for just under 50 percent of the country's total fertilizer consumption. Cereals are cultivated on a large-scale in Australia for both the domestic market and export. The country produced 52 million tonnes of coarse grains – including wheat barley, grain sorghum, maize, oats and triticale – from more than 18 million hectares of land in 2016/17. Wheat growing predominates, accounting for more than two-thirds of grain production.

Fig. 2: **Australian fertilizer use by crop, 2014**



Source: IFA

According to IPNI[1]: "A grain farm in Western Australia uses between 20-60 kg/ha of MAP or DAP at seeding (April/May), sometimes with 20-100 kg/ha MOP. As the crop grows, additional N – usually as urea, UAN or ammonium sulphate – is top-dressed, once or twice. Good seasons may see an added 35 kg/ha N applied."

Fertilization of pasture for **cattle and sheep grazing** accounts for a further one-fifth of Australian fertilizer use. Livestock rearing is an Australian agricultural mainstay and around 1.4 million hectares of land is sown to pasture annually. Fertilizer applications to grassland are strongly associated with both potash and phosphate fertilizer consumption.

"The typical dairy farm in Victoria uses approximately 150 kg/ha of N, applied as urea in the autumn and spring, and 20 kg/ha of P and 16 kg/ha of K annually. The use of N on dairy farms has increased over the past 10 years as pastures changed from mixed clover and ryegrass to become more grass dominant, and as more feed is grown on farm in fodder crops," comments IPNI[1].

Sugar cane is produced by around 3,500 farms along the sub-tropical and tropical regions of Australia's northeast coastline, mostly in Queensland. Growers are very exposed to international sugar prices, although the industry has proved to be productive and relatively stable[1].

"On average sugar farmers in northern Queensland spend around $500/ha on fertilizer, which is about 15 percent of total costs. Often the crop's entire P and K requirements and part of the N needs are applied at planting. The use of N is usually during the very early wet season as a single urea application over small cane, at a rate of around 200 kg/ha/year," comments IPNI[1].

The following fruit and vegetable growing regions[1] also provide a market for speciality and value-added fertilizer products:

- **Wine growing regions** in South Australia, New South Wales and Victoria produce premium quality wines for export and domestic consumption.
- **Tropical crops** like mangos, avocado, macadamias, bananas (3,500 ha), pineapples (3,700 ha) and citrus are produced in tropical Northern Australia.
- **Tree crops** like apples, pears, peaches, apricots, almonds and olives are cultivated in the temperate south.
- The main **citrus growing** regions are along the Murray River. Oranges predominate, but lemons, grapefruit and mandarins are also common.
- **Vegetables** are invariably produced under irrigation, with most major cities consuming produce from local farms. The largest growing areas are devoted to potatoes (29,500 ha), tomatoes (5,000 ha), pumpkins (6,275 ha), lettuce (7,925 ha), carrots (2,146 ha) and melons (6,346 ha). The export of vegetables to Southeast Asia is a developing market, especially in Northern Territory and Western Australia.

Australia's regional fertilizer consumption is shown in Figure 3.

Fertilizer preferences

Around 57,000 Australian farm businesses applied 4.8 million million tonnes of fertilizers to agricultural land in the year to June 2017, according to the Australian Bureau of Statistics, a four percent fall on the previous year (Figure 4). Western Australia and New South Wales use the largest amounts of fertilizers, with both states applying just over one million tonnes in 2016/17.

Urea is Australia's most widely applied fertiliser (1.4 million tonnes, 28 percent of total consumption) and its use has increased significantly over the last decade. Grain and cotton provide a market for other nitrogen products such as anhydrous ammonia and liquid UAN.

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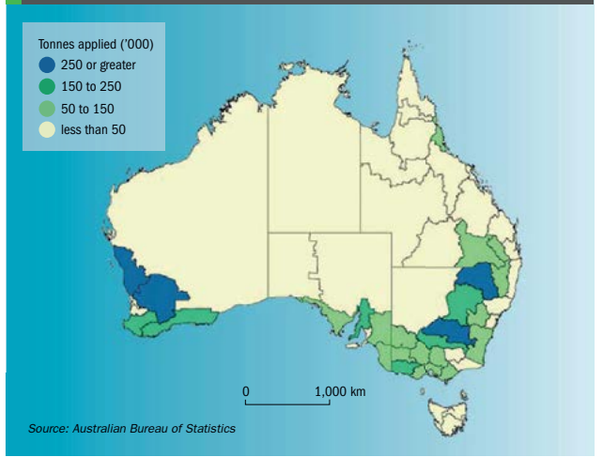
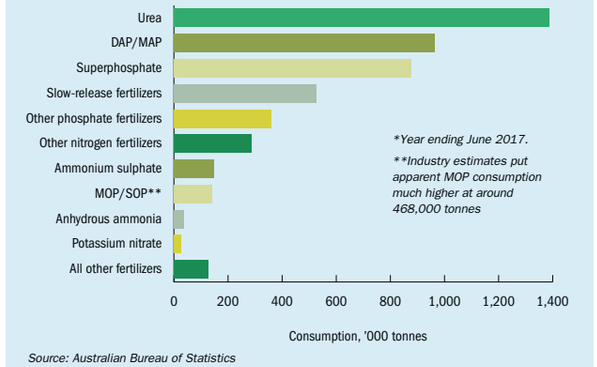
Fig. 3: **Australian fertilizer consumption 2016/17, by natural resource management region**



Source: Australian Bureau of Statistics

Fig. 4: **Australian fertilizer use, 2016/17***



Source: Australian Bureau of Statistics

Phosphate fertilizers are typically applied to crops during sowing and on pasture as a top-dressing. DAP and MAP (963,000 tonnes, 20 percent of total consumption) are generally favoured for application to crops. Single superphosphate (SSP) remains a popular phosphate product choice in Australia (700,000 tonnes, 14 percent of total consumption) although its use is in decline. While SSP is still commonly applied to pasture in livestock grazing, supplying both sulphur and phosphorus, its usage on crops has fallen due to competition from higher-analysis MAP and DAP.

Fruit and vegetables and the turf and ornamental sector provide a market for controlled-release fertilizers and other specialty products.

Production and trade

Australia manufactures about half of its fertilizer needs, according to trade body Fertilizer Australia, relying on imports for the remainder. The country possesses significant mining/manufacturing capacity for:

- Phosphate rock: 2.5 million t/a
- Ammonia: 2.1 million t/a
- Diammonium phosphate (DAP): 1.2 million t/a
- Single superphosphate (SSP): 350,000 t/a
- Urea: 300,000 t/a
- Ammonium sulphate (AS): 200,000 t/a

Monoammonium phosphate (MAP) and urea ammonium nitrate (UAN) are also produced domestically.

SSP manufacture in Australia relies on externally-sourced phosphate rock – this requiring the import of 476,000 tonnes in 2017. Historically, phosphate rock for SSP production was supplied by Christmas Island, an Australian territory in the Indian Ocean. This is no longer the case, however, and more than 90 percent of the phosphate rock exported from Christmas Island in 2017 (661,000 tonnes) went to Indonesia and Malaysia, while only one percent (8,000 tonnes) was destined for Australia. Instead, more than half of Australia's 2017 phosphate rock imports were met by Togo (245,600 tonnes), supplemented by volumes from Vietnam (53,000 tonnes), Nauru (49,000 tonnes), Morocco (32,700 tonnes), Algeria (31,500 tonnes), Peru (25,000 tonnes) and China (17,800 tonnes).

Australia has a large and growing import requirement for urea. This totalled 2.2 million tonnes in 2017, according to GTIS data. Three Gulf states, Saudi Arabia (529,600 tonnes), Qatar (513,900 tonnes) and Oman (189,100 tonnes), collectively provided almost 60 percent of import needs, while within the region Malaysia (311,500 tonnes) and China (227,800 tonnes) together supplied a further 25 percent of urea imports.

GTIS data also reveal that Australia's MAP imports exceeded one million tonnes in 2017. The United States (455,700 tonnes) and China (428,800 tonnes) were the main suppliers, followed by Saudi Arabia (110,400 tonnes), Mexico (45,300 tonnes) and Morocco (5,500 tonnes). China and the US also shipped significant volumes of UAN (83,400 tonnes) and NP fertilizers (77,900 tonnes), respectively, into the Australian market in 2017.

Australia is completely reliant on potash imports for its agricultural requirements. These totalled 468,000 tonnes in 2017 with Canpotex supplying more than three-quarters of this volume (361,600 tonnes), topped up with additional potash imports from Belarus (59,900 tonnes) and Germany (43,800 tonnes).

Australia, as well as producing DAP for domestic agriculture, is also a significant regional supplier, exporting a total of 369,000 tonnes in 2017, GTIS data show. Two-thirds of DAP exports were destined for Pakistan (243,300 tonnes), with other major destinations including Thailand (37,900 tonnes), Vietnam (22,000 tonnes) and the Middle East (55,000 tonnes).

Table 1: **Typical lead times for imported fertilizers**

Product	Source	Typical days travel
Urea	Malaysia, Arab Gulf	18 24
Phosphate rock, MAP, DAP	China, North Africa	20 34
DAP, MAP	US Gulf	45
Potash	Russia, North America (West Coast)	30 23

Source: Fertilizer Australia

Fig. 5: **Location of Incitec Pivot (green) Yara Australia (black) fertilizer production plants. Leading greenfield projects (red) also shown.**

Source: Company information

Domestic fertilizer industry

The origins of Australia's fertilizer industry go all the way back to the start of guano mining in Western Australia in 1850. Imports of phosphate rock began in the early 1900s, when rising demand led to the formation of merchant groups, including the founding of the Pivot Phosphate Co-operative in 1919.

Single superphosphate (SSP), the first fertilizer to be produced in Australia, has long been favoured by the grazing industry for application to pasture. But agricultural diversification over the years, particularly the expansion of crop growing and horticulture, has seen a shift in Australia's fertilizer mix, with a greater reliance on high-analysis DAP/MAP and urea. The country's fertilizer industry, in turn, has itself evolved and grown to meet changes in agricultural demand.

Today, the Australian fertilizer industry ranges from large-scale manufacturers, bulk importers and international suppliers/agents to downstream distributors and farm retailers. The industry is represented nationally by trade body Fertilizer Australia. Its role includes the management of stewardship programmes and industry training and accreditation schemes. The highly-regarded *Fertcare®* programme – which train agronomists to offer fertilizer advice to farmers – remains one of its core activities.

Australian farmers collectively spend about AUD 2.2-2.3 billion on fertilizers annually. Demand is seasonal, peaking between March and June, reflecting application timings and the high nutrient requirements of crops and pasture during this period. Managing this uneven demand relies on advanced purchasing and ensuring there is enough storage capacity at key points along the supply chain.

Orders for imported fertilizers typically need to be placed more than three months in advance, due to the long shipping times to Australia (Table 1). Bulk fertilizer shipments also require storage on arrival. While smaller importers may only have storage capacity for one or two shiploads (5,000-10,000 tonnes), major importers typically store large volumes of fertilizers (18,000-45,000 tonnes) in warehouses close to the port of arrival.

More than 85 percent of dry fertilizers on the Australian market are transported and sold in bulk. Correspondingly, less than 15 percent of dry product is sold in bags, ranging from 20 kilos in size to one tonne. Fertilizers are typically distributed from regional and local storage depots, capable of storing hundreds or even several thousand tonnes of product. The majority of liquid fertilizers are also sold in bulk, although some is still sold in containers of up to 1,000 litres in size.

Major fertilizer producers

Incitec Pivot Limited (IPL) is Australia's largest fertilizer manufacturer. The company produces a range of fertilizer products and fertilizer raw materials – including DAP/MAP, ammonia, urea, sulphuric acid and superphosphates – at six manufacturing sites across eastern Australia. IPL is the country's only domestic DAP/MAP and urea manufacturer.

Incitec Pivot's DAP/MAP plant at Phosphate Hill, Queensland, is the biggest fertiliser plant in Australia (Figure 5). Located 900 kilometres west of Townsville, it has an annual capacity in excess of 950,000 tonnes. The plant is supplied with feedstock from Australia's only phosphate rock mine, the Duchess Mine, located 150 kilometres to the north. More than two million tonnes of phosphate rock is extracted annually at Duchess by open-cut mining.

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The ammonia required for DAP and MAP manufacture at Phosphate Hill is produced on-site from natural gas supplied under long-term contract. The plant also sources its sulphuric acid requirements from the world-scale Mt Isa plant, 160 kilometres to the north.

IPL also produce ammonia, urea and ammonium sulphate at its Gibson Island plant in Brisbane, southeast Queensland (Figure 5). The site has the capacity to manufacture 300,000 tonnes of ammonia, 280,000 tonnes of urea and 200,000 tonnes of ammonium sulphate annually. The fertilizers produced at Gibson Island are distributed to more than 4,000 cotton, sugarcane and sorghum farmers in Queensland and northern New South Wales.

Production at the complex is cost-competitive thanks to its close proximity to domestic fertilizer markets and its low-cost, long-term gas supply arrangements. Incitec Pivot recently confirmed that manufacturing at Gibson Island would continue until the end of 2022, securing the jobs of 400 workers, after agreeing a new gas supply contract for the complex.

IPL announced the closure of its Portland, Victoria, single superphosphate (SSP) plant in May. The move consolidates the company's SSP production at the Geelong, Victoria, SSP plant, around 300 kilometres to the east (Figure 5). Geelong's maximum SSP output (350,000 t/a) is almost double that of the Portland plant (180,000 t/a).

The decision to close the Portland SSP plant followed a strategic review of operations. IPL has rationalised SSP production due to domestic overcapacity and competitively priced superphosphate imports. The company relies on externally-supplied sulphuric acid and imported phosphate rock for its SSP operations. Phosphate rock is sourced internationally, while sulphuric acid is sourced domestically from Nyrstar's zinc smelter in Tasmania. The company's requirements for both raw materials are expected to decline as a result of Portland's closure.

Orica is Australia's leading specialist nitrogen fertilizer manufacturer, offering two products – anhydrous *Precision™ Ammonia* and liquid *Precision™ UAN*. The anhydrous ammonia is sourced from Orica's plants at Kooragang Island near Newcastle, New South Wales, and Yarwun near Gladstone, Queensland. Kooragang Island's ammonia plant produces around 360,000 tonnes of ammonia annually from natural gas.

Orica began constructing a new urea ammonium nitrate (UAN) plant in Moree, New South Wales in 2018, as part of a wider fertilizer business launch by the company. The new liquid fertilizer plant will supply grain and cotton growers across New South Wales and Queensland.

Orica confirmed it would supply and make UAN available from the start of 2018, in advance of completion of the Moree plant, and would also start to supply growers on Australia's east coast with anhydrous ammonia. The company subsequently rolled-out a fleet of 26 state-of-the-art anhydrous ammonia nurse tanks along the eastern seaboard last July. This fleet enables Orica to directly deliver ammonia from its manufacturing plants to the region's cotton and grain farmers.

"These investments will bring increased competition, as well as a secure and consistent supply of liquid and gas nitrogen fertiliser, to growers on the east coast of Australia," Orica said in a statement. The company added that it will not be selling solid urea to farmers.

Liquid fertilisers have been applied with great success in Western Australia, with growing interest in the country's eastern states, according to Orica's senior business manager, Paul Scutt.

"We believe the market is ready to embrace the benefits of UAN including precision application during specific crop growth stages, reducing passes over paddocks and the reliance on pending rainfall for incorporation of fertiliser. We are building on Orica's extensive manufacturing footprint and proven track record in safe and reliable transport to provide direct delivery to farm," he said.

Yara Australia has been operating on the continent for 25-years. The company, as Nipro, first began manufacturing bulk liquid fertilizers in Moree, New South Wales in 1994 for use in the cotton growing industry. It subsequently expanded through the acquisition of Nipro bulk liquid and Phosyn foliar product brands and their associated production assets.

Yara Australia currently operates three bulk liquid fertiliser production plants at Moree and Griffith, both in New South Wales, and Boundary Bend in Victoria (Figure 5). The New South Wales plants manufacture a range of bulk liquid NPKs and liquid foliar products.

Yara Pilbara Fertilisers opened a AUD 700 million liquid ammonia plant on the Burrup Peninsula, near Karratha, Western Australia, in 2006. This world-scale plant produces around 850,000 tonnes of ammonia annually. The plant's output is used domestically as a raw material in fertilizer manufacture. Yara also exports ammonia from the plant to Korea, Indonesia and other Southeast Asian markets. Ammonia is delivered by pipeline to the Port of Dampier and then transported internationally using Yara's dedicated ammonia shipping fleet.

Fertilizer producer **CSBP** has roots reaching back to 1910. The company started as Cumming Smith & Company, the first Western Australian manufacturer of superphosphate fertilizer. Today, CSBP is one of eight Wesfarmers Chemicals, Energy and Fertilisers (WesCEF) companies, serving both domestic and international markets. WesCEF itself is part of Wesfarmers Limited, one of Australia's largest publicly-listed companies.

CSBP is particularly committed to both product development and providing science-based advisory services to farmers. It helps growers increase yields and optimise profits by offering a range of products and nutrient planning and management tools. These are complemented by crop advisory services. This integrated approach to crop nutrition, says the company, is designed to ensure farm businesses remain sustainable throughout the year.

CSBP offers a wide portfolio of fertilizers for cropping, pasture and horticulture. Its cropping range includes a variety of seeding fertilizers that supply essential nutrients such as nitrogen, phosphorus, potassium and sulphur. These locally-developed products also have excellent storage and handling characteristics. For pasture, the company offers a choice of high-quality fertilizers for local soils. Its *Super Phos* and *Super Potash* products contain a balanced mix of phosphorus, potassium and sulphate-sulphur for improving pasture production. CSBP's horticultural product range is suitable for a large array of crops. These products can also be customised to meet the nutrient needs of specific soils. Additionally, the company offers custom blends and coating systems for micronutrients and fungicides.

CSBP's liquid fertilizer sales have grown rapidly in recent years. Sales of it liquid *Flexi-N* product, for example, reached close to three million tonnes in 2018. *Flexi-N* – introduced following a trial with only six customers 20 years ago – was Australia's first liquid nitrogen fertilizer for broad acre agriculture. It now accounts for over half of CSBP's total nitrogen sales with approximately 100 new farmers adopting the product every year.

Field trials have formed the basis of CSBP's scientific approach to agronomy and crop nutrition since 1923. This company says the agronomic advice given to five generations of Western Australian growers is the foundation of its longevity within the industry.

A team of agronomists at CSBP support customers with fertilizer and farm planning recommendations. The company specialises in designing best practice field trials. These consider a host of different variables such as soil and product type together with application rates, methods and timings. Nutritional management tools such as *Decipher*, drone imagery and *NUlogic* are used to benchmark each trial site.

CSBP believes in collaboration when it comes to the design and delivery of field trial programmes – as this approach often leads to the development of new and more efficient fertilizer products, as well as ensuring these are practical, sustainable and easy to adopt. New product innovations, in its view, are often a result of discovering new and better ways of doing things.

CSBP says its long-term relationships with farmers are based on shared values and agronomic expertise. Its vision statement – *the best for growers* – sums up its approach to supporting Australian farmers and promoting the prosperity and development of the country's rural communities. ■

SELECTED GREENFIELD PROJECTS

Karratha urea project gains pace

Perdaman Chemicals and Fertilisers plans to build a two million tonne capacity urea plant on the Burrup Peninsula, some 20 kilometres from Karratha on the northwest coastline of Western Australia. The AUD 4 billion Karratha project will use local natural gas as a feedstock for fertilizer production, using innovative and low-emissions technologies.

Perdaman signed a binding heads of agreement with SNC-Lavalin for engineering, procurement and construction (EPC) work on the project last November. Chris Brown, SNC Lavalin's president for oil & gas, said the company was pleased to be part of this important Australian project. "Our vast experience in delivering major projects that involve constructing state of the art technology will be vital in bringing this project to completion over the next four years," he said.

Perdaman has selected Haldor Topsoe's new *SynCOR™* technology for the Karratha's ammonia plant. This will make the project the first in the world to use Topsoe's state-of-the-art technology for large-scale ammonia production. Stamicarbon's *LAUNCH MELT™* pool condenser design has also been selected for urea production.

Karratha has been designated a 'project of state significance' by Western Australia's state government. Project construction is currently scheduled to start at the end of this year or early in 2020, but remains conditional on environmental approval.

Fast-track phosphate project

Centrex Metals is fast-tracking its flagship Ardmore phosphate rock project in Northwest Queensland using the AUD 1.4 million proceeds from the sale of its Port Spencer landholding in South Australia. The company took a strategic decision last year to 'switch out' of iron ore mining and enter the fertilizer market instead.

Centrex says Ardmore is now "fast approaching" production. The company is planning to start-up operations in mid-2019 and produce 30,000 tonnes of phosphate rock concentrate initially. The company will use this to supply priority customers with 5,000-6,000 tonne trial shipments.

Queensland's Department of Environment and Science granted Ardmore an environmental permit for start-up mining and processing operation last December. Centrex also released a definitive feasibility study for the Ardmore project in October 2018. The maiden ore reserve estimate of 10 million tonnes (30.2% P_2O_5) is enough for a 10 years mine life at an annual production of 800,000 tonnes phosphate rock concentrate.

The building of a modular wet processing plant at the project site began in June, according to the latest project progress report. The plant's commissioning, scheduled for later this year, will provide up to 30,000 tonnes of product for trial shipments to priority customers. Centrex has agreed a second sales contract with New Zealand's Ballance Agri-Nutrients for 5,000 wet tonnes of product from Ardmore's start-up operation. Previously, Ballance has successfully trialled 400 wet tonnes of Ardmore phosphate rock in SSP production.

Australia to produce SOP by 2020?

Kalium Lakes is on schedule to start sulphate of potash (SOP) production at the Beyondie project in Western Australia in 2020, according to its latest quarterly report. The Beyondie project, which entered into supply agreement with K+S Group earlier this year, also received the offer of AUD 102 million in finance from Germany's KfW IPEX-Bank in July.

Beyondie's bankable feasibility study (BFS) was completed last September – the first BFS for any Australian SOP project. Kalium is planning to start SOP production at 90,000 t/a – before eventually ramping-up to 180,000 t/a, allowing both domestic and international sales. A mine life of 30-50 years is anticipated.

The project's technical and financial feasibility was confirmed in a front end engineering and design (FEED) update in March. This was followed by an AUD 20.8 million cornerstone investment from Greenstone Resources in April. Key contracts for the purification plant totalling AUD 60 million were subsequently awarded in May. These included contracts for: engineering, procurement and supervision (EPS) with K-UTEC and Ebner; engineering, procurement and construction management (EPCM) with DRA Global; and compaction plant equipment with Köppern.

A final investment decision, expected in mid-2019, could see the Beyondie project enter production as early as next year. ■

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Africa Fertilizer Agribusiness Conference 2019

CRU events will convene the 2019 Africa Fertilizer Agribusiness Conference at the Cape Town International Convention Centre, Cape Town, South Africa, 1-3 October.

Cape Town, South Africa, is the spectacular setting for this year's CRU Africa Fertilizer Agribusiness Conference. The conference is the fifth in a series of agribusiness events held by CRU throughout Africa since 2016. It is returning to Cape Town for the second time, building on the success of last year's event. Previous conferences have been held in Tanzania, Mozambique and Ghana.

A collaboration with AFAP

These conferences, which regularly attract 300 local and international delegates, are produced in collaboration with the African Fertilizer Agribusiness Partnership (AFAP). Their overall purpose is to promote investment, partnerships and innovation in the African agribusiness sector. The events also offer excellent networking opportunities. In particular, they enable fertilizer producers, traders and policy-makers from across the continent to link-up with large-scale commercial farming enterprises and smallholder farmers.

Africa's premier fertilizer marketplace

Africa Fertilizer Agribusiness has established itself as a leading marketplace where business gets done. This year's conference is officially endorsed by the Western Cape's Department of Agriculture and Wesgro, the Western Cape's tourism, trade & investment agency. It also has the support of key national and international bodies, such as FERTASA and ADASA – South Africa's fertilizer and agrodealer associations – and the International Fertilizer Association (IFA).

The conference provides an invaluable opportunity for delegates to meet up with hard-to-reach fertilizer industry decision-makers. Ma'aden is this year's lead conference sponsor and the global fertilizer supply chain is once again sending senior executives to meet with traders and distributors. Companies such as Arab Potash, Dangote Industries, Evergrow, OCP Africa, Omnia, PhosAgro, Sabic, Sirius Minerals and Toyota Tshusho have already confirmed their participation.

Both CRU and AFAP look forward to welcoming delegates to Cape Town in October. This year's conference is expecting record attendance from African policymakers, smallholder farmers and agribusiness SMEs, thanks to the sponsorship of AFAP and support from the Western Cape Department of Agriculture

Tom Willatt, Portfolio Director at CRU Events, said: "We are delighted to be working so closely with key industry partners, and it will help ensure the discussions meet the needs of the whole sector, whether they are smallholder farmers, large commercial agribusinesses, fertilizer producers, or policymakers from across Africa. I am sure the 2019 conference will build on all of the excellent connections and discussions started at our previous events."

Event highlights

- Pre-conference AFAP fertilizer policy workshop
- Formal conference opening by **Rhoda Peace Tumusiime**, Former Commissioner for Rural Economy and Agriculture at The African Union
- Keynote from **Omri Van Zyl**, Executive Director, Agri SA, the voice of 28,000 commercial farmers across South Africa
- Other keynotes from **Ivan Meyer**, Minister. Western Cape Department of Agriculture, and **Rebbie Harawa**, Head of Soil Fertility and Fertilizer Systems, Alliance for a Green Revolution in Africa (AGRA)
- Visit to Langgewens Research Farm and Thokozani Wines

Conference sessions

- Soil science and specialty fertilizer forum
- Fertilizer innovation showcase
- Fertilizer industry leadership
- Agribusiness perspectives
- Solutions for small holder farmer and SME agrodealer network development
- Fertilizer and agribusiness investment panel
- Understanding the African fertilizer landscape
- Regional perspectives on boosting trade

PHOTOS: ABOVE: WOLFPOWER/SHUTTERSTOCK.COM. OPPOSITE: STOCKPHOTO.COM/PAOLO TOFFANIN

Confirmed speakers

- Kalim Shah, Chief Investment Officer, **International Finance Corporation**
- Devakumar Edwin, Group Executive Director, **Dangote Industries**
- Jason Scarpone, Present and CEO, **African Fertilizer and Agribusiness Partnership (AFAP)**
- Senior representative, **Ma'aden**
- Chris Giannakis, co-CEO, **Meridian Group**
- Makala Jeffrey Ngaka, Co-ordinator: Comprehensive Producer Support Policy, Department of Agriculture, Forestry and Fisheries, **Government of the Republic of South Africa**
- Tsépiso Makgothi, Chief Director: Strategic Partnerships and Customer Care, Incentive Development and Administration Division (IDAD), Department of Trade and Industry, **Government of the Republic of South Africa**
- Dr Johan Labuschagne, Researcher: RTDS – Plant Sciences, **Western Cape Department of Agriculture**
- Rajiv Ram, Demand Analyst, **CRU**
- Maksim Poltoradnev, Marketing Director, **United Fertilizers Company Limited**
- Yohannes Assefa, Director of Agriculture and Agribusiness, **USAID East Africa Trade and Investment Hub**
- Svet Varadzhakov , Investment Director, **AgDevCo**
- Kefa Nyakundi, Managing Director, **Ennovative Capital**
- Grace Chilande, Fertilizer Market Specialist and AfricaFertilizer.Org Coordinator, **IFDC**
- Luambo Munzhedzi, Chairperson, **Agro dealers Association Southern Africa (ADASA)**
- Officer, **DSM Corridor Group Ltd**
- Ralph Koekkoek, Project Development Manager, **Stamicarbon**
- Clive M Smith, Chief Executive Officer (Ag), **Walvis Bay Corridor Group**
- Dr Pedram Dehdari, Managing Director, **Ensymm UG&Co.KG**
- Cleiton de Sequeira, Global Market Development Manager – Agriculture, **US Borax, Rio Tinto**

King protea, the national flower of South Africa.

See you in Cape Town!

Fertilizer International magazine is once again proud to be the official media partner for the 2019 Africa Fertilizer Agribusiness Conference. We will be exhibiting at the event and are very much looking forward to meeting industry friends, both old and new.

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Micronutrient biofortification

Micronutrient-enriched fertilizers have a major role to play in tackling deficiencies in both crops and human diets. Zinc deficiency, in particular, affects nearly half of cultivated soils worldwide. The range of soil-applied, foliar and fertigation products are reviewed.

Micronutrients are essential for plant growth and a necessary part of balanced crop nutrition. They include boron, copper, iron, manganese, molybdenum and zinc. Although required in much smaller amounts, micronutrient availability is arguably as important to plant nutrition as primary and secondary macronutrients. A lack of one or more micronutrients in soil can still limit plant growth, even when adequate levels of other nutrients are present.

Hidden hunger

Micronutrient deficiencies in human diets also have marked health impacts, particularly for vulnerable, malnourished children. The understandable priority, when it comes to feeding the world, has been to produce more calories. Consequently, the nutritional value of food has been largely ignored, as *The Economist* reported in 2011:

"Nutrition has long been the Cinderella of development. Lack of calories – hunger – is the headline-grabber. But the hidden hunger of micronutrient deficiencies harms even more people and inflicts lasting damage on them and their societies. It, too, worsens as food prices rise: families switch from costly, nutrient-rich, fruit, vegetables and meat to cheaper, nutrient-poor staples."

Widespread and growing iron and zinc deficiency in humans has been detected by the World Health Organization (WHO) in recent decades.

"Zinc is an essential element for animal and plant life, and zinc deficiency, particularly in children, has become such a threat to public health that many countries in zinc-deficient regions are implementing programmes to increase the use of zinc in fertilizers," commented Stefan Schlag, director of specialty chemicals at IHS.

Similarly, iodine deficiency has been on the increase globally since the 1970s. Selenium deficiency also now affects large swathes of China and Africa.

Micronutrient mining of soils is partly to blame, as some of these deficiencies are linked to the depletion associated with the 'Green Revolution' – the large increase in crop production achieved in in the middle decades of the 20th Century.

Over three billion people on the planet are believed to be suffering the consequences of micronutrient deficiencies. Even mild cases of hidden hunger in children can damage mental and physical development, lowering disease resistance and causing blindness and other ailments.

A special issue of medical journal *The Lancet* in 2008 helped reveal the true human costs of micronutrient deficiencies for the first time. This showed that more than 450,000 children under the age of five die each year in developing countries due to zinc deficiency alone.

Agronomic biofortification

The rise of innovative, speciality fertilizers able to correct micronutrient deficiencies, effectively and economically, means crop nutrition is at the vanguard when it comes to tackling hidden hunger. Indeed, agronomic biofortification – the use of measures such as crop management and crop fertilization to increase micronutrient levels in crops – is a proven strategy for tackling deficiency.

To date, agronomic biofortification has been most effective for zinc and selenium. In one celebrated example from Finland, the addition of selenium to NPK fertilizers increased crop Se contents and the Se status of the whole population.

Most research, however, has focussed on zinc, with mounting evidence that Zn fertilization can increase both crop yields and their nutritional quality. Zinc fertilization trials in Turkey, for example, increased yields and grain Zn concentrations for a range of cereals (maize, sorghum, barley, wheat) and other crops (soybean, safflower, pea, common bean, canola). Notably, zinc concentrations in wheat grains increased threefold in response to both soil and foliar Zn application.

Field trials on rice in India demonstrated that the use of zinc-enriched urea increased crop yields and grain Zn concentrations by up to three times. A review of trials in 10 African countries has also shown that zinc application to soil increased the Zn concentration in maize, rice and wheat grains by 23 percent, 7 percent and 19 percent, respectively. For the same crops, zinc concentration in grains increased even further, by 30 percent, 25 percent and 63 percent, respectively, when Zn was applied to crops as a foliar spray[1].

Field trials on the zinc enrichment of wheat, rice and maize have been carried out in 12 countries over the past 7-8 years as part of the Harvest Zinc project, part of the wider international Harvest Plus programme. Wheat was found to have the most marked response to zinc foliar sprays, showing increases in grain Zn content of up to 83 percent, while rice showed a more moderate response with increases in grain Zn content of up to 27 percent. Maize, in contrast, was less responsive[2].

A recent review[2] has concluded that zinc fertilization is an effective strategy for biofortifying food crops with Zn. It also offers other advantages by contributing to:

- Better yields depending on the extent of soil Zn deficiency
- Improved seed and seedling vigour
- Reduced root uptake of cadmium and lower Cd accumulation in shoots and grains.

The need for speciality products to replenish micronutrients in soils is growing due to a combination of factors. High-yielding crops are removing more micronutrients from soil than was previously the case, for example. The prevalence of high-analysis NPK fertilizers, which have fewer trace impurities, also means less micronutrients are being applied.

Crops show a range of yield responses to micronutrients (Table 1). The following crops are particularly responsive to boron, copper, manganese and zinc:

- **Boron:** alfalfa, apples, sugar beet, cotton, peanuts, sweet potato, tomato
- **Copper:** citrus, lettuce, tomato
- **Manganese:** cotton, lettuce, oats, sweet potato, soybean, wheat
- **Zinc:** corn, grain sorghum, potato

Table 1: **Crop yield responses to micronutrients**

Crop	B	Cu	Mn	Zn
Alfalfa	High	Low	Low	Medium
Apples	High	Medium	Low	Medium
Sugar beet	High	Low	Low	Medium
Citrus	Medium	High	Medium	Medium
Corn	Medium	Low	Low	High
Cotton	High	Low	High	Medium
Grain sorghum	Low	Medium	Medium	High
Lettuce	Medium	High	High	Medium
Oat	Low	Medium	High	Medium
Peanut	High	Low	Medium	Low
Irish potato	Low	Medium	Medium	High
Sweet potato	High	Low	High	Medium
Rye	Low	Low	Low	Medium
Soybean	Low	Medium	High	Medium
Tomato	High	High	Medium	Medium
Wheat	Low	High	High	Low

High *Medium* *Low*

Source: Mosaic

Table 2: **Potential yield response to micronutrients application**

Nutrient	Crop	Application	Yield (kg/ha)
Zn	rice	soil	36
Zn	pomegranate	foliar	18
Fe	bean	foliar	133
Fe	soybean	foliar	45
Fe	soybean	soil	9
B	cotton	soil	13
B	sunflower	foliar	49
B	soybean	soil	39
Mn	maize	soil	16
Mn	bean	soil	19
Cu	rice	soil	8.5
Cu	bean	soil	32
Cu	wheat	soil	63
Mo	rice	soil	13

Source: Dimpka & Bindraban (2016)

The increases in crop yields that are potentially achievable by applying micronutrients are shown in Table 2.

Application methods

Soil application of micronutrients remains the most common application method for crops. Recommended application rates are low (usually <10 lb/acre, <11 kg/ha), making separate field applications difficult. Because of this, granular or liquid NPK fertilizers are commonly used as micronutrient carriers. Incorporating micronutrients as part of a fertilizer mix is a convenient application method as it enables uniform distribution in the field with conventional spreading equipment. There are four main methods of applying micronutrients mixed with fertilizers:

- **Incorporation during manufacture:** this results in uniform distribution of micronutrients within compound NPK granules.
- **Bulk blending with granular fertilizers:** this produces fertilizer grades at the recommended micronutrient rate, although segregation can result in an uneven nutrient distribution.
- **Coating onto granular fertilizers:** coating powdered micronutrients onto granular NPK fertilizers decreases the risk segregation.
- **Mixing with liquid fertilizers:** fertigation has become a popular method of application although compatibility tests are required.
- **Foliar sprays** are also widely-used to apply micronutrients, especially iron and manganese. Soluble non-chelated inorganic salts are usually chosen as they are generally as effective as more expensive chelated products. Use of a sticker-spreader agent in the spray is often advised to help micronutrients adhere to foliage.

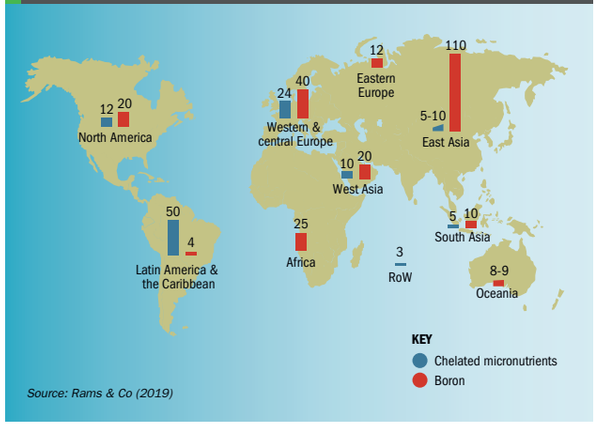
Non-chelated and chelated forms

Micronutrient fertilizers can be split into two main categories: non-chelated and chelated products. Demand for **non-chelated micronutrient products** is rising rapidly, making these products the fastest growing segment of the speciality fertilizer market globally. The largest producers are Yara, Rio Tinto Borax, Agrichem, Cheminova, Brandt Consolidated, COMPO and Valagro[3].

Non-chelated products are formulated using inorganic micronutrient sources, typically oxides, carbonates and sulphates, borates and molybdates. They are able to be applied flexibly and can be incorporated into both compound fertilizers and foliar treatments. Co-formulants are generally incorporated to ensure stability and optimise performance during foliar application and seed coating. Complexing agents are used in concentrated liquid micronutrient fertilizers to produce the desired mixing behaviour.

Chelated micronutrient products, as the name suggests, benefit from the incorporation of a chelating agent. Because they are a popular choice in fertigation, growth in demand has tracked the rise in the global

Fig. 1: **Agricultural consumption of boron and chelated minerals, by region, 2018**



Source: Rams & Co (2019)

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COMPASS MINERALS: COMBATTING ZINC DEFICIENCY

Although the spring growing season is behind us in North America, cool, wet weather during early development can cause zinc deficiencies in corn and other row crops. Implementing a starter fertilizer programme, to spoon-feed a crop throughout the season and ensure optimal plant nutrient availability, is the best way to successfully manage yield potential.

ProAcqua® water-soluble fertilizers

The two water-soluble products we recommend for in-season zinc deficiencies are *ProAcqua Zn EDTA* and *Nourish Zn*. Both are formulated with high-quality ingredients and a blend of proprietary adjuvant blends to support plants under stressful conditions. Both *ProAcqua Zn EDTA* and *Nourish Zn* can be used for in-furrow and foliar applications. The EDTA chemistry protects the zinc from tie-up – both in the soil and in the tank.

Wolf Trax™ *DDP*® micronutrients

Making sure the right nutrients are available when plants need them most is important. But so is making sure these nutrients are delivered closer to the plant roots – resulting in earlier plant uptake.

Products such as *Wolf Trax Zinc DDP* use exclusive *EvenCoat*™ technology to ensure nutrients are thoroughly coated onto each granule in a fertilizer blend. This results in uniform, even distribution across the field. Nutrients are placed closer to the roots, resulting in increased uptake during critical stages of development that set the plant's yield potential. The improved distribution also means nutrients are applied at rates that align more closely with plant needs.

Rocket Seeds™ seed-applied nutritionals

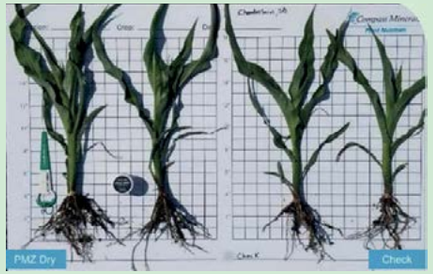
Providing proper nutrition to the seed ensures earlier availability of key nutrients at the very beginning of a plant's life cycle. Earlier this year, Compass Minerals Plant Nutrition launched *Rocket Seeds*, a portfolio of dry and liquid nutrient products for seeds, featuring unique patent-pending formulations. This new portfolio is designed to increase early root growth and accelerate plant vigour.

By providing proper nutrition to the seed, plants can better withstand early season cold and water stress while progressing through the vegetative growth stage.

"*Rocket Seeds* allows us to get the right nutrient package onto the seed for any crop," said Ryan Bartlett, vice president, innovation and product development, Compass Minerals Plant Nutrition. "Once we added *Rocket Seeds* to our portfolio, we were able to enter a new market with a superior product."

Rocket Seeds products can be used on corn, soybeans, wheat and all other major row crops. The products have been thoroughly tested both in the laboratory and in the field. Through extensive research and development, Compass Minerals is dedicated to developing new technologies, like *Rocket Seeds*, to ensure better, early availability of nutrients for every plant, at every crop stage, across every acre.

Two *Rocket Seeds* dry products, *PMZ Dry* and *Moly Dry*, both address zinc deficiencies in plants. *Rocket Seeds PMZ Dry* has a patent-pending formulation (1-10-0, 8% Zn, 2% Mn) and makes an excellent talc and graphite replacement. Its unique nutritional package creates a longer, more developed root system. *Rocket Seeds Moly Dry* (1-5-0; 1.5% Fe, 3% Mn, 3% Mo, 10.5% Zn), in contrast, is an ideal soybean and legume formulation for early growth.



PMZ Dry applied on corn vs. Check, June 2019, South Dakota.

market for water-soluble fertilizers and drip irrigation (*Fertilizer International* 475, p33). **AkzoNobel**, the current world leader in chelated micronutrients, markets and distributes eight trademarks globally. AkzoNobel's *Rexolin* brand is distributed worldwide by Yara International and its *Rexene* brand is distributed by SQM. France's Angibaud & Spécialitées also distributes AkzoNobel's *Ferica* brand. Compass Minerals, SQM and Mosaic also have a strong presence in this market[3].

An attractive growing market

Boron dominates the global agricultural market for micronutrients. The application of boron in agriculture reached 300,000 tonnes (B_2O_3) in 2018, equivalent to around 15 percent of global B consumption. That compares to total global sales volume of around 65,000 tonnes for chelated micronutrients[4].

The main boron-consuming regions are East Asia, Latin America and Europe (Figure 1). About 35 percent of Chinese soils are thought to be boron deficient. Brazil's acid soils also tend to be deficient in Boron as do the acid and sandy soils of Northern Europe.

World consumption of chelated micronutrient products in agriculture was in the region of 63,000-68,000 tonnes in 2018. Europe is the pre-eminent regional market with a global market share of around 40 percent (Figure 1).

Historically, chelated micronutrients were developed in Europe for application to vegetables. Demand generally tracks the water-soluble fertilizer (WSF) market. High premiums have, to date, limited their market penetration in India and China[4].

The better performance of chelated micronutrients, relative to their non-chelated counterparts, means they can be sold at a higher price in the market. The nutrient and water efficiency of fertigation – a key market for chelated micronutrients – also generates enough cost savings to support this price differential[3].

Although the size of the segment is relatively small in volume terms, higher value and better margins make micronutrients an

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PROFILE: AB ETIPRODUCTS OY

Eti Maden IGM is Turkey's biggest national mining company. It was established in 1935 to take advantage of the country's vast boron deposits – these holding almost three-quarters of world reserves. The company has since become the world's leading boron minerals and boron chemicals producer, and the largest exporter of refined boron products and minerals globally.

Eti Maden – previously known as Etibank and Eti Holding – set up a joint venture (JV) with the Finnish mining and multi-metal company Outokumpu Group in 1982. Known as Ab Etiproducts Oy, this Finland-based JV is responsible for the international marketing and sales of the boron products produced by Eti Maden. The company initially sold into the Scandinavian market, although its marketing and sales activities have expanded greatly over time. Ab Etiproducts Oy's exclusive sales area now covers the Scandinavian and Baltic countries, Germany, Poland, Ukraine, Moldova and the whole of the African continent.

Boron has a number of important functions in plants. It plays a role in:

- Cell wall structures and membrane integrity
- The reproductive phases of plants
- The transport of carbohydrates
- Root nodule growth and nitrogen fixation
- Pollination and seed production.

PHOTO: ETI MADEN

Borate mining.

To meet different crop requirements, Eti Maden offers several types of boron product in its agricultural portfolio. Boron can generally be provided to plants two ways, typically being applied either in solid, granular form to soils or in liquid form directly onto plant leaves. Agricultural products are generally either quickly dissolving sources of boron, such as *Etidot-67* and boric acid, or slow-release granular products (2-4mm size) such as colemanite and ulexite.

Application methods and product selection depend on several external factors, such as soil conditions, rainfall and the target crop. Ab Etiproducts Oy therefore advises that an agronomist is consulted prior to application. More information about the use of boron in agriculture, and the full Etiproducts boron product catalogue, is available online at etiproducts.com/agriculture. ■

attractive global market – one which looks set to grow at a fast rate for the foreseeable future[3].

In North America, there is a view that any softening in the pricing of N, P and K macronutrients could also leave more farm dollars available for spending on micronutrients. If true, higher zinc applications to corn and manganese applications to soybeans are likely to be the main beneficiaries.

Selected products and producers

North America has a healthy micronutrient market. They are often supplied in products alongside sulphur (*Fertilizer International* 476, p19). **The Mosaic Company** has led the way with its pioneering sulphur-enhanced monoammonium phosphate (MAP) product range, *MicroEssentials*. This broke through the one million t/a barrier at the end of 2013. One of the main formulations offered is the zinc-fortified *MicroEssentials SZ* (12-40-0 10S 1Zn). This combines 12% nitrogen, 40% phosphorus and 10% sulphur with 1% zinc.

The proprietary *Fusion* process used in the manufacture of *MicroEssentials* joins together nitrogen, phosphorus, sulphur and zinc to create a nutritionally-balanced granule capable of boosting crop yields by 3-7%, compared to conventional MAP or DAP.

In 2014, Mosaic also launched a new micronutrient product, *Aspire*, a boron-enhanced potash fertilizer. This first-of-its-kind premium potash fertilizer (0-0-58-0.5B) combines potassium chloride (58% K_2O) with boron (0.5%). This is uniformly distributed within granules using proprietary *Nutriform* technology. *Aspire* is being targeted at the growing micronutrient needs of crops like corn, soybeans, alfalfa and cotton.

US-based **Cameron Chemicals** has expanded and made significant investments in micronutrients production since it was founded in 1986. The company's original micronutrients plant in Suffolk, Virginia, produces granular micronutrients for the North America market. Its convenient location close to the Port of Virginia also enables it to supply a growing contingent of offshore customers as well.

Cameron expanded its capabilities in 2015 with the purchase of the Reese, Michigan, operations of **Advanced Micronutrient Products (AMP)**. This plant manufactures granular oxy-sulphate micronutrients as well as micronutrient-enriched compound NPK fertilizers. Both these production lines have the flexibility to make single-element, multi-element and proprietary mixes for customers.

Cameron's investment continued in 2017 with the addition of the **Ultra Yield Micronutrients** zinc sulphate plant located in Moxee, Washington. The plant produces several grades of zinc sulphate including liquid, granular and powder products.

Together, Cameron, AMP and Ultra Yield Micronutrients, are the largest producers of granular micronutrients in North America. Cameron Chemicals is currently in the process of patenting a new technology – one that it says promises to be a game changer in the US market.

Cameron offered the following positive advice to North American farmers following the difficult spring application season:

"The weather induced fallow offers a unique opportunity to intensively soil sample and to look for hidden hungers that can be corrected for next year's crop and beyond. Cameron encourages all [farmers] to soil sample and analyse for micronutrient deficiencies. From this, a product mix can be developed that will fit the needs of a majority of the soil types in an area."

Nachurs Alpine Solutions (Nachurs) is an industry leader in low salt and high-quality liquid orthophosphate fertilizer solutions. These can be applied in a variety of ways: in-furrow at planting, in-season foliar application, and via pivot/drip fertigation. In recent years, Nachurs has expanded its product offering to include liquid potassium solutions. These can be used in the same way as liquid orthophosphates. They can also be applied side-dressed with nitrogen solutions, in strip tillage or by deep placement.

Nachurs offers a number of orthophosphate products enriched with EDTA-chelated micronutrients. These are compatible with orthophosphate and meet the long-term quality and storage criteria which Nachurs insists on.

Nachurs advises that micronutrients with NPK orthophosphates are used in-furrow at planting to promote early root growth and development. This is followed up with a balanced, tank-mixed NPK plus micronutrients formulation, with herbicides/insecticides, in the early stages of plant growth.

Nachurs largest volume micronutrient is zinc, followed by manganese, iron, copper, calcium, and magnesium. The company has seen greater interest in boron, molybdenum, and cobalt in recent years due to their beneficial effects on plant reproduction, nitrogen efficiency and/or sugar movement.

Norway's **Yara International** occupies a leading position in the overlapping water-soluble fertilizer, fertigation and micronutrient product markets. Its *YaraTera KRISTALON* water-soluble NPK product range contains a full spectrum of micronutrients in chelated form. These are suitable for drip, tape, sprinkler or pivot irrigation systems. The company's *YaraTera REXOLIN* product range also incorporates fully water-soluble chelated micronutrients. These are suited for soil, foliar and hydroponic applications, and ensure micronutrients remain available to crops, without the risk of precipitation or fixation. A third chelated micronutrient product, *YaraTera TENSO COCKTAIL* is a wettable powder that can be tank mixed with other water-soluble fertilizers to address micronutrient deficiencies in hydroponic and fertigation applications.

A range of micronutrient formulations are also offered as part of the company's *YaraVita* product range. The foliar fertilizer *YaraVita BEETRAC*, for example, is designed to prevent micronutrient deficiencies in sugar beet (*Fertilizer International* 467, p24) and contains manganese, sulphur, boron, copper and zinc. *YaraVita BRASSITREL PRO*, a liquid suspension for foliar application to oilseed rape (*Fertilizer International* 477, p15), brassicas (*Fertilizer International* 472, p40) and legumes, contains manganese, magnesium, boron and molybdenum.

Two other foliar liquid suspension products, *YaraVita BUD BUILDER FL* (Mg, Zn, N, B and P) and *YaraVita GRAMITREL* (N, Mn, Mg, Cu and Zn) are targeted at soft fruit flowering and cereal yields, respectively. A formulation of the *YaraMila* NPKS fertilizer incorporating magnesium, sulphur, boron, iron, manganese and molybdenum is also available in either prill or granule form. ■

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SPECIALITY PRODUCTS

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Maintain quality, minimise loss

The degradation of finished fertilizers during transport, handling and storage can be avoided by protecting surfaces with chemical agents. We survey the range of anti-caking, water repellent and anti-dusting additives currently on the market.

Caking destroys value

The caking of fertilizers, if not prevented, can be a major headache during storage, transport and field application. It can destroy the value of fertilizers, halt loading and unloading, damage handling equipment and be a safety hazard.

Caking often occurs when fertilizers contain moisture or are exposed to humidity. This allows soluble salts to crystallise and form solid bridges between particles. Fertilizer stored under pressure can also deform plastically and fuse, especially when stockpiled in bulk in open bins.

Surface caking can also be a warehouse hazard due to the formation of unstable cliffs in fertilizer stockpiles. These can become dislodged and fall when equipment operators remove materials from the base of piles.

Changes from factory to field

If handled and stored incorrectly, the physical qualities of fertilizers can deteriorate during their journey from the factory to the field, being influenced by[1]:

- Physical properties of finished fertilizers at the production stage
- The storage environment, particularly fluctuations in temperature and humidity
- Loads and impacts during handling and transport.

The qualities that most affect the handling, storage and spreading of products are:

- Hygroscopic behaviour
- Caking
- Particle size, shape and size distribution
- Particle strength and mechanical resistance
- Segregation
- Tendency to generate dust and fines
- Bulk density
- Chemical and physical compatibility of components in blends.

Particle size matters

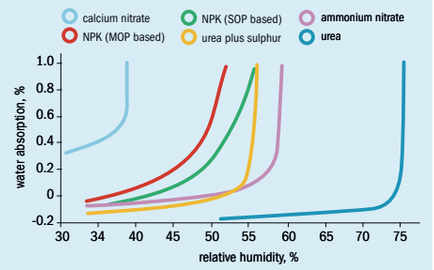
Finished fertilizers can cake during storage and transport forming unwanted and hard-to-handle lumps, especially when exposed to humidity or placed under loads when kept in piles. Caking behaviour is particularly influenced by particle size as this parameter determines both the material's surface area – and hence its ability to take up moisture from air – and the number of contact points between particles. A wide particle size distribution also has an effect as a mix of smaller and large particles in a product will increase the number of contact points.

Humidity problems

All fertilizers tend to be hygroscopic to some degree (Figure 1) and are therefore prone to water absorption during storage and handling (Figure 2). Water uptake can trigger a range of undesirable physical changes[1]:

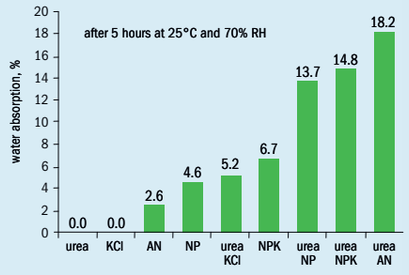
- Particles start to swell or crack and become soft and sticky
- Dust and fines can form
- Particle strength is reduced and the tendency to cake increases
- Handling and field spreading equipment can become clogged
- Storage warehouse floors become slippery
- Ammonium nitrate loses its thermal stability.

Fig. 1: **Critical relative humidity (CRH) of various fertilizers at 25°C**



Source: Yara

Fig. 2: **Water absorption in blends**



Source: Survey dept, Yara

Under tropical conditions, where temperatures of 30°C and 80 percent relative humidity (RH) can be the norm, the exposed surface of urea piles can absorb more than three kilos of water per metre squared within several days. Condensation from air will also transfer moisture to stored fertilizer piles when the air temperature falls below dew point during the night time. Avoiding wide variations in temperature and RH is therefore critical for reducing crusting, caking and lumps formation during warehouse storage and bulk transport.

The moisture content of finished products is also an important quality consideration as it can lead to dust formation and caking subsequently. Fine needle-like crystals can form during drying and storage from liquid held within capillaries, becoming a dust nuisance during bulk transfer and bagging. Cement formed from a liquid meniscus at particle contact points can also cause urea to become caked when stacked or bagged.

Granulated NPKs

Their variable particle-size and chemistry generally make NPKs more prone to caking than urea prills and granules. For NPKs, water absorption is generally triggered when RH exceeds 50-55 percent, a threshold known as the critical humidity, as can happen in tropical countries during the rainy season and as a result of daily temperature fluctuations.

Urea-based NPK blends are highly hygroscopic and will absorb 15 percent water by weight when exposed to 70 percent RH for five hours at 25°C (Figure 2). Under tropical conditions (30°C and 80% RH), the surfaces of NPK (17-17-17) piles can absorb as much as 5.8 kg/m^2 of water within 72 hours, almost double the surface take-up of urea granules.

Maintaining quality

Fertilizer product quality can be maintained by keeping physical parameters within certain values and adopting storage and handling recommendations[2]:

- **Large granules**: 95 percent between 2-4 mm, SGN > 250
- **Uniform size**: uniformity index > 55
- **Low angle of repose**: keep to <30 degrees by more efficient sieving
- **Low moisture**: keep end-product moisture content < 0.8 percent
- **Low granule porosity**: <0.5 percent desirable
- **High granule strength**: >3.0 kg crush strength for three millimetre granules, for example
- **Low fines and dust**: ensure no material <1mm in product
- **Temperature control**: maintain a constant warehouse temperature to prevent the migration and absorption of moisture
- **Storage**: avoid keeping bagged products with a high caking potential in high stacks
- **Warehouse management**: apply the first in/first out principle

> **Finished fertilizers can cake during storage and transport forming unwanted and hard-to-handle lumps, especially when exposed to humidity.**

Minimising loss

The degradation of finished products during handling and transport can be reduced or avoided through the addition of anti-caking agents (*Fertilizer International* 477, p28; *Fertilizer International* 453, p26; *Fertilizer International* 464, p32). These agents are usually applied as surface coatings and help prevent dust formation and caking by reducing water absorption under humid conditions. They include both manufactured and natural non-toxic compounds. These need to be harmless to soil, plants and humans. Coating chemicals generally function by:

- Controlling dust formation
- Minimising caking and particle bridging
- Enhancing powder flow
- Reducing moisture absorption
- Enhancing appearance
- Regulating nutrient release.

They are often combined with a pigment to introduce colour.

Urea, urea-based NPKs, ammonium nitrate, calcium nitrate and other NPK fertilizers are more hygroscopic and will therefore often benefit the most from the addition of anti-caking agents, according to Indian process chemicals manufacturer Fertibon Products. In comparison, the need for anti-caking treatment for fertilizers such as phosphates and ammonium sulphate can be lower as they are less hygroscopic.

Selected producers and products

Yara Technology Centre has developed a range of coating systems for its fertilizer product range. These can reduce dust release during bulk handling by up to 90 percent. Treating *YaraLiva* calcium nitrate fertilizers with the company's proprietary *Tropicote* coating also drastically reduces water absorption[1].

ArrMaz has been a leading seller of coatings and process control chemicals to the fertilizer industry since the late 1960s. The company coats over 40 million tons of fertilizers every year for some of the world's major fertilizer producers with its *Dustrol* range of dust control agents and *Galoryl* range of anti-caking agents. These are generally suitable for all solid fertilizers including granules, prills and powders. *Dustrol* coatings supress dust by forming a barrier around granular products and will also adsorb dust after it is generated. The company's *Galoryl* range is targeted at the industrial ammonium nitrate and nitrogen fertilizer market and is available in both aqueous and non-aqueous formulations. The Florida-based company was recently acquired by **Arkema Group**, a global specialty chemicals manufacturer with headquarters in France.

The *CHEMISIL* range of additives offered by Spanish firm **Chemipol** are designed to prevent fertilizer caking during manufacture and storage. They are based on two main formulations. *CHEMISIL NS* is a soluble sulphonated coating agent designed to prevent caking in bagged fertilizers stored under load on pallets. The anti-caking agent *CHEMISIL AG*, in contrast, is a highly-absorbent form of silica dioxide used to prevent agglomeration during the manufacture of powdered fertilizers.

China's biggest fertilizer additive producer **Forbon Technology** manufactures four anti-caking agents for urea, phosphates and compound fertilizers under the *Hisoft* brand name. These oil-based and powder-form coating agents are designed to solve fertilizer quality problems such as

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HOLLAND NOVOCHEM: Consistent quality & reliability

Spray coating fertilizer on a conveyor belt.

Holland Novochem markets a long-established range of anti-caking, moisture repellents and de-dusting agents. **John Brennenraedts**, Area Manager, Fertilizer Additives, at Novochem Group introduces the company's product lines.

Holland Novochem is an independent company located close to Amsterdam in the Netherlands. For decades, we have been a leading global supplier of speciality chemicals for the fertilizer industry. The company's success – ever since its foundation in 1992 – has been built on its dedication to fertilizer additives and their quality.

Product range

Holland Novochem serves fertilizer industry customers in more than 90 countries through four branch offices located across Eastern and Western Europe. The company is well known for its extensive range of Novo-branded fertilizer additives. These low-toxicity, environmentally-friendly products successfully address many of the problems associated with the production, storage and transportation of fertilizers, whether in solid or liquid form. The Novo product range includes:

- ***NovoFlow*** anti-caking and moisture repellent coatings: these provide protection against caking and moisture uptake. They are suitable for all major types of fertilizers. Formulations are custom-made – according to the specific needs of fertilizer producers – to reduce caking and/or moisture.
- ***NovoDust*** anti-dust coatings: these substantially reduce dust generation during the handling and storage of fertilizers. Dust prevention is becoming an increasingly important due to the introduction of ever more stringent environmental and safety regulations – and the general requirement for cleaner workplaces.
- ***NovoCor*** corrosion inhibitor for liquid fertilizers: the addition of an inhibitor is essential for highly corrosive liquid fertilizers, such as UAN and AN solutions. *NovoCor* works by creating a stable organic barrier film on metal surfaces. This provides long-term corrosion protection for the whole of the distribution chain, from production to the end-user.
- ***NovoFoam*** anti-foaming agent: this strong anti-foaming product controls foam formation during the reaction of phosphate rock with acids.
- ***NovoTec*** granulation additive: this granulation enhancer can optimise the production process and/or improve the quality of fertilizer granules for a variety of fertilizer grades, especially AN, CAN and NPKs.

Success factors

Over the years, Holland Novochem has built up a strong reference list that includes all the major fertilizer-producing companies. The company attributes its success to the following factors:

- **Dedicated staff**: building long-term partnerships with our customers is the priority of our multi-disciplinary and highly-experienced chemical, technical, logistic and commercial teams.
- **Independence**: the way we operate means the company is not restricted to using specific in-house raw materials, such as amines.
- **Cost awareness**: where possible, operations are adapted to take account of changing input costs, e.g. for minerals oils.
- **State-of-the-art laboratory**: our modern lab has all the necessary facilities to run specific tests on fertilizer additives, enabling us to design custom-made formulations and to develop new applications.
- **Consistent high quality and reliability**: this applies to both products and logistics. Our production, from one single location close to Rotterdam, allows us to take full advantage of our very experienced production and logistics teams.
- **Sustainable technology**: pure raw materials are used in all products, with strict adherence to the maximum limit of two percent polycyclic aromatics. Holland Novochem has also successfully developed bio-based coatings not derived from crude oil. This enables us to supply customers with products that are free of microplastics and conform to environmental regulations such as REACH. Use of bio-based coatings also avoid the price fluctuations that can affect inorganic products. ■

caking, dust generation and weak granule strength.

India's **Neelam Aqua & Speciality Chem Ltd** markets the *NEELCOAT* range of anti-caking agents for granular NPK, ammonium phosphate (DAP/MAP), and calcium ammonium nitrate fertilizers. The company's *NEELCOAT DS* products combine anticaking behaviour with dust suppressant properties. They are derived from plant extracts and are fully biodegradable. Neelam Aqua also offers three *URECOAT* anti-caking formulations for urea, the first designed for prills, the second incorporating neem oil and the third including an urease inhibitor.

Fertibon Products manufactures a wide range of fertilizer additives, including anti-caking agents and colourants, at its production site in Maharashtra, India. These are non-toxic and also designed to protect conveyor belt systems as they are inert when in contact with rubber.

Kao Global Chemicals sells paste and powder anti-caking agents for a wide range of fertilizers (AN, CAN, DAP and NPKs) under the *SK FERT* marque. It also offers the liquid anionic surfactant product *URESOFT A-10*, a low-toxicity anti-caking agent designed especially for urea and ammonium sulphate. ■

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10th GPCA Fertilizer Convention

The Kempinski Hotel, Muscat, will hold the 10th GPCA Fertilizer Convention in September 2019.

The Gulf Petrochemicals and Chemicals Association (GPCA) is holding the 10th GPCA Fertilizer Convention at the Kempinski Hotel, Muscat, Oman, 24-26 September 2019.

This year's GPCA Fertilizer Convention has the theme "Transformation: A New Era for the Agri-nutrients Industry". The Convention returns to Muscat for the second consecutive year. This follows the success of the 2018 event, which attracted more than 300 regional and global delegates.

Distinguished speakers

The GPCA has secured an impressive line-up of high-level speakers for this year's convention. **Dr Abdulrahman Jawahery**, GPCA's vice chairman and the president of GPIC, will welcome delegates to the event by delivering the opening remarks. **Samir Al-Abdrabbuh**, SABIC's executive vice president, agri-nutrients, will present the keynote address on the first day, while **John Baffes**, senior economist at the World Bank's Development Prospects Group, will deliver the second keynote address on day two. Other distinguished speakers include:

- **Ismahane Elouafi**, director general, the International Center for Biosaline Agriculture (ICBA)
- **Khaled Mohammed Al-Aboodi**, managing director, Saudi Agricultural and Livestock Investment Company (SALIC).

Warmly welcoming delegates

Dr Abdulwahab Al-Sadoun, GPCA secretary general, looks forward to welcoming delegates to Oman:

"Building on the success of last year's event, we are proud to be organizing the 10th GPCA Fertilizer Convention for the second year in Oman. I look forward to welcoming stakeholders from across the board to exchange valuable ideas and learn from one another at this prestigious industry event.

"We will once again showcase our industry's achievements to a diverse international audience and share key learnings from across the globe on how to meet the challenges affecting the market head on. Addressing global food security remains at the top of the industry's agenda, and the deployment of innovative technologies and digitalization along the entire value chain will prove especially important to meet this challenging goal."

Leading regional event

The GPCA Fertilizer Convention has established itself as the Gulf region's leading fertilizer industry networking event. Each year, it gathers together regional and global industry experts, thought leaders and executives. The event provides an invaluable opportunity to connect with industry peers, and share knowledge and insights about the latest trends in the fertilizer market.

This year's GPCA Fertilizer Convention will cover a wide variety of topics, including:

- Food security in the Arabian Gulf region
- Technology trends and disruptions
- Strategies for growth
- Fertilizer market trends
- Producing enhanced quality fertilizers.

These themes reflect the strategic consolidation taking place within the fertilizer industry. That is being accompanied by an increasing focus on innovation, the manufacture of higher value-added products, and new opportunities in the key emerging markets which are driving fertilizer demand.

This year's convention notably includes a workshop on "Human Capital: Making the workforce ready for the future". This will discuss diversity and inclusion in the fertilizer industry. It will be accompanied by a series of technical workshops. These will provide delegates with opportunities to learn about industry best practices, both regionally and globally, from leading technology providers.

Fertilizer International magazine is proud to be the official media partner for the 10th GPCA Fertilizer Convention. Please visit www.gpcafertilizers.com for more information about this year's event.

About the GCC region

The Gulf Cooperation Council (GCC) region benefits immensely from its abundant hydrocarbon resources, strategic geographic location and competitive feedstock position, making it an important global producer of high-quality fertilizers. The fertilizer industry contributes significantly to job creation within the region and its economic growth. The expansion of fertilizer production also forms a vital part of the strategy to diversify the economies of countries within GCC region. ■

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Next-generation fertilizer colourants

PHOTO: MILLIKEN

Water-soluble fertilizers coloured with Liquitint Agro.

Novel colourant technology is creating new opportunities for fertilizer manufacturers. Milliken believes that the time is ripe for new colourant technology in agriculture, as **Adam Newberry**, Milliken's Global Product Line Manager, explains.

Agriculture generates a world of wonderful colour – from bold red tomatoes and deep green spinach to golden yellow corn and vibrant purple grapes. Visual appearance – shape, colour or shade – is important in almost any product. Furthermore, decades of market research have shown that colour has a huge positive influence on consumer buying decisions. Yet, until now, due to several challenges, this rainbow of colours hasn't been a significant feature of fertilizers – the key products that allow us to grow agricultural produce.

Traditionally, colourant technologies used in fertilizers have been crystalline, solid materials, most commonly dry and dusty powders. While undoubtedly good at imparting colour, powders can easily become airborne. This is a major disadvantage as, clearly, producers only wish to colour their fertilizers – not equipment, production plants, and the clothing and skin of their operators! Inevitably, any extra and unwanted colouration also leads to contamination, waste, long product transitions and downtime, which all translates into extra costs.

The alternatives available for some of these colourants – liquid dispersions or solutions – can also have issues of their own, including low colour strength, short shelf-life, high water or solvent content, and poor compatibility and coverage. Neither do they overcome the significant problem of extraneous staining.

Additionally, the colouration of water-soluble fertilizers (WSFs) remains a particular challenge. While commonly sold as powders, customers require WSFs to be completely soluble when added to their irrigation systems. This is a big obstacle when pigments are used, as these consist of insoluble particles or agglomerates. No WSF manufacturer wants to add a colour to a formulation only to have it clog the customer's spray nozzles or settle to the bottom of the mix tank.

Maximising the benefits of colourants

Despite these challenges, farmers and manufacturers in the agricultural sector understand that there are clear advantages to the use of colour in fertilizers. These include helping growers to choose the right formulations – to maximise the benefits of fertilizer use – as well as allowing producers to build and differentiate their products and brands.

For growers there are two key reasons for using colourants in fertilizers, seed treatment and crop protection.

First, there is **indication**. This provides a visual cue showing that a particular material or item is present. It is hard, for example, to know if table salt is present in a glass of water because it forms a clear and colourless solution. (The only quick way to detect its presence would be by taste.) Whereas adding a soluble colourant first would make the presence of salt very apparent immediately, both as a solid and in aqueous salt solution.

Second, there is **identification**. This is where a colourant is used to colour-code a specific item or trait when faced with a choice of products. Vegetable farming provides a great case study. A farmer may need to match-up different fertilizer blends with the individual crops they're intended for. But, if at the height of the season they all look alike, it can be difficult to ensure the correct fertilizer blend is matched with the right crop. This can lead to costly mistakes. One easy solution to this, for example, would be to colour a tomato-specific fertilizer red and one designed for leafy vegetables green. This shows that fertilizer colourants are not simply a visually-pleasing afterthought – they can be a valuable, money-saving addition to a formulation.

21st century challenges

Fertilizer technology helped lift hundreds of millions of people around the world out of poverty by making the Green Revolution a reality in the 1960s. Similarly, innovation will continue to be crucial in this century, as we look to technology for solutions to tackle global food security and environmental challenges.

Fertilizer producers are making substantial R&D investments currently. Developing more sustainable formulations and fertilizers with low carbon footprints are two priorities. Another focus is the development of products that offer unique and advantageous properties for growers. These include special nutrient products, designed to maximise crop yields, and products containing agents that control nutrient release.

The power of colourants should not be ignored when it comes to product innovation. Having access to an unlimited number of colours can help to boldly differentiate new product offerings. Indeed, colourants, by setting products apart, can help producers to realise the margins they deserve. That is a win-win for both manufacturers and growers alike.

The potential advantages that colour can provide do not end there either. There is a growing recognition in the industry that the use of colour goes beyond its functional benefits to users. Many brands, for example, are synonymous with a specific colour. Just think of a bright orange soft drink or a deliberately multi-coloured type of candy. These colours have helped to build strong brand recognition. Colour, by offering customisation, can help to set a product apart from its competitors on the store shelf, differentiating it from the pack. Brands that recognise this potential, and get it right from the beginning, may enjoy the often significant benefits of 'first mover' advantage.

Breakthrough *Liquitint Agro* colourants

Milliken is at the forefront of colourant innovation. The company has captured recent technical and scientific advances in chemistry – to help overcome the challenges of using traditional pigments and dyes – and applied these in applications ranging from fertilizers to seed treatment and crop protection. Milliken, by learnings from other industries, such as seed, turf & ornamental, and industrial vegetation management, has translated some of their key value aspects to fertilizers.

The outcome of Milliken's research efforts has been the development of *Liquitint Agro* colourants. These next-generation liquid products are neither a traditional pigment nor a dye, but a novel technology that exhibits a number of unique benefits, particularly its non-staining nature.

For the manufacturer, *Liquitint Agro* – being a liquid product – resolves the dusting issues that occur when handling a traditional powder colourant. The non-staining behaviour of these colourants also significantly reduces both changeover times and product waste. This novel technology – in addition to delivering deep, bright colours to highlight high-quality fertilizers – provides broad blendability, high chemical stability, and easy handling. *Liquitint Agro* also offers improved shelf life, better coverage, more uniform coating and complete solubility. Formulations also address environmental concerns by avoiding the use of heavy metals.

The technology also creates greater flexibility. With *Liquitint Agro*, it is possible to blend thousands of colours from across the spectrum on demand from only three liquid primary colourants held in inventory. This flexibility supplements *Liquitint Agro*'s many other benefits, such as quick colour changes between batches, no dusting, no staining of plant equipment, and no detrimental issues for the fertilizer product itself.

Creating a brighter future

Liquitint Agro is creating new opportunities for colourants in agriculture. This is happening at a time when an increasing number of fertilizer manufacturers are looking at how colour can play a significant, and highly beneficial, role in their fertilizer formulations. Valuably, *Liquitint Agro* makes it easy to obtain bright, deep colours – highlighting the quality and breadth of product portfolios. This applies to fertilizers, seed treatment and crop protection products, greatly advancing the use of colouration in the agricultural industry. ■

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Enhanced nitrogen products

PHOTO: SOLVAY

Corn field.

Enhanced efficiency fertilizers have a definite role to play in the sustainable increases in crop production that will be required to feed a growing population. Controlled-release and stabilised urea products are capturing a greater share of the market and being applied more to broad acre crops, as Solvay's **Krish Shanmuga** explains. Asia, in particular, is showing huge potential for stabilised nitrogen fertilizers, as is Europe, where the introduction of new regulations is expected to boost demand.

Introduction

With the world's population expected to exceed nine billion by 2050, feeding everyone will require worldwide food production to increase by an estimated 70 percent over the next 30 years. Maintaining global food security in the face of population growth and limited land resources – and doing so sustainably – is one of the humankind's greatest challenges. Consequently, there is a clear agronomic, economic and environmental need for innovative technologies capable of boosting crop production while achieving this in the most sustainable way.

Nitrogen fertilizers are vital for crop production – this primary nutrient being essential for plant growth and development. This has made the application of nitrogen in large amounts common practice in agriculture.

Urea is the most widely-applied nitrogen fertilizer worldwide due to its availability and high N content (46%). The use of conventional nitrogen fertilizers such as urea, while greatly increasing crop yields, can cause environmental pollution and soil nutrient imbalances. Indeed, the overuse of nitrogen in some parts of the world damages both crops and the wider environment.

Some calculations suggest that, on average, only fifty percent of the nitrogen applied to the soil as urea is taken up by growing crops. The unused nitrogen can remain in the soil, be removed by leaching or through runoff, or be lost to the atmosphere by volatilisation. Despite improvements in agronomic practices, nitrogen use efficiency (NUE) is still unsatisfactory with the proportion of N recovered by crops generally remaining below 60 percent.

As an industry, it is our clear responsibility to develop and employ management practices that use nitrogen fertilizers both effectively and efficiently. This can be achieved by combining the 4R nutrient management principles (right source, right rate, right time, right place) with the use of modern fertilizer technologies.

Slow- and controlled-release and stabilised fertilizers (SCRSFs), also termed enhanced efficiency fertilizers (EEFs), have come under the spotlight in recent times. The adoption of these speciality products provides growers with an invaluable tool for improving NUE and reducing the negative environmental impacts associated with commodity nitrogen fertilizers such as urea.

The nitrogen loss problem

Soil applied nitrogen can be lost to the environment by a number of processes, including:

- Ammonia volatilisation
- Nitrification/nitrate leaching
- Denitrification/nitrous oxide emissions.

In volatilisation, the urease enzyme present in the soil rapidly hydrolyses urea to plant-available ammonium. If it is not incorporated into the soil, either by irrigation or rain, then a major proportion (~30%) of applied urea can be lost to the atmosphere as ammonia. The risk of nitrogen loss through volatilisation or leaching depends on weather, soil conditions, the type of fertilizer used and fertilizer application frequency.

Nitrification is the biological process in which the ammonium form of nitrogen is transformed to the nitrate form by soil bacteria. Nitrate is plant-available but also very susceptible to leaching as it is highly mobile in the soil.

Applied nitrogen can also be lost through denitrification. This microbial process biologically reduces nitrate – ultimately to molecular nitrogen (N_2) – via a series of intermediate nitrogen oxide gases. These include nitrous oxide (N_2O), a greenhouse gas with 300 times more global warming potential than carbon dioxide.

SCRSFs as the solution?

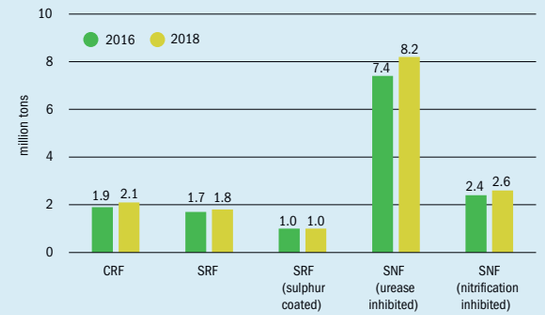
SCRSFs are able to improve NUE by delaying or controlling the release of nitrogen and inhibiting urease and nitrification reactions in the soil. This group of speciality and 'smart' products is increasingly viewed as one solution to the problem of how to reduce nitrogen losses and protect the environment. The main types of SCRSF, their mode of action and relative costs are summarised in Table 1 and described below.

Table 1: **Main types of SCRSF: mode of action, technology and cost**

Types	Mode of action	Technology	Cost in use
Slow release fertilizer (SRF)	Microbial	Urea-aldehyde	$$$$
	Physical	Sulphur coated urea (SCU)	$$
Controlled release fertilizer (CRF)	Physical	Polymer coated urea	$$$$$
Stabilised nitrogen fertilizer (SNF)	Biological	Treated with urease and nitrification inhibitors	$$

Source: Solvay

Fig. 1: **World consumption of SCRSFs: 2018 vs 2016**



Source: Rams & Co for IFA, 2019.

Slow-release fertilizers (SRFs)

SRFs supply nutrients at a much slower rate than readily-soluble fertilizers such as ammonium sulphate, ammonium nitrate or urea. For nitrogen-based SRFs, this delayed-release is achieved by chemically combining a nitrogen-source, such as urea, with an aldehyde – urea formaldehyde or urea isobutyraldehyde being two notable examples. The delayed-release mechanism generally relies on microbial/chemical action in the soil.

The pattern and duration of nutrient release in SRFs is not closely controlled because their microbial breakdown is dependent on a host factors – including the nature of the growing medium, its moisture level and temperature. The release time for SRFs is typically 2-5 months. The main markets for SRFs – similar to CRFs – are non-agricultural applications such as landscape, turf and sports fields.

Some SRFs are also sulphur coated. In sulphur coated urea (SCU), for example, the release mechanism involves the movement of water through pores or fissures in the sulphur coating. Polymer sulphur coated urea (PCSU) is another similar type of SRF in which an inner sulphur coating is encapsulated within an outer coating of polymer. Animal manures and composts are also sometimes classed as slow-release fertilizers.

Controlled-release fertilizers (CRFs)

CRFs differ fundamentally from SRFs in both their technology and mode of nutrient release. In CRFs, single- or multi-nutrient granules are coated or encapsulated to delay release. These coatings act as either a permeable or semi-permeable membrane. As their name suggests, the release of nitrogen from CRFs is 'controlled', with much greater regulation in the rate, pattern and duration of nutrient release than is possible with SRFs. Nutrient release, because it is a diffusion process, is mainly controlled by the thickness of the polymer film together with temperature. Release times of up to a year or even longer are possible. The main market for CRFs is the turf and ornamental sector.

Stabilised nitrogen fertilizers (SNFs)

SNFs typically combine urea with urease and/or nitrification inhibitors. They work by delaying the conversion of nitrogen into forms that are readily lost to the environment through leaching, denitrification and volatilisation. Urease inhibitors delay the hydrolysis of urea while nitrification inhibitors delay the biological conversion of ammonium to nitrite and nitrate. These delays allow time for rainfall to move the urea into the soil where it is less prone to volatilisation. The use of inhibitors also keeps nitrogen within the plant/soil system for longer. Broad acre crops are the major application for these stabilised nitrogen products.

Market value and volume

The value of the global SCRSF market was estimated at $4.7 billion in 2018, and looks set to grow at nine percent p.a. to exceed $10 billion by 2028. The consumption of SCRSFs reached 15.7 million tonnes in 2018, up from 14.4 million tonnes in 2016. Market growth was mainly due to the rising popularity of SNFs, particularly urea stabilised with urease inhibitors. (Figure 1).

SNFs occupy a dominant position in the SCRSF market with a market share of more than 50 percent. The nitrification inhibitor (NI) market is mainly in the US where consumption is highest in the anhydrous ammonia segment. Neem coated urea (NCU) is a large volume (~30 million t/a) but niche product that is sometimes classed outside of the SCRSF market. NCU is a product specific to India. The country's government mandated that all producers coat 100 percent of their urea output with neem oil – which acts as a nitrification inhibitor – under a regulation introduced in 2015.

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Table 2: **List of selected stabilised nitrogen fertilizer (SNF) products and producers**

Company	Product name	Technology	Uses
BASF	Limus	NBPT, NPPT	Urea/UAN
Corteva	PinnitMax	NBPT	Urea/UAN
Corteva	Instinct	Nitrapyrin	Urea/UAN
Corteva	N Serve	Nitrapyrin	Anydrous ammonia
Eurochem	ENTEC	DMPP	Urea/UAN/ ammonium fertilizer
Koch	Agrotain	NBPT	Urea/UAN
Koch	Super U	NBPT+DCD+urea	Urea
Koch	Centuro	Pronitridine	Anydrous ammonia
Koch	Anvol	Duromide	Urea/UAN
SKW Piesteritz	Alzon	DCD and 1,2,4-triazole	Urea/UAN
Solvay	AgRho N Protect	NBPT	Urea/UAN
Solvay	AgRho NH4 Protect	DCD	Urea/UAN/ anydrous ammonia
Solvay	AgRho N Dual Protect	NBPT+DCD	Urea/UAN

Key:
NBPT: N-Butyl thiophosphoric triamide (urease inhibitor) DCD: Dicyandiamide (nitrification inhibitor)
DMPP: Dimethylpyrazole phosphate (nitrification inhibitor) UAN: Urea ammonium nitrate
NPPT: N-propyl thiophosphoric triamide (urease inhibitor)
Source: Company information

Table 3: **List of selected controlled-release fertilizer (CRF) products and producers**

Company	Product name	Technology
Haifa	Multikote, CoteN	Polymer
ICL	Osmocote	Polymer
Kingenta	Ekote	Polymer
Koch	Polyon, Duration	Polymer
Nutrien	ESN	Polymer
Sumitomo Chemical	SR Coat	Polymer

Source: Company information

Table 4: **List of selected slow release fertilizer (SRF) products and producers**

Company	Product name	Technology
Compo Expert (Grupa Azoty)	Floranid	IBDU
ICL	Sierraform GT	Methylene urea
ICL	Ekote	PSCU
Kingenta	Polyon, Duration	SCU
Koch	ESN	Methylene urea
Koch	SR Coat	SCU
Koch	Nitamin/NFusion	Methylene urea+Triazone
Nutrien (Loveland)	N-Pact	Triazone
Sadepan Chimica (Italy)	Sazolene	Methylene urea
Tessenderlo kerley	N Sure	Triazone

Key:
IBDU: Isobutylidine diurea SCU: Sulphur coated urea PSCU: Polymer sulphur coated urea
Source: Company information

Market products and producers

An increasingly wide range of enhanced efficiency nitrogen products are becoming available on the global market. A selection of leading SNF, CRF and SRF products and their producers are listed in Tables 2, 3 and 4, respectively.

Market drivers and trends

Historically, large-scale commercial and innovation-driven farming has provided a ready market for speciality fertilizers.

In the SCRSF market, the main drivers of growth are the desire to increase yields, nutrient use efficiency (NUE) and profitability, alongside resource management and environmental concerns. New environmental protection legislation and regulations designed to combat climate change, as well as 4R nutrient stewardship programmes, are also supporting market growth.

Enhanced efficiency nitrogen fertilizers are used as a value-added substitute for commercial base fertilizers such as urea, anhydrous NH_3, UAN and other nitrogen fertilizers. SNFs are mostly applied in broad acre agriculture whereas CRFs and SRFs are only applied in crops where their cost premium is justified.

For SCRSFs, the value proposition, as well as sustainability benefits, can be viewed in two main ways:

- Substitution of an untreated nitrogen fertilizer with an SCRSF product at the same standard application rate to deliver a 5-15 percent yield improvement; or
- Substitution of an untreated nitrogen fertilizer with an SCRSF product at a lower application rate to obtain the same of better yield.

On the regulatory front, SNF market growth has been strongly supported by:

- China's zero fertilizer growth policy
- *RenovaBio* biofuels regulation in Brazil
- Regulations in Germany making treatment of nitrogen fertilizers with inhibitors mandatory, or requiring their incorporation into the ground.

Complex fertilizer registration processes, on the other hand, can hinder the adoption and sale of SNFs. The introduction of a new EU regulation on polymer biodegradability is also likely to limit European CRF demand in the medium-term. Several CRF producers are, however, fast-tracking the development of lower-cost biodegradable coatings to comply with the regulation.

SNFs are the fastest growing segment within the overall SCRSF market. These inhibited products are generally proving to be the most cost-effective at improving NUE currently, although their adoption varies widely from country-to-country – the degree of market penetration being partly spurred by local regulations. Although the SNF market in China is very large, somewhat paradoxically, adoption rates remain low, although this does highlight the future growth potential in the East Asia region. In contrast, the adoption and market penetration of SNFs is much higher and more long-standing in North America's large urea and anhydrous ammonia market. Elsewhere, SNF use in Brazil's urea market is large and growing, while in Europe the SNF market, although small, is growing too.

CRFs are generally more expensive, relative to SNFs and SRFs, a factor that has largely restricted their use to the high-value ornamental and turf market. Over the last 10 years, however, CRF use on conventional crops, and not just in high-end markets, has certainly increased. The success of Nutrien's ESN *Smart Nitrogen* CRF product for broad acre crops is one notable example. CRFs have also become popular in field agriculture in Japan as a way of cutting labour costs by reducing the frequency of fertilizer applications. CRFs are also being tested on palm oil (Indonesia) and sugar cane (Australia and Brazil) currently.

In general, SRFs show low or limited potential for greater market access due to their inability to compete on cost and performance. Nevertheless, SRF/SCU use is particularly high in China, with East Asia accounting for nearly 90 percent of total global demand. Applications are largely non-agricultural, such as landscape, horticulture, and sports fields. But SRFs are used for rice growing in East China, an agricultural market with potential for higher penetration. In developed countries, product sales to golf courses and for turf are the main SRF markets.

Conclusion

In future, slow- and controlled-release and stabilised fertilizers will have a role to play in the sustainable increases in crop production that are going to be required to feed a growing population. Modern technologies such as SCRSFs, used alongside 4R management practices, can improve the use-efficiency of nitrogen fertilizers and reduce their negative environmental impacts.

In particular, there is a huge potential for stabilised nitrogen fertilizers in Asia – where urea usage is high – as well as in Europe, where the introduction of new regulations is expected to boost demand. For controlled-release fertilizers, the next step is likely to be the development of cost-efficient and biodegradable polymer coatings. The market growth potential of SRFs is constrained by their high cost and a corresponding lack of competitiveness – although more uptake by rice growers in Asian countries is expected.

Further development of SCRSFs could have a significant impact on sustainable agriculture over the longer-term. There is room in the market to develop the next wave of niche products, although lower crop prices are holding back development. But adoption does take time with proof of concept being key.

Finally, it needs to be recognised that one size does not fit all. That makes matching the right enhanced efficiency nitrogen product with the correct application of paramount importance. ■

SPECIALITY FERTILIZERS

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Improving nutrient use efficiency

More of the nutrients applied to soil will need to be taken up by crops, rather than being lost to the environment, if we are to produce more food from the same area of land in future. New controlled-release fertilizers (CRFs) suitable for broad-acre agriculture show great potential for improving crop yields and improving farm economics while minimising nutrient losses. **Harold van der Zande**, business development manager at Stamicarbon, explains how 'smart' fertilizers such as CRFs can bring about a step-change in nutrient use efficiency.

The food challenge

We need to produce much more food. That is the stark challenge facing world agriculture as we move towards 2050 with a global population approaching 10 billion inhabitants. The future food challenge is a dual one too. It involves satisfying both growing demand for *more* food and growing demand for *better quality* food – that includes an ever greater appetite for meat and dairy products as we become more prosperous.

To grow these extra crops, existing acreages will need to be used much more efficiently in future – if we are to avoid the large-scale release of greenhouse gas emissions that will result from major forest clearances needed for agricultural land expansions.

On average, fertilizers typically have a nutrient use efficiency of less than 50 percent at present, with more than half of nutrients applied to soil ending up being lost to the environment. Therefore producing more food per hectare, based on current agricultural practices, would undoubtedly require a strong rise in fertilizer use. However, such rises are unlikely to be justifiable or sustainable if they further jeopardise the existing fragile environmental balance.

Nutrient losses associated with fertilizer use have already reached critically high levels at a number of places around the world. As a consequence, we are currently witnessing grave environmental problems such as dead zones in the Gulf of Mexico and Chesapeake Bay, serious algal pollution at the Great Lakes, and widespread surface water eutrophication in China, to name just a few regrettable examples.

At the same time, in response to these negative impacts, environmentalists are lobbying for greater regulatory control and reductions in fertilizer use. Authorities in places such as Florida and New Zealand, faced by these pressures and environmental sensitivities, have been forced to take action against fertilizer and manure use.

Overall, this raises one key question: how can the fertilizer industry rise to the future food challenge while simultaneously reducing the environmental impacts associated with fertilizer use? In this article, Stamicarbon and Pursell Agri-Tech argue that increasing the nutrient use efficiency of fertilizers helps address both these problems.

Stamicarbon, the innovation and license company of Maire Tecnimont Group, and their US partner Pursell Agri-Tech are committed to developing fertilizer systems which can support the required shift to greater nutrient use efficiency. We elaborate on how this might be achieved below.

Technology holds the key

Potential solutions to the problem of how to reduce rising environmental pressures associated with increased food demand were presented in a recent *Nature* paper. This suggested that technology change has the largest potential to reduce environmental pressures. A dietary shift towards less meat and dairy, and food waste reduction (one third of all food is wasted before it is consumed), could also be effective measures.

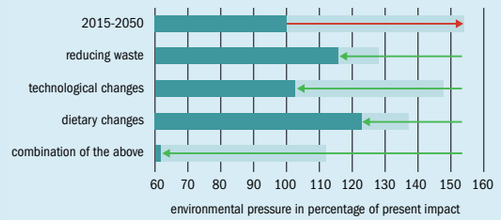
Business as usual is certainly not an option. The *Nature* article suggests that, if policies were left unchanged and eating behaviour went unchecked, pressures on the environment would inexorably increase by more than 50 percent by 2050 in order to satisfy rising food demand. More positively, it should be possible to maintain environmental pressure at today's levels, if effective technologies were fully implemented. Indeed, if all three promising measures were successfully introduced, including technological change, dietary change and food waste reduction, there is potential to actually reduce environmental pressures by 60 percent by 2050, relative to the present day (Figure 1).

Controlled-release fertilizers (CRFs)

In recent decades, optimising how fertilizers are applied to soil has been at the heart of efforts by the fertilizer industry to help their customers – farmers – use fertilizers more sustainably. The focus has been on a four-part message:

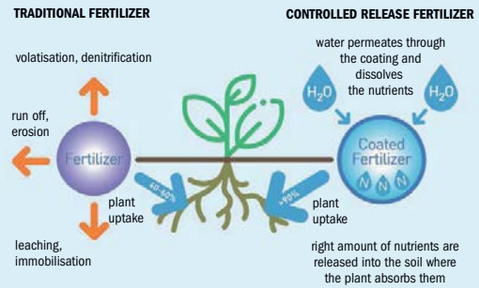
- The right timing of fertilizer applications
- at the right amount, based on results from soil testing
- with the right type of fertilizer, containing required nutrients in the correct quantities
- using the right equipment to ensure fertilizers are properly placed and applied.

Fig. 1: **Increase in environmental pressures associated with food demand, 2015-2050 (top column) and three measures (other columns) with greatest potential to reduce these**



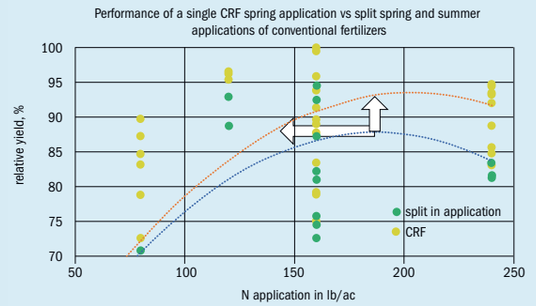
Source: Nature/Stamicarbon

Fig. 2: **Comparison between traditional and controlled-release fertilizers (CRFs)**



Source: Stamicarbon

Fig. 3: **US corn trials, 2017-2018**



Source: Stamicarbon

This effective and easily communicable approach, known as the 4R principles (right source, right rate, right time, and right place), can be summed up as the 'smart use of fertilizers'. Although it has been successfully taken up by many farmers globally, the roll-out of 4R fertilizer management has to date only partly improved nutrient use efficiency, leaving significant potential for further improvement.

Another approach to nutrient use efficiency, one that has arguably received far less attention than the 4Rs, is 'the use of smart fertilizers'. These 'smart' products are able to supply plant nutrients in-sync with crop demand, with a single application being able to match nutrient demand over the whole of the growing season, unlike conventional fertilizers which typically need to be applied several times.

Typically, the high solubility of conventional fertilizers means that the nutrients provided dissolve quickly in the soil and are only available to the plant for a short time after their application. Controlled-release fertilizers (CRFs), in contrast, offer the timed release of nutrients, in-sync with the continuous crop demand for these, during the whole growing season (Figure 2). CRFs are one of just a few types of 'smart' fertilizer currently available on the market.

Although CRF technology is not new, products suitable for mass application in broad-acre agriculture have only recently become available. The full potential of CRFs is only starting to be recognised too.

The World Economic Forum, for example, in its 2019 report on *Top 10 Emerging Technologies*, states:

"Controlled-release fertilizers are part of a sustainable approach to agriculture known as precision farming. This approach improves crop yield and minimizes excessive nutrient release by combining data analytics, AI and various sensor systems to determine exactly how much fertilizer and water plants need at any given time and by deploying autonomous vehicles to deliver nutrients in prescribed amounts and locations."

Better farm economics

Improving environmental protection and increasing food production are both vital and necessary objectives for world agriculture. But, for individual farms and farmers, financial returns usually provide the best incentive when it comes to changing fertilizer purchasing and application decisions.

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PHOTO: PURSELL AGRI-TECH

Fig. 4: Pursell Agri-Tech's Sylacauga CRF demonstration plant.

Numerous field studies over the last decade have compared the performance of controlled-release fertilizers with conventional split-application fertilizers. A statistical analysis of these results should help us better understand the performance of these 'smart' fertilizers.

The analysis shown in Figure 3 is based on US field trials with corn in 2017 and 2018. It compares a single spring application of a controlled-release fertilizer (CRF) to split applications with conventional fertilizers in spring and early summer. For each individual test site and test year, the highest yield obtained is recorded as 100 percent and used as a yardstick. All other results were then measured against this maximum reference point.

Although not every crop yield result for CRFs is higher than the corresponding yield result for a split application with conventional fertilizers, the statistical analysis does reveal a clear and unambiguous trend: CRFs in general offer a steady yield improvement over conventional split applications (Figure 3). Results also confirm that nutrient use efficiency improves with CRFs resulting in higher yields, or lower application rates, due to a reduction in volatility and leaching losses.

Based on the above field trial results, the following observations on cost have been made for a single CRF application versus split applications of conventional fertilizers, assuming $400/t for the urea price and $4/bushel for the corn price:

- **At similar application rates:** the 6-7 percent yield improvement achieved means CRFs are still cost competitive with conventional fertilizers even when sold at a premium of more than $200/t.
- **At 25 percent lower application rates:** the similar yield achieved by a lower amount of CRF allows for a price premium of $130/t.

The above calculations are conservative estimates as they do not include additional savings to the farmer such as the fuel saved from the single application of CRFs. In general, the business case for CRFs is always positive, providing a sound financial incentive for their increased adoption and use. We estimate that, for broad-acre agriculture in North America, targeting a $100/t price premium over urea for CRFs provide significant financial incentives for farmers to switch from commodity to coated fertilizers.

A complete production package

Stamicarbon in cooperation with Pursell Agri-Tech is offering a complete package for controlled-release fertilizer production – one that is based on a novel coating technology exclusively developed for this purpose. This production package, based on a batch coating process in a high intensity mixer, is able to encapsulate a wide variety of different fertilizer products with a new kind of polymer coating. This coats fertilizer granules within an extremely thin and durable membrane. The controlled release of nutrients can be adjusted over a time span of between one and 12 months, depending on the weight of the applied coating.

The novel polymer used in the production process is exclusively supplied by a major global polymer producer. The equipment manufacturer, also working in exclusive cooperation, is able to supply customers with a complete production installation on a lump sum, turn key basis.

The guarantees provided by these exclusive arrangements eliminate the investment risk in new plant capacity, and provide a solid foundation for a major expansion in controlled-release fertilizer production. This production package makes it possible for fertilizer producers, importers and distributors to access CRF production technology and manufacture products for their domestic customers. The production units are designed to be located close to the end-user (farmers) so as to avoid the unnecessary handling of the coated product.

The first CRF demonstration plant, operated by Pursell Agri-Tech in Sylacauga, Alabama (Figure 4), has been performing successfully since spring 2018. The plant is currently running 24 hours a day, in five days a week operation, providing just under 100,000 t/a of coated product capacity. The current coating line can coat nearly all fertilizer grades, including granular and prilled urea, DAP, MAP, NPK, etc.

New EU regulations

The new European Fertilizer Regulation, a replacement for the previous 2003 regulation, will require all fertilizer polymer coatings to be biodegradable in the near future. The regulation requires 90 percent polymer degradation within 48 months after the fertilizer is applied. The regulation comes with a transition period of 3-4 years, after which all products on the market will have to comply.

However, the test method for compliance with the new biodegradation requirements has yet to be defined, although it will need to be decided on within the next five years. Fulfilling the normal requirements of a controlled-release coating, while at the same time satisfying the EU's conditions for soil and water biodegradability, will be quite a challenge for CRF producers. Nevertheless, Pursell Agri-Tech in partnership with Stamicarbon are actively developing innovative yet practical biodegradable coating solutions for the European CRF market. ■

Kingenta researchers performing crop trials.

PHOTO: KINGENTA

Kingenta, the global innovator

We profile Kingenta Ecological Engineering Group, China's leading compound and speciality fertilizer producer. With its growing international presence, ambitious retail expansion and commitment to innovation and sustainability, Kingenta is helping reinvent fertilizer manufacturing for the 21st century.

Fig. 1: **Location of Kingenta's domestic operations**

Source: Kingenta

Kingenta has grown exponentially from relatively modest beginnings in just over two decades (see box). Founded in 1998, the company first entered the Chinese fertilizer market with the start-up of a single 50,000 tonne capacity fertilizer production line.

Today, the company is truly international, with a diverse mix of domestic and international assets, having emerged as world leader in the speciality fertilizer market and an innovative champion of climate-smart agriculture. Shenzhen Stock Exchange listed with a current market capitalisation of about CNY 10.5 billion ($1.5 billion, mid-August 2019), Kingenta is also pursuing an aggressive retail-led expansion in its domestic market via its Kingfarm chain of farm stores.

Its annual fertilizer production capacity has also expanded to exceed seven million tonnes. This manufacturing might underpins Kingenta's diverse product portfolio. The company has the ability to offer 100 plus product types including compound NPK fertilizers, slow- and controlled-release fertilizers (SCRFs), water-soluble fertilizers (WSFs) and bio-fertilizers. These wide-ranging speciality products are sold into an equally diverse range of agricultural and horticultural end-markets, both within China and increasingly overseas.

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KINGENTA: COMPANY MILESTONES

1998-2005

EARLY YEARS

- **Started-up in 1998 with a 50,000 t/a capacity fertilizer production line.**
- **This was followed in 2003 by the start-up of 100,000 t/a SOP-based NPK production line.**
- **The company also developed a CRF patent during this period in cooperation with Shandong AG University.**

2006-2014

PRODUCT DEVELOPMENT

- **Start-up of the first SCRF production line in 2006.**
- **DEG invested $20M in 2007**
- **National SCRF standard, drafted by Kingenta, implemented in 2009.**
- **Company goes public on Shenzhen Stock Exchange in 2010.**
- **Start-up of 600,000 t/a capacity CRF production line.**

2015-2019

EXPANSION

- **Nongshang No.1 launched in 2015.**
- **Acquired Navasa S.A., Compo GmbH and Ekompany International B.V. in 2016.**
- **German-based DeltaChem GmbH founded in 2016/17.**
- **Established Kingfarm as a modern retail platform in 2017.**
- **Qintu No.1 launched with a focus on soil improvement.**

KINGENTA IN NUMBERS

15.5 billion CNY
in revenues (2018)

570 million CNY
of research investment

7.1 million tonnes
of fertilizer production capacity

5.4 million tonnes
fertilizer sales (2018)

9,110
employees

726
researchers & agronomists

196
patents

2
science & technology awards

100+
types of fertilizer products in 12 categories

49
partnerships with universities and institutes

16
domestic factories

Enhanced efficiency fertilizer giant

Kingenta has the world's largest slow- and controlled-release fertilizer (SCRF) production base. It has also been instrumental in drafting national standards for SCRF products in China.

Kingenta operates 16 domestic fertilizer production sites distributed across Shandong, Guangdong, Guizhou, Henan, Liaoning and Yunnan provinces (Figure 1). These are supplemented by overseas operations in the United States, Norway, Israel, Germany, Vietnam and Spain etc. The company combines operating assets worth more than CNY 11 billion with a staff compliment of almost 10,000 employees, and an annual production capacity of 7.1 million tonnes (see box).

Kingenta went public in 2010 with a Shenzhen Stock Exchange listing. In 2016, sales revenues and pre-tax profits reached CNY 18.7 billion and CNY 1.0 billion, respectively. The group's revenues subsequently grew by more than 10 percent year-on-year to CNY 20.8 billion in 2017. Revenues fell back to CNY 15.4 billion last year although earnings remained healthy at CNY 1.1 billion.

Retail expansion

Kingenta is setting up hundreds of new retail service centres across China over the next five years as part of a $1 billion project. The new centres, which go under the name **Kingfarm Cooperative**, are promoting efficient fertilizer usage and climate-smart agriculture. The project's overall aim is to increase crop yields and boost the income of millions of Chinese farmers.

Kingenta's retail expansion is co-funded by the International Finance Corporation (IFC), part of World Bank Group. Kingenta secured $200 million in finance from the Corporation in July 2018.

IFC's finance package includes $70 million in equity, $75 million as a senior loan and $55 million from IFC's managed co-financing portfolio. IFC also mobilised a further $80 million in finance from other multilateral lenders.

Kingenta and IFC have set-up and funded a new joint venture company, Kingfarm Agricultural Services Co Ltd, as part of their new partnership. Kingfarm controls and operates several individual projects in China, including:

- **Service centres:** this project involves converting about 300 existing Kingenta distribution centres in rural farming areas into Kingfarm one-stop retail farm shops.
- **Upgrade plants:** this project is carrying out upgrades and constructing new lines at 20 production sites to convert their output from commodity to speciality fertilizers. New manufacturing processes will include mixing, formulation, and granulation and the storage of final products in warehouses.

Both projects are being developed over a three-year period, according to IFC.

The new Kingfarm centres are providing Chinese farmers with access to training, enhanced efficiency fertilizer (EEF) products and other high-quality inputs. The availability of EEFs to Chinese farmers could increase crop yields by as much as 10-40 percent, compared to conventional commodity fertilizers, suggests IFC, delivering higher farm productivity while also reducing environmental impacts.

Kingenta's ambitious retail expansion is targeting crop productivity across 3.8 million hectares of land farmed by three million farming families. The resulting shift to climate-smart agriculture and appropriate fertilizer use could deliver a carbon saving of 377,000 tonnes (CO_2 equivalent) each year.

Wider adoption of speciality fertilizers such as EEFs should also reduce the oversupply of nutrients to soil and help prevent water pollution. Such fertilizers represent only about 30 percent of the annual fertilizer usage in China currently, compared with 50-60 percent in other large food-producing countries, such as Brazil and Thailand. The phase-out of less efficient commodity fertilizers – which are often applied to land in unnecessarily large quantities – is being encouraged in China as part of the government's strategy to reduce pollution and mitigate climate change.

Kingfarm Cooperative's chairman, Li Jiguo said: "Kingfarm Cooperative – as China's first modern agricultural service platform as well as a group dedicated to farmers – is committed to building an integrated agricultural value chain. We will consolidate resources and different channels in order to deliver comprehensive services for 50 million farmers in China."

Sérgio Pimenta, IFC's director for manufacturing, agribusiness, and services, said: "Kingenta's innovative distribution strategy offers a sustainable solution to increasing farm productivity and encouraging the adoption of climate-smart farming techniques and technology."

PHOTO: KINGENTA

Kingenta's impressive national research centre.

International expansion

Kingenta has expanded internationally over the last five years through a number of astute strategic acquisitions and partnerships overseas.

2016 was a landmark year that saw Kingenta embark on a flurry of significant European company purchases. The year began with the acquisition of Netherland-based **EKompany** International in January 2016. Ekompany is the developer and producer of the leading *Ekote* controlled release fertilizer (CRF) product range.

This was followed in April by the purchase of Germany's **Compo**, a European market leader in the consumer gardening product market with strengths in lawn and plant care products, potting soils and garden fertilizers. This acquisition subsequently led to the launch of Compo China in Weng'an, Guizhou, by a joint Chinese-German team in 2018.

Spain's **Navasa** was purchased in September 2016. The company, originally founded in 1961, specialises in the supply of automatic fertigation equipment and liquid fertilizers for intensive agriculture and is based in the Almeria region of southern Spain.

Research and development

Mention Kingenta to anyone in the fertilizer industry and the first thing they usually mention is the company's impressive commitment to research and the development of new products.

The company's international R&D centre, led by Dr Li Xinzhu, has a 500-strong staff complement, this including a 'brains trust' of 220 expert collaborators from around the world. Kingenta's main R&D themes are:

- Improving fertilizer and nutrient use efficiency
- Soil amendments
- Improving crop growth and resistance
- Promoting crop quality
- Crop protection.

Four Kingenta centres outside of China, in the US, Europe, Israel and Japan, are also engaged in R&D. The wide-ranging priorities of the United States R&D centre, embedded at **Fer-land** Agriculture Technology Corporation in Los Angeles, California, include:

- Microbial fertilizers
- Controlled-release fertilizers
- Soil amendments
- Bio-control products
- Biostimulants
- Advanced fertilization technology.

The **Compo**-run European centre in Munster, Germany, has a similarly ambitious R&D programme:

- Stabilised fertilizers
- Controlled-release fertilizers
- Biostimulants
- Specialty fertilizers
- Bio-control products
- Crop freshness technology.

While the under-construction **KLAD** R&D centre in Israel will pursue new opportunities in:

- Fertigation technology
- Drip irrigation products
- Biostimulants
- Precision fertilization technology

Lastly, the Japanese R&D centre in Hokkaido is directing its attention at:

- Organic agriculture
- High-quality agriculture
- Precision agriculture

New products

Bringing to market new products that improve nutrient use efficiency is one of Kingenta's major R&D priorities, particularly the development of novel and innovative controlled-release fertilizers (CRFs) and stabilised fertilizers (SFs).

A new line of **enhanced efficiency CRF products** incorporate organic components – fulvic acid (FA) and the water-soluble polymer polyaspartic acid (PASP) – into urea, diammonium phosphate (DAP) and NPK fertilizers, alongside inorganic micronutrients (EDTA-chelated zinc and copper).

New **advanced soil technology (AST)** combines a range of active constituents such as biostimulants, phosphatase, nitrogen and phosphorus activators with urea phosphate. The resulting AST products can increase the phosphorus utilisation rate in soil by more than 20 percent and prolong the period of nitrogen release by 20-30 days, compared to conventional fertilizers.

New **enhanced efficiency SF products** are also under development. These encapsulate urea, DAP and NPK fertilizers within an outer coating that incorporates both nitrification and urease inhibitors. Kingenta is also bringing new biostimulant products (fulvic acid and chitosan) to market. ■

COMPANY PROFILE

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Maize crop in Siaya Kenya, 9 weeks after planting (2018 Shell Thiogro Urea-ES/Special-S Field Trial).

PHOTO: INTERNATIONAL PLANT NUTRITION INSTITUTE

Enhancing urea with sulphur

Shell Thiogro Technologies are changing the way the fertilizer industry thinks about elemental sulphur, as agronomist **Dr Kent Martin** explains. Two innovative technologies from the company, *Urea-ES* and *Special-S*, are helping fertilizer producers diversify their product portfolios. Both products provide farmers with a flexible source of sulphur fertilizer and are well-suited to a wide variety of growing conditions and crop requirements.

More from less

The fertilizer industry is responding to the sustainable intensification of agriculture, and the need to get more from less in particular. Greater awareness of the need for nutrient stewardship, plus the rise of precision agriculture, are changing how farmers around the globe choose and think about their fertilizer inputs. With an increasingly competitive operating environment, leading fertilizer producers are also recognising that having a diverse product portfolio is no longer just a luxury but instead is becoming essential for their future relevance and success.

By combining elemental sulphur with nitrogen, Shell Thiogro's latest suite of technologies enables fertilizer producers around the world to offer farmers a flexible source of sulphur – one that can be applied at the right rate and is well-suited to a wide variety of soils, growing conditions and crop requirements.

Shell Thiogro technologies

Having successfully commercialised and patented sulphur technology for ammoniated phosphates in the early 2000s, Shell began to develop new processes able to incorporate elemental sulphur in urea-based fertilizers. Urea is an excellent carrier for sulphur and – as the world's most widely-applied fertilizer – has the potential to offer many more growers access to much-needed sulphur.

Shell's efforts culminated in the introduction of *Urea-ES* to the market in 2016. This innovative Thiogro technology suspends 7-20 percent elemental sulphur in a urea matrix with a nitrogen content of 43-37 percent. Shell subsequently introduced *Special-S* shortly afterwards in 2017. This technology produces a high sulphur product that is co-granulated with urea (11-0-0-75ES).

Sulphur: the fourth crop nutrient

Alongside nitrogen, phosphorus, potassium, magnesium and calcium, sulphur is one of the six major nutrients considered essential for plant growth. Indeed, sulphur – complementing nitrogen, phosphorus and potassium – has been called 'the fourth crop nutrient'.

Most crops require an application of 15 to 30 kilograms of sulphur per hectare. Some crops, such as oilseed rape (canola) require even more.

Sulphur is one of the main building blocks of two amino acids, cysteine and methionine. As such, sulphur contributes to several critical aspects of plant development including:

- Protein, enzyme and chlorophyll synthesis
- Oil content in seeds
- Nutritional quality of forages.

Unsurprisingly, therefore, soil sulphur deficiency can result in sub-optimal crop yields and poor crop quality. Sulphur-deficient crops are typically characterised by lower quality protein, lower oil and protein content, and lower nutritional quality, for example.

Today, many soils across the globe are becoming increasingly sulphur-deficient. It is also estimated that only half of the sulphur requirement of crops is currently being met through sulphur fertilizer applications. This leaves significant soil deficits and unmet demand for sulphur that still needs to be addressed. It is also anticipated that soil sulphur deficits will continue to grow due to the following factors:

- Cleaner low-sulphur fuels resulting in less atmospheric deposition
- Prevalence of high-analysis fertilizers with much lower sulphur contents than their lower-analysis predecessors such as single superphosphate (SSP)
- Higher yielding crop varieties removing more and more sulphur from soils.

In many parts of the world, therefore, fertilizer producers will need to offer sulphur-enriched products as part of their portfolios – in order to address growing soil deficiencies and truly enable farmers to maximise crop yields.

Traditional sulphur sources

Two main types of sulphur fertilizer are currently available and applied to combat soil sulphur deficiency: (1) sulphate-based fertilizers and (2) fertilizers that incorporate elemental sulphur. Both types have contrasting benefits and drawbacks.

Advantageously, sulphate-based products – because sulphate is plant-available – offer crops an immediate supply of sulphur early in the growing season. However, sulphate is also highly mobile in soils, due to its water solubility, making it susceptible to leaching in coarse-textured (sandy) soils and/or during high rainfall and under irrigated conditions. Because of these characteristics, sulphate-based fertilizers may only offer a short-lived supply of sulphur and may no longer be available by the end of the growing season.

Elemental sulphur, on the other hand, is not immediately available for plant uptake, as it needs to be oxidised by soil bacteria into sulphate to become plant-available. However, this does have the advantage of offering a slower and longer pattern of sulphur release. Also, because elemental sulphur is not water-soluble, it is not leached away under wet conditions and therefore continues to release sulphur to plants during the entire growing season.

However, the historical challenge with elemental sulphur has been trying to ensure that the sulphur applied becomes available when crops actually need it. To compensate for its slower release behaviour, fall application and/or over application are commonly practiced with elemental sulphur sources. Practices such as over application, while an effective mitigation strategy that ensures nutrient availability, do typically incur additional costs. The oxidation rate of elemental sulphur can also be increased by grinding it into a very fine dust. However, this has its own drawbacks as tiny sulphur particles readily develop an electrostatic charge, potentially creating explosion and safety risks.

Improving elemental sulphur availability

Technology holds the key to improving the plant availability of elemental sulphur. The particle size of elemental sulphur has a direct impact on the rate of oxidation, with smaller particles oxidising into sulphate faster than larger particles due to their higher surface area (Table 1).

Both *Urea-ES* and *Special-S* include Shell Thiogro's patented micronisation process for elemental sulphur. This process produces elemental sulphur particles with an average size of around 30 microns. This significantly improves the oxidation rate of the elemental sulphur in products produced using Thiogro technology versus traditional elemental sulphur sources whose particle size is typically >100 microns at minimum.

The unique technology used to produce these products translates into better field performance. The sulphur particles in products produced using Thiogro technology have a range of sizes, with some smaller and some larger than the 30 micron average. This broad size distribution is valuable as some particles will oxidise faster than others in the soil. This allows sulphur to gradually becomes plant-available over time, mirroring and mimicking the uptake requirements of crops. Products produced with Thiogro technology are therefore able to combine some of the near-term availability of sulphate-based products – without the substantial leaching losses – with longer-term sulphur availability throughout the crop cycle.

Table 1: **Impact of sulphur particle size on oxidation rates**

Particle size	% S oxidised	
(microns)	2 weeks	4 weeks
>2,000	1	2
840-2,000	2	5
420-840	5	14
180-420	15	36
125-180	36	68
90-125	61	81
60	80	82

Source: canola.okstate.edu

Shell wanted to improve its understanding and fully demonstrate the effects of elemental sulphur micronization on both sulphur availability and crop yields. The company therefore commissioned more than 50 agronomic field trials across North America, Latin America and Africa over a several year period.

In these trials, average crop yields with *Urea-ES* and *Special-S* were equal to or greater than ammonium sulphate yields and consistently higher than sulphur-bentonite yields. Overall, the results demonstrated that both *Urea-ES* and *Special-S* are commercially-competitive as an agronomic source of sulphur for crops (see Figures 1 and 2). Importantly, the reduced risk of sulphate losses partly contributed to the greater yields achieved by Thiogro produced products in several trial results.

Higher nutrient content equals lower logistic costs

In addition to the agronomic benefits of its elemental sulphur products, these co-granulated fertilizers typically contain more nutrients than the traditional sulphur product alternatives. The 86 percent nutrient content of *Special-S* (11-0-0-75ES), for example, compares to the 45 percent nutrient content of ammonium sulphate (21-0-0-24S). Growers choosing to meet

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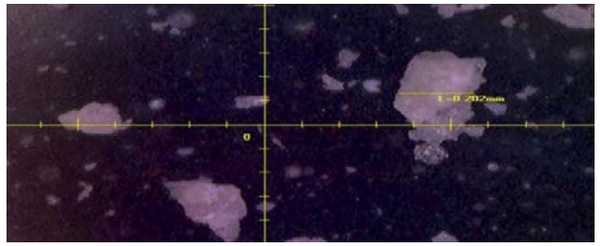


PHOTO: SHELL

Digital microscope image of sulphur bentonite (0-0-0-90ES) showing particle size of >100 microns.

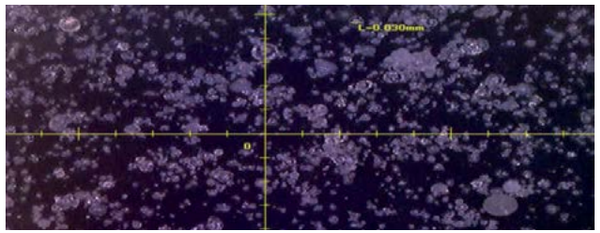
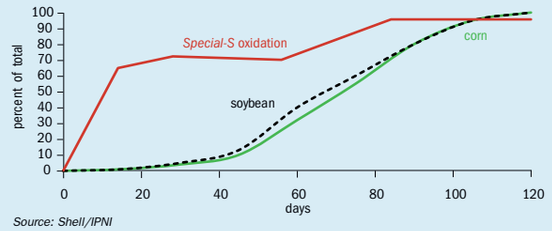


PHOTO: SHELL

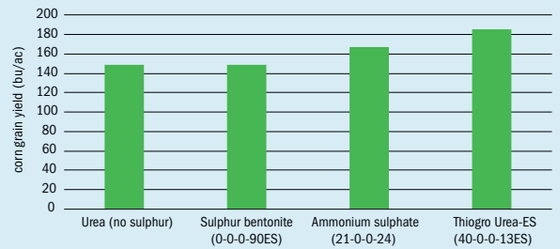
Digital microscope image of Special-S (11-0-0-75ES) showing average particle size of 30 microns.

Fig. 1: ***Special-S*: sulphur oxidation and sulphur crop uptake versus time**



Source: Shell/IPNI

Fig. 2: **2018 corn yield trial results for an irrigated field in Missouri: *Urea-ES* versus other products**



Source: Shell

their sulphur requirements using *Special-S* will still be able to apply less finished product (kg/ha), even when taking into account additional nitrogen requirements. Higher nutrient content equates to lower application rates, also providing the farmer with an application cost saving. Efficiency gains at farm level, from using less product to achieve the same results, will also translate into savings further up the supply chain as a result of lower product shipment and storage costs.

Technology partnerships

Shell has successfully collaborated with both thyssenkrupp and IPCO, leading industry providers of fluid bed granulation and the *Rotoform* fertilizer finishing process. These partnerships have ensured that *Urea-ES* and *Special-S* technologies are accessible to a wide range of fertilizer producers looking to diversify their product portfolios with high-performing and nutrient-dense sulphur-enhanced fertilizers.

tkFT fluid bed granulation

Shell and tkFT (thyssenkrupp Fertilizer Technology GmbH) began collaborating on the fluid bed granulation of *Urea-ES* in 2015. Two teams from both companies worked together to determine the modifications required to incorporate *Urea-ES* technology into the fluid bed granulation process. Ultimately, only limited modifications were necessary, due to the flexibility of the fluid bed granulation process, requiring the installation of just a few pieces of equipment, including:

- *ThioMill* sulphur dispersion unit
- *ThioAdd* feed additive system
- Small recycle evaporation
- Upstream sulphur feed system.

Once the initial design work was finalised, the teams switched their attention to modifications to tkFT's pilot plant in Leuna, Germany, enabling it to produce granular sulphur-enhanced urea products. These efforts ultimately resulted in a successful pilot plant trial in February 2016. Several formulations of sulphur-enhanced urea were produced (pictured) during subsequent plant runs. Valuably, the completed test runs generated more than five tonnes of products for agronomic testing.

The *Urea-ES* granules obtained have the same or better physical properties as standard urea granules in terms of:

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PHOTO: TKFT

Thiogro Urea-ES installation at tkFT pilot plant in Dortmund Germany.

- Size distribution (equal)
- Hardness (higher)
- Bulk density (higher)
- Storage (equal)
- Dust abrasion (lower).

These properties allow *Urea-ES* granules to be transported, stored and applied in exactly the same way as standard urea granules. If required, the *Urea-ES* granules also can be produced with a proprietary formaldehyde-free granulation additive offered by tkFT.

The fluid bed granulation process developed by Shell and tkFT is suitable for producing different grades of *Urea-ES* with an elemental sulphur content in the 7-20 percent range. The technology is well-suited to urea producers who have access to sulphur and would like to expand their product offering and optimise their production assets (*Nitrogen+Syngas* 358, p48).

IPCO *Rotoform* technology

IPCO and Shell Thiogro joined forces in 2016, building on many years of combined sulphur solidification experience. The aim was to integrate Shell's unique and innovative *Urea-ES* and *Special-S* products with IPCO's versatile *Rotoform* fertilizer finishing technology. This concept was successfully demonstrated during a series of continuous plant trials at IPCO's productivity centre in Fellbach, Germany. The trials confirmed that it was possible to produce granules (pastilles) of *Special-S* using IPCO's *Rotoform* process. These uniform-sized pastilles contain a large proportion (up to 75 percent) of finely-dispersed elemental sulphur in a urea matrix.

The pastilles are produced by an IPCO *Rotoform* unit from a homogeneous molten urea/sulphur emulsion feed. The *Rotoform* unit deposits the emulsion as 2-4 mm diameter droplets across the width of a steel belt cooler. Cooling water is sprayed onto the underside of this moving solid steel belt. This is highly effective at absorbing heat while also ensuring that no cross-contamination occurs between the product and cooling water. The liquid droplets eventually solidify into pastilles as they are conveyed along the steel belt. The final solid product is collected at the end of the belt and then sent to the downstream handling system – conveying, storage silo, bagging, etc.

H Sulphur Corp, one of Asia's leading sulphur suppliers and sulphur-bentonite producers, has licensed *Special-S* technology and commissioned the first ever production facility in South Korea in February. In doing so, the company has fully realised the powerful potential of Shell Thiogro technology, both in terms of expanding its customer offering and limiting its exposure to commodity-based products.

PHOTO: TKFT

Urea-ES produced at tkFT pilot plant.

H Sulphur has already begun manufacturing and selling *Special-S* under its own *Super S* brand name. This product has been successfully sold and shipped to customers in Canada and Australia and Brazil, where it is being applied by farmers this season. ■

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PHOTO: H SULPHUR

PHOTO: H SULPHUR

Shell Thiogro and H Sulphur Team at newly commissioned Special-S plant in Ulsan, South Korea.

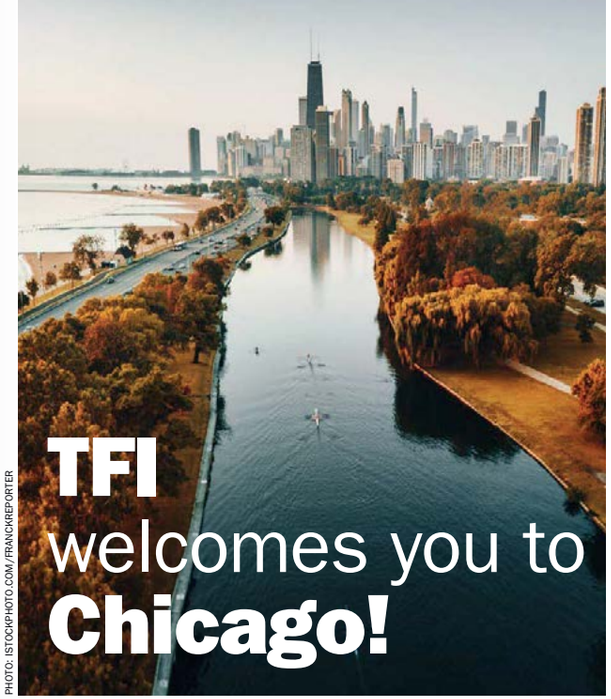

PHOTO: ISTOCKPHOTO.COM/FRANCKREPORTER

TFI welcomes you to Chicago!

PHOTO: HYATT.COM

The Hyatt Regency, Chicago, Illinois, is the venue for The Fertilizer Institute's 2019 World Fertilizer Conference, 23-25 September.

Main image: The Chicago skyline in the Autumn. Above: The Hyatt Regency, Chicago at night.

The Fertilizer Institute (TFI) is hosting this year's World Fertilizer Conference at the Hyatt Regency in Chicago. The late-September event is TFI's largest meeting of the year. Although US-based, the conference is truly global, bringing together around 700 industry delegates from 60 countries.

The opportunities for networking and conducting business has long made the World Fertilizer Conference a key date on the industry's annual calendar. The three-day event and exhibition opens for registration on Monday 23rd September. This year's conference then formally begins with a welcome reception on the Monday evening.

From the Green New Deal to climate change

Speakers at this year's conference will be exploring the theme of disruption in the fertilizer industry – covering a range of subjects from the impact of the Green New Deal to the risks of climate change. The organisers hope this highly topical theme will provoke lively discussions between those attending. The event's popular networking lounge will be open from the Monday through to Wednesday, and provides valuable extra space for business meetings, networking, or simply a coffee break.

Breakfast speakers

In keeping with conference tradition, delegates will hear from two distinguished and entertaining business speakers during breakfast sessions on Tuesday 24th and Wednesday 25th September. Speaking this year are **Kate Rebernak**, the founder of leading consultancy Framework LLC, and **David Oppedahl**, a senior business economist at the Federal Reserve Bank of Chicago.

In Tuesday morning's breakfast session, Kate Rebernak will tell delegates about how to thrive in a changing business climate. Kate has been advising companies her entire professional life. She was previously a highly successful commercial-litigation attorney before going on to found Framework LLC in 2003. Kate leads the firm's consulting work, advising clients on integrating environmental, social, and governance (ESG) issues into their corporate strategies and operations. Her impressive client list includes The Coca-Cola Company, The Hershey Company, NVIDIA, Symantec, and the Global Compact Network. Kate currently serves on the board of directors of Cornerstone Capital. She has been published in Ethical Corporation, Green Biz and Triple Pundit. Framework LLC is also regularly cited by the Harvard Business School, Forbes, and Bloomberg.

David Oppedahl will speak about the current financial state of US farming at Wednesday's closing breakfast session. David advises the Federal Reserve Bank of Chicago on the agricultural sector and rural development. He also oversees a regular survey of agricultural banks for the Chicago Federal Reserve District, and frequently briefs the Chicago Fed's president on the agricultural economy. David was a consultant in the economic research department of the Federal Reserve Bank of Dallas before starting his career at the Chicago Fed.

Join us in the Windy City

As we have done for many years, Fertilizer International will be exhibiting at TFI's World Fertilizer Conference in Chicago this September. We are very much looking forward to being in the Windy City to meet industry friends, both old and new.

For more information about the event, please visit: www.tfi.org/conferences/world-fertilizer-conference ■

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The US fertilizer industry: sustainability champion

The priorities of the US fertilizer industry are becoming strongly aligned with United Nations Sustainable Development Goals (SDGs). **Lara Moody** and **Melinda Sposari** of The Fertilizer Institute explain how US fertilizer producers, distributors and retailers are raising the bar on sustainability and making a very real contribution towards SDGs.

Sustainable Development Goals (SDGs) are an urgent call to action. The 17 SDGs, formally adopted by the United Nations in 2015, are designed to eradicate global poverty and create a more prosperous world. The culmination of decades of global collaboration, they recognise that efforts to improve health and education and tackle climate change will also bring economic benefits by spurring world growth.

Through their support of SDGs, more than 178 countries have committed themselves to a global partnership on sustainable development, with a particular focus on improving lives and protecting the environment. Over the next two decades, governments across the globe will be expected to collaborate with stakeholders, including industry, to meet the 17 SDGs. Expanding and accelerating efforts to protect the earth's oceans and forests will be central to achieving these objectives.

The 17 SDGs form the core of the recently-published *Transforming our world: the 2030 Agenda for Sustainable Development*[1]. Each SDG includes a number of specific targets to help monitor progress towards achieving the overarching goal. In turn, each target comes with its own quantifiable indicator. These indicators, adopted by the UN General Assembly in 2017, provide a standard and common template that allow businesses, industries and countries to measure and report on progress towards achieving the SDGs.

Why link business actions to SDGs?

Valuably, the SDGs provide a ready-made platform that industry can use to guide its own efforts on sustainability when communicating and engaging with employees. In 2010, the US Department of Commerce recognised that better understanding of sustainable practices improves competitiveness, profitability and job growth[2].

The SDGs require countries, governments, and businesses to work together collectively, taking a three-pronged, integrated approach towards protecting human rights, promoting gender equality and protecting the planet and natural resources. The benefits to business are two-fold.

First, sustainable investing – making investments that specifically target and reward sustainable business behaviour – is on the rise and experienced triple digit growth between 2012 and 2014. This exponential growth is being linked to the rise in 'ethical' investments by millennials entering the workforce. A report by Morgan Stanley found that millennials incorporate sustainability into their investment decisions and overall consumer behaviour[3]. The collective influence of millennials is certainly rising. As a group, they became the largest generation in the workforce in 2018. This desire for more sustainable investing is reflected by the work of the Sustainability Accounting Standards Board (SASB). It recently published a set of industry-specific standards. These focussed on those sustainability indicators most likely to financially impact companies[4].

Second, SDGs offer companies a standard, common language for communicating their priorities on sustainable development. Referring to SDGs can help businesses strengthen their employee and stakeholder relations. Having a common language on sustainability also opens the door to partnerships with governments, other companies and social enterprises. By acknowledging and addressing the SDGs, companies can create and implement their own sustainable solutions and innovative practices. Such actions mitigate risks for the company, their employees, surrounding communities, and the wider environment. In summary, integrating the SDGs within the corporate structure and across the value chain is a win-win-win for companies, people – both employees and wider society – and the environment.

Aligning US fertilizer industry actions with SDGs

The Fertilizer Institute (TFI) released its fourth annual *State of the Industry Report* in February 2019. The report's key performance indicators (KPIs) are based on a rigorous assessment by TFI in partnership with its fertilizer industry members. Using the KPIs, the US fertilizer industry can track continuous improvements across a range of economic, social and environmental activities. The KPIs also provide a valuable yardstick for comparing US fertilizer industry actions and achievements with United Nations Sustainable Development Goals.

While some industry members are contributing to sustainability more widely, the following five SDGs have been identified as particularly relevant and a focal point for TFI:

- Goal 2: Zero hunger
- Goal 6: Clean water and sanitation
- Goal 7: Affordable and clean energy
- Goal 9: Industry, innovation and infrastructure
- Goal 13: Climate action

How the US fertilizer industry is contributing to these goals, and specific SDG targets and indicators, is summarised below. Sustainability achievements are illustrated by case studies from TFI member companies.

Goal 2: Zero hunger

The aim of Sustainable Development Goal 2 is to end hunger, achieve food security, improve nutrition and promote sustainable agriculture.

The fertilizer industry clearly has a vital role to play in achieving zero hunger. After all, we supply the nutrients needed to grow the crops that feed the world. Fertilizers, in the apt words of Bill Gates, are: "A magical innovation that's responsible for saving millions of lives from hunger and lifting millions more out of poverty by boosting agricultural productivity."

But, as an industry, we also have an important role to play in increasing agricultural productivity while simultaneously reducing the environmental impacts of farming.

Goal 2 includes the wide-ranging Target 2.4. Its objectives include ensuring that food production systems are sustainable as well as implementing agricultural practices that:

- Are resilient
- Increase productivity and production
- Help maintain ecosystems
- Strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters
- Progressively improve land and soil quality.

Progress towards this target will be measured by Indicator 2.4.1. This monitors the proportion of agricultural land being farmed productively and sustainably.

The objectives and actions of the fertilizer industry overlap and align very strongly with Goal 2 and its subsidiary targets and indicators. In the US, for example, the fertilizer industry is leading the way on sustainable agriculture through its efforts to boost farmer awareness of 4R nutrient stewardship.

The 4Rs approach is based on best management practices (BMPs) for fertilizers. These identify the right nutrient source and apply it at the right rate, the right time and in the right place. Actions by TFI member companies on 4Rs in the US include:

- Employing accredited agronomic professionals to advise farmers
- Investing in product research, technological innovation and infrastructure
- Creating partnerships with leading academic, agricultural, and environmental organisations including the World Wildlife Fund.

TFI members contributed $1.1 million to the North American 4R Research Fund in 2017. To date, this fund has awarded a total of $8.1 million to 4R researchers in the US and Canada. Additionally, three TFI member companies are investing $5.5 million in research and development that specifically supports the 4Rs and innovative product development.

Goal 6: Clean water and sanitation

The objective of Sustainable Development Goal 6 is to ensure water and sanitation is available for all and is sustainably managed. The goal includes a specific target to increase **water-use efficiency** across all sectors (Target 6.4). This is needed to substantially reduce the number of people suffering from water scarcity by 2030.

Another target covers **the protection and restoration of ecosystems**, including mountains, forests, wetlands, rivers, aquifers and lakes (Target 6.6.) It includes an indicator that measures improvements in these water-related ecosystems over time.

The US fertilizer industry's efforts on water use efficiency and environmental protection are closely aligned with Goal 6 and these two specific targets.

Water-use efficiency

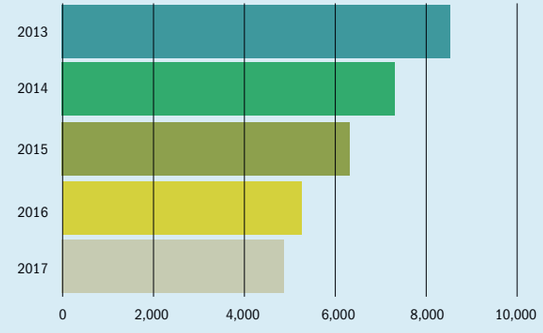
Sustainable water use is a key part of resource conservation for many industries which consume large volumes of water in production processes. US fertilizer manufacturers have been prioritising water recycling and reclamation for a number of years by setting water efficiency and zero-discharge goals.

Indeed, some 29 fertilizer production sites run by TFI members have now achieved zero-discharge status, as shown in TFI's 2018 *State of the Industry Report*. These efforts contributed to the recycling of 516 billion gallons of water during US fertilizer manufacturing in 2017.

Additionally, water use in US nitrogen fertilizer production (per ton of product) has fallen by 42 percent since 2013, thanks to production upgrades at existing plants and the opening of new, more efficient plants (Figure 1). This is a significant and remarkable reduction, given that the United States is the world's fourth-largest nitrogen fertilizer producer.

In summary, the water efficiency improvements achieved by the US fertilizer industry over the last five years directly contribute to the UN Sustainable Development Goals (SDG Target 6.4, Indicator 6.4.1), and help meet the obligation of all sectors to deliver major water-use efficiency savings by 2030.

Fig. 1: **The US fertilizer industry has reduced water use per ton of nitrogen produced by 42 percent over five years**



Source: TFI

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CASE STUDY Apache Nitrogen Products, Inc (APNI)

APNI's Benson, Arizona, site produces nitric acid and ammonium nitrate (AN) in dry and liquid form. Process heating and cooling requires 650 gallons per minute of water. The site's water requirements are sourced from groundwater held in deep aquifers.

Two recycle methods are used to capture and treat different water streams generated by the nitric acid production process. First, all liquid waste streams are captured and reprocessed using state-of-the-art, automated Swiss technology to generate clean feedstocks. Second, blowdown streams from cooling towers and boiler systems are collected and reprocessed in a brine concentrator to generate high purity water for AN production. Comprehensive water recycling has increased on-site water use efficiency and allowed APNI to operate Benson as a zero-discharge plant. ■

Protecting and restoring ecosystems

Industry action to reduce the environmental impacts of fertilizer products can contribute directly to the protection and restoration of water ecosystems (SDG Target 6.6). Increasing farm adoption of fertilizer best management practices – based on 4R nutrient stewardship – is a high priority for the US fertilizer industry. Wider uptake of 4Rs by farmers can reduce nutrient movement into surface waters and groundwater, so protecting ecosystems, by limiting nutrient losses from cropping systems.

The US industry is committed to educating, advising and engaging with farmers on 4R nutrient stewardship and best management practices. On average, the industry currently employs 2.3 agronomy professionals at each retailer location. Around 25 percent of these agronomists have a professional accreditation, such as Certified Crop Advisor.

Joe Huebener, CHS Shipman (left), and farmer Kyle Brase (right).

PHOTO: TFI

CASE STUDY CHS Shipman

Joe Huebener is a *YieldPoint* precision ag specialist at CHS Shipman in Shipman, Illinois. Joe works closely with farmers in his area, enabling them to make decisions based on profitability, environmental impact and time management. Corn farmer and customer Kyle Brase says Joe's advice has improved nitrogen use efficiency (NUE) at his farm from 1.5 to 0.9 pounds per bushel. The approach recommended by CHS Shipman has increased corn yields – while using less fertilizer – to deliver a $10-12/acre cost savings. Improving NUE can increase crop production using less applied fertilizer. It also means applying the right type of fertilizer exactly when and where the crop needs it. Over time, these practices have an environmental benefit too, as they reduce the amount of nitrogen making its way into surrounding ecosystems. ■

Goal 7: Affordable and clean energy

Sustainable Development Goal 7 is designed to ensure access to affordable, reliable, sustainable and modern energy for all. More specifically, this goal requires a substantial increase in the renewables share of the global energy mix by 2030 (Target 7.2). The US fertilizer industry, being an energy-intensive sector, is participating in this wider shift to more affordable and clean energy.

Fertilizer manufacturers can capture the waste heat generated during the production process and use this for heating and electricity generation to reduce their energy footprint. In TFI's latest *State of the Industry Report*, 101.8 million GJ of waste heat was captured by participating US fertilizer companies in 2017. This is equivalent to 51 percent of their total energy use. Additionally, companies were able to generate 2.3 billion kilowatt hours of electricity using waste heat sources.

The above achievements on energy generation and reuse by the US fertilizer industry make a direct contribution to the SDG target to increase the contribution of renewable energy to final energy consumption (SDG 7, Target 7.2, Indicator 7.2.1).

Goal 9: Industry, innovation and infrastructure

Resilient infrastructure, sustainable industrialisation and innovation are all promoted by Sustainable Development Goal 9. Achieving this will require widespread infrastructure upgrades and industry retrofits to make these more sustainable (Target 9.4). Countries will deliver on this by increasing their resource-use efficiency and adopting 'cleaner and greener' technologies and industrial processes by 2030. Progress will be partly judged by monitoring industry CO_2 emissions per unit of value added (Indicator 9.4.1).

All these themes chime with the US fertilizer industry, which is continuing to innovate and invest sustainably in production capacity and infrastructure.

Recent investments across the US fertilizer sector meet the objectives of Goal 9.

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PHOTO: TFI

Yara International's joint venture with BASF, Freeport, Texas

CASE STUDY Yara North America

Yara in partnership with BASF opened a new ammonia production plant in Freeport, Texas, in April 2018. This first-of-its-kind plant produces ammonia from hydrogen feedstock, rather than the natural gas used at conventional plants. Hydrogen is sourced as by-product from nearby chemical plants, along with nitrogen feedstock supplied by several air separation plants. This innovative plant uses resources more sustainably and avoids GHG emissions, as its hydrogen feedstock was unwanted previously and burned by the chemical plants.

CASE STUDY Foundation for Food and Agronomic Research project

In 2017, the US fertilizer industry in partnership with the Foundation for Food and Agronomic Research jointly funded a $2 million, multi-state research project. This was organised through the 4R Research Fund and coordinated by Iowa State University. The project is measuring phosphorus and nitrogen losses, including N_2O emissions, from multiple sites where the 4Rs are practiced at locations across the US Midwest. Project observations and outcomes will be used to improve knowledge about the 4Rs and fine-tune strategies that help reduce the environmental impact of fertilizer use in food production systems.

The evidence shows that the industry's capital expenditure is having positive impacts on safety, environmental and energy performance. Companies participating in the *2018 State of the Industry Report* invested an average of $3.8 billion annually in new production plants and infrastructure upgrades between 2015 through 2017. These investments have increased operating efficiency, reduced energy and water use, and cut greenhouse gas (GHG) emissions. The shift towards more sustainable production also strengthens the US economy.

The amount of GHGs associated with fertilizer production fell from 1.6 to 1.1 metric tons per nutrient ton, as a result of upgrades and new plants coming online in 2016. This emissions reduction fulfils SDG objectives on reducing the amount of CO_2 emissions per unit of value added (Indicator 9.4.1).

Investments in technology and tools to protect the environment are equally important in the fertilizer retail sector, as these enable retailers to help farmers deliver 4R nutrient stewardship in their nutrient management plans. High-tech farm equipment often comes with a price tag well into six figures. Retailers, by deploying expensive precision agriculture tools on customer farms, can help farmers meet or exceed their economic and environmental goals.

Goal 13: Climate action

Sustainable Development Goal 13 requires urgent action to combat climate change and its impacts. It includes a target to integrate climate change measures into national policies, strategies and planning (Target 13.2). Progress towards this is monitored by the successful introduction of integrated policies/strategies/plans that foster climate resilience and low GHG emissions but do not threaten food production (Indicator 13.2.1).

TFI has successfully added a priority research area in the latest US Farm Bill. This ensures funds are available to evaluate and advance 4R practices. This is a prime example of how the fertilizer industry can contribute directly to Sustainable Development Goals on climate action (Goal 13, Target 13.2, Indicator 13.2.1).

Under certain conditions, GHGs in the form of nitrous oxide (N_2O) can be emitted from the nitrogen fertilizer applied to soils on farms. Such emission are site-specific, however, being linked to location and weather conditions as well as the 4Rs (fertilizer source, rate, timing and placement).

In 2018, the 4th National Climate Assessment identified the 4Rs as an effective climate change adaptation tool. The US fertilizer industry is working closely with others to raise awareness of the ability of fertilizer management to reduce GHG emissions. Companies in the food supply chain are key stakeholders when it comes to mitigating GHG emissions from crop production. The industry is therefore working with these companies, helping to inform and engage, through its 4R research. It is also collaborating with Field to Market, an NGO that unites those working in the food supply chain to deliver sustainable outcomes for the whole of agriculture.

The 2018 State of the Industry Report

The Fertilizer Institute is proud of the great strides being taken by the US fertilizer industry and its member companies to address UN Sustainable Development Goals. For greater insight and more examples of US industry actions on sustainability, the full *2018 State of the Industry Report* can be viewed here: tfi.org/our-industry/state-of-industry

About the authors

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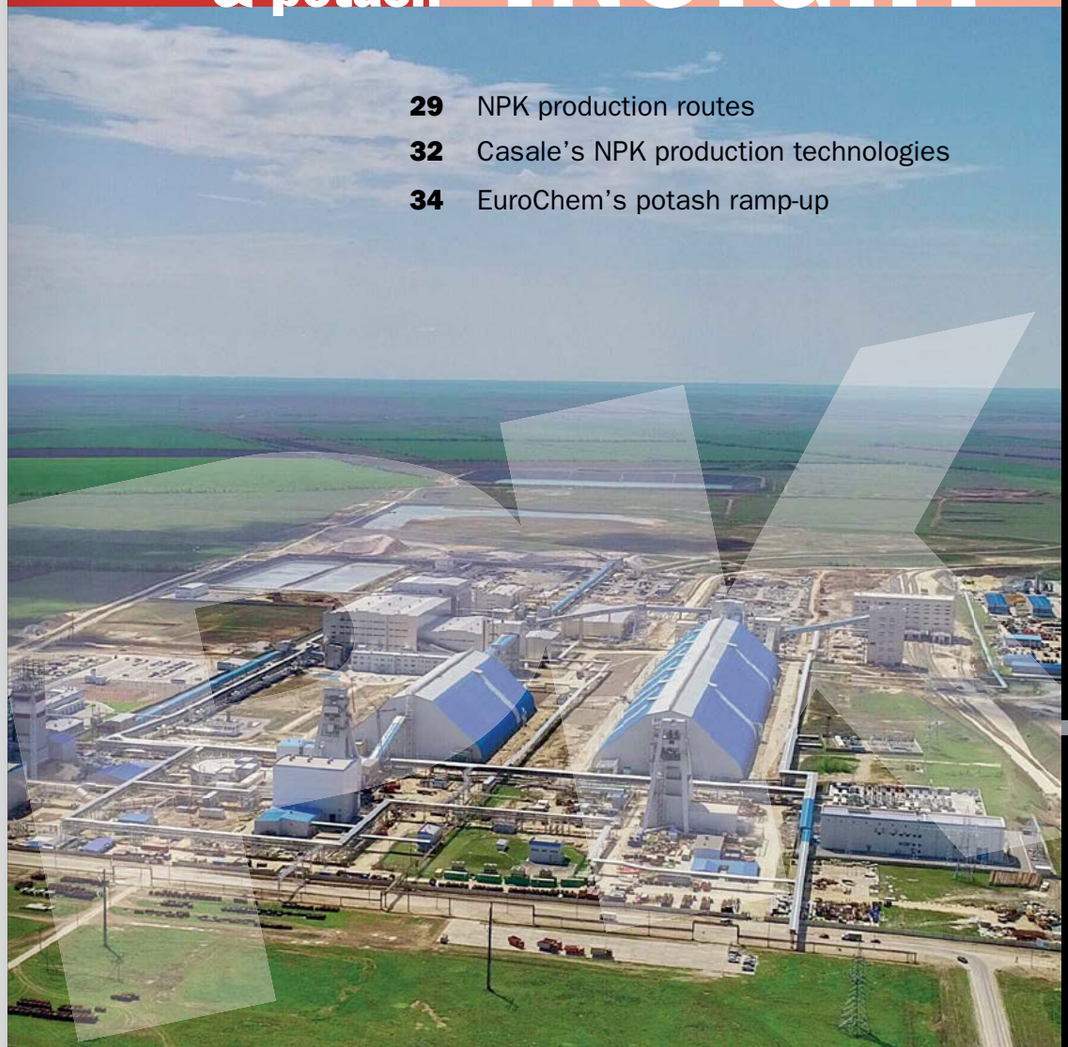

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NPK production routes

Higher margins and better market growth prospects are behind the changeover in plant capacity from phosphate fertilizers to NPKs. **Dave Ivell** of Worley describes the main production routes for NPK manufacture – and their relative merits and demerits.

Diammonium phosphate (DAP) and monoammonium phosphate (MAP) are mass-produced commodity fertilizers. As the most widely traded phosphate products globally, they adhere to narrow and very specific formulations.

NPK products, in contrast, fall into a completely different category. NPK is a very broad term covering a multitude of different nutrient formulations, each having their own process characteristics. Indeed, the term 'NPK' itself is a catch-all phrase given to any fertilizer that contains the primary plant nutrients nitrogen, phosphorus and potassium. Similarly, 'NPS' is a generic term for fertilizers that contain significant quantities of sulphur alongside nitrogen and phosphorus. They are also referred to as ammonium phosphate sulphate (APS) products.

NPK/NPS fertilizers can be produced from various raw materials via different manufacturing routes – to generate granular products containing N, P, K and S in a wide range of ratios. There are several production methods for NPKs, the main manufacturing routes being:

- Steam granulation
- Chemical granulation
- Bulk blending.

This article outlines the advantages and disadvantages of each of the above methods as well as their relative costs, in terms of both capital expenditure (capex) and operational expenditure (opex). The different types of NPK products – and the challenges faced when designing plants to produce different NPK grades and formulations – are also discussed. Finally, we include a case study describing how a plant designed to produce DAP was modified to manufacture a range of NP/NPK products containing large quantities of sulphuric acid instead.

A summary of the main merits and demerits of the three NPK process routes is provided in Table 1.

Table 1: **Summary of the advantages and disadvantages of steam granulation, chemical granulation and bulk blending**

	Bulk Blending	Steam Granulation	Chemical Granulation
Raw Material Cost	High	Medium	Low
Utilities Cost	Low	Medium	High
Fixed Cost	Low	Medium	High
Capex	Low	Medium	High
Overall Production Cost	Lowest	Higher	Higher
Multiple Grade Flexibility	High	Low	Low
Product Quality	Low	Medium	High

Source: Worley

Steam granulation

In the steam granulation route, solid raw materials are mixed and granulated using steam and/or water. The process generates granular products through agglomeration. The addition of steam/water causes part of the solid raw materials to go into solution. This promotes the agglomeration of solids by forming crystal bridges that bind particles together.

In granulation, an end product of between 2-4 mm in size is usually desirable. How efficiently these product-sized granules will form determines the recycle ratio of the process – a ratio of 2/1 or less being typical.

Product granules formed by steam granulation have the following characteristics:

- Fairly uniform chemical composition
- Low strength
- Poor shape
- Wide particle-size distribution.

A relatively long dryer residence time (typically 20 minutes) is also required. This is because most of the moisture is present inside of granules and needs time to diffuse to the surface before it can evaporate.

Changing NPK grade at the end of a production run can be time consuming – given that the entire plant is left full of fertilizer of the previous composition. 'Change-over' formulations are therefore used to speed up the switch in production from one grade to another. These exaggerate the normal feed rates required for the new grade during the changeover period. This technique can be applied when different grades of the same type of NP or NPK product are being produced. But if the production change is from an NPK product to an NP product then the only real choice is to empty the plant beforehand.

A typical steam granulation flowsheet is shown in Figure 1. The flowsheet can vary slightly, depending on the grades produced. The main variations include where to place the screening and crushing operations – either before or after the cooler – and whether to pass some of the process gases through baghouses rather than wet scrubbing.

Chemical Granulation

The chemical granulation route manufactures granular products by reacting phosphoric acid and sulphuric acid with ammonia. This produces a slurry which is

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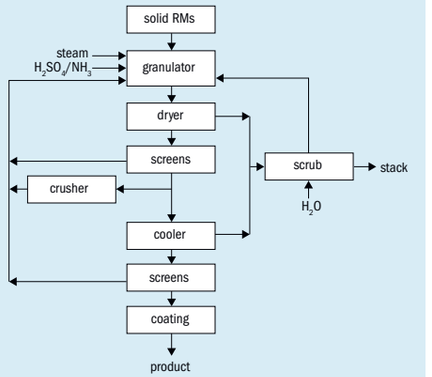
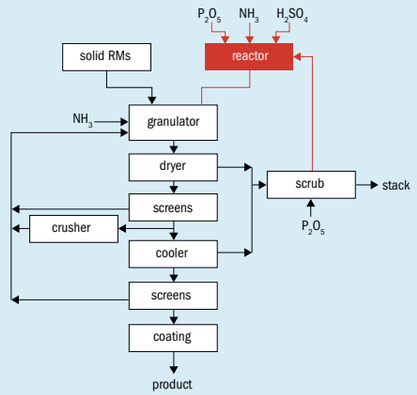
Fig. 1: **Typical steam granulation flowsheet**



Source: Worley

Fig. 2: **Typical chemical granulation flowsheet**



Source: Worley

sprayed onto recycle material in the granulator. Solid raw materials – such as potash if NPKs are being produced – are also fed to the granulator along with the recycle. Granulation occurs partly through agglomeration but mainly by layering.

The recycle ratio in this process route is usually higher than in steam granulation – a typical value is 4/1 – and is determined by the granulator's heat and water balance. Keeping to this higher ratio often requires the recycling of product-sized material to the granulator to maintain the correct heat and moisture conditions.

The resulting granules, as with steam granulation, are uniform in chemical composition. However – due to the layering mechanism and the higher recycle ratio – the granules formed are harder, more spherical and typically have a narrower particle-size distribution. The required dryer residence time is also shorter (typically 7–12 minutes depending on grade) as moisture is mostly on the surface of the granules leaving the granulator.

A typical chemical granulation flowsheet is shown in Figure 2. This is similar to the steam granulation flowsheet except for the added reaction stage and the use of phosphoric acid rather than water as the scrubbing medium.

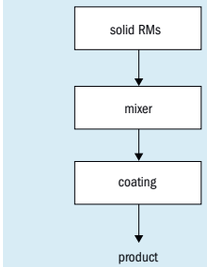
Chemical granulation also faces exactly the same production challenges as steam granulation when changing NPK and NP product grade.

Bulk blending

Bulk blending (Figure 3) simply involves mixing together dry, granular raw materials. This physical blending operation is very simple and low-cost, in capex and opex terms, in comparison to the other two granulation routes.

The chemical composition of granules is heterogeneous, not uniform, varying according to the raw material type. Granules present in bulk blends are also of different sizes, shapes and densities (see photo). Because of this, segregation causing uneven spreading on fields can be an issue. The incorporation of micronutrients may also present a problem, although these can now be applied as a liquid coating on the surface of the granules.

Fig. 3: **Bulk blending flowsheet**



Source: Worley

Raw materials

Raw material requirements vary with the NPK process route. Bulk blending requires the purchase of premium granular products. Steam granulation, in contrast, consumes predominantly non-granular solid raw materials. This route often consumes by-products, off-specification materials, or even 'spoiled' substances available from nearby industries. Chemical granulation uses the cheapest possible liquid chemicals as feed. Costs are kept low because third party suppliers do not need to be compensated for converting these liquid feeds into solid raw materials, as they are typically generated on-site within the chemical granulation plant.

PHOTO: WORLEY

Typical bulk blended product.

The typical raw material requirements of the three different process routes in the production of 15-15-15 NPK are shown in Table 2.

Table 2: **Raw material requirements for production of 15-15-15 NPK: steam granulation, chemical granulation and bulk blending**

Raw material, kg/t	Bulk Blending	Steam Granulation	Chemical Granulation
Granular urea	24	-	-
Prilled urea	-	58	36
Granular ammonium sulphate	400	-	-
Standard ammonium sulphate	-	360	-
Granular DAP	329	-	-
Powder MAP	-	292	-
Granular potash	253	-	-
Standard potash	-	253	253
Ammonia	-	22	165
Phosphoric acid (P_2O_5)	-	-	154
Sulfuric acid	-	31	295
Coating oil	4	4	4

Source: Worley

Focus on chemical granulation

The remainder of this article will focus on the production of NPK and NPS grades via the chemical granulation route – as this produces the best quality products out of all the three process routes. The main differences between the manufacture of NPK/NPS and DAP/MAP products are highlighted.

In particular, high and low mole ratio types of the following NPK and NP product categories are discussed:

- Ammonium phosphate/potash mixtures
- High sulphate NP grades
- High sulphate NPK grades
- High urea content NP grades
- High urea content NPK grades

The mole ratio measures the relative proportion of phosphoric acid and ammonia in the feed and is an important parameter for adjusting and 'tuning' the granulation process for the best product quality and output.

Table 3: **The total heat of reaction and steam generated in the reactor by 20-20-0 compared to DAP**

Grade	Total heat of reaction, kcal/t product	Reactor steam release, kg/t product
20-20-0	430,200	384
18-46-0 (DAP)	314,200	267

Source: Worley

Ammonium phosphate/ potash mixtures

The **high mole ratio mixtures** in this category are DAP-based. The reactor is operated at a mole ratio of 1.4-1.45. Further ammonia is then added to the granulator to raise the mole ratio to the level required for the final product.

Typical NPK grades produced under these process condition include 10-26-26 and 10-20-30. These mixtures are much less soluble than DAP. This means they granulate at higher moisture contents and, consequently, higher dryer inlet temperatures are required. In addition, the consumption of larger amounts of potash, as dry, solid feed, means that the required recycle ratio is less than for DAP.

High mole ratio mixtures may not granulate as well as DAP. Reducing the mole ratio in the granulator – to 1.65–1.7 for example – to increase solubility is one technique that can alleviate this problem. This can be a possible option, depending on the source of the phosphoric acid, while still maintaining the required nitrogen content in the final product.

Low mole ratio mixtures behave similarly to their high mole ratio counterparts, except that they are MAP- rather than DAP-based, meaning that the mole ratio is a lot closer to one than to two. The NPK grade 5-24-24 is a typical product in this category.

For these mixtures, granulation can be improved by raising the mole ratio above 1.0 to 1.1–1.15, for example. The reactor can be operated below mole ratio 1.0 (typically 0.6–0.7) with ammonia being added in the granulator to increase the mole ratio. Alternatively, it can be operated above mole ratio 1.0 (typically 1.4–1.45) with phosphoric acid added in the granulator to reduce the mole ratio to the level required to produce the final product. The latter option is known as back-titration and is the method recommended by Worley for these low mole ratio ammonium phosphate/potash mixtures.

High sulphate NP grades

The typical **high mole ratio grade** in this category is 20-20-0. The main feature of these formulation is their very high sulphuric acid content (around 40%) and the resulting much larger heat of reaction compared to DAP – typically 37 percent higher (Table 3).

The higher heat of reaction for 20-20-0 translates into significantly higher steam release rates in the reactor and greater airflow requirements for the reactor/granulator system. The impact of this can be reduced by feeding liquid rather than gaseous ammonia to the reactor. How well this mitigates the issue depends on whether an air chiller is incorporated into the flowsheet.

Because of the above issues, existing DAP plants that are converted to the production of 20-20-0, or similar grades, will be limited to much lower production rates unless the reactor/granulator system is revamped to install larger equipment items.

Practical experience has taught us that operating the reactor at high mole ratio, for example 1.45, requires a very high slurry water content to maintain fluidity. For this reason, we recommend operating at a mole ratio of 0.6–0.65. Further ammonia is then fed to

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CASE STUDY

Worley (formerly Jacobs) was recently contracted to debottleneck a fertilizer plant. This was originally designed to produce DAP and non-urea based NPK but is now required to produce ammonium phosphate sulphate (APS) grades. These NP and NPK grades, such as 20-20-0 and 15-15-15, contain large amounts of sulphuric acid. Due to the significantly higher heat of reaction, the production rate for these grades is severely restricted by the originally installed R/G (reactor/granulator) scrubbing system. The objectives of the revamp are as follows:

1. Increase capacity for the original DAP/NPK design grades
2. Remove the bottlenecks for APS production
3. Improve the finished product quality – primarily the particle-size distribution
4. Reduce the stack emissions and reduce raw material consumption.

The revamp modifications being implemented are briefly described below.

Reactor replacement

The traditionally designed cylindrical pre-neutraliser will be replaced by a modern low residence time pre-neutraliser. The diameter of the upper steam disengagement section will be larger than the current vessel to cope with the significantly higher volumes of steam generated.

R/G scrubbing system

The R/G fan will be replaced with a significantly larger capacity fan to ensure complete evacuation of the reactor and the granulator. A dual mole ratio scrubbing system will be installed to reduce stack emissions.

The existing venturi-cyclonic R/G scrubber will be replaced with a low pressure drop duct-cyclonic scrubber. The scrubber is designed to operate at high L/G ratio at a similar mole ratio to the current plant (1.4–1.5). The aim is to recover approximately 60-70 percent of the ammonia reporting to the scrubber in the gas stream.

A new variable throat venturi-cyclonic unit will be installed as the second stage scrubber. This scrubber is a highly efficient unit that will operate at low mole ratio (0.6-0.7) to recover almost all of the ammonia escaping the first stage scrubber.

The dryer, cooler and equipment vent scrubbers will also operate at the same mole ratio as the R/G scrubber in order to improve ammonia recovery.

Tail gas scrubber

The existing square section void tower will be replaced with a new and appropriately-sized cyclonic scrubber able to deal with the increased evacuation rate. Water circulating around this scrubber will be regulated at pH 4–5 by injecting a small quantity of sulphuric acid. This ensures that any remaining traces of ammonia will be captured without excessive fluorine loss.

Granulator

The granulator internals (slurry distribution system, ammonia sparger and support system) will be completely re-designed to optimise operating conditions. One of the major problems faced in existing plant operation is the generation of excessive lumps. A grizzly system will therefore also be installed to ensure that any lumps formed do not pass to the dryer.

Dryer

The lump breaker at the dryer discharge is currently bypassed due to on-going maintenance issues. This will be removed and the dryer discharge will be retrofitted with an integral grizzly. This breaks lumps autogenously by lifting and dropping so that no lumps larger than the opening in the grizzly can pass to the downstream equipment.

Screening and recycle

The current screens have sufficient area but the split of material between the four screens and the distribution across their width is very poor. The feed system will therefore be completely refurbished so that the installed screening area is effectively and fully utilised. In addition, a final polishing screen will be installed to ensure that the final product meets the 2–4 mm size requirements.

The recycle control system will also be revamped to ensure that recycle rate can be accurately controlled, as part of the overall plan to improve granulation quality. ■

the granulator to reach the desired mole ratio. The product mole ratio may be in the 1.65-1.8 range, depending on the source of the phosphoric acid. The addition of a small amount of urea may also be necessary to boost the nitrogen analysis to the specified value.

The typical **low mole ratio grade** in this category is 16-20-0. The main feature of these NPK grades, as with 20-20-0, is their very high sulphuric acid content. Similarly, the operational factors discussed above for 20-20-0 also apply here, except that 16-20-0 is essentially a MAP-based grade, rather than DAP-based, and no urea is required. Optimum product mole ratio is in the 1.1–1.15 range. Some filler will normally be required to prevent over-formulation.

High sulphate NPK grades

Typical **high mole ratio grades** in this category are 15-15-15, 16-16-8 and 14-28-14. The sulphate levels are slightly lower than for 20-20-0 but still require the sulphuric acid feed to be above 30 percent of the formulation. Similar to 20-20-0, the reactor is operated at low mole ratio to maximise slurry fluidity. The impacts on the reactor/granulator system seen with 20-20-0 also apply to these grades. 15-15-15, as with 20-20-0, is likely to need a small amount of urea to make nitrogen grade. The high potash content, particularly in 15-15-15, means that product mole ratio is often used to optimise granulation.

A typical **low mole ratio grade** in this category is 12-24-12. While the sulphate levels in this NPK grade are still high, sulphuric acid is only about 20 percent of the formulation. A product mole ratio of 1.1–1.15 is used to improve granulation and, as with 16-20-0, filler is generally needed to prevent over-formulation.

High urea NP grades

A typical **high mole ratio grade** is 28-28-0. The main feature of this NPK product is the high urea levels in the feed – around 30-35 percent of the formulation. This causes a host of difficulties, including:

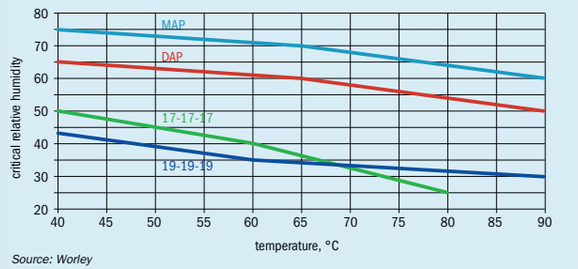
- Very high solubility
- Very low melting point
- Very low critical relative humidity (CRH)

These grades are much more soluble than DAP because of the high urea levels. The moisture required for granulation is therefore significantly lower and the required recycle ratio higher. To some extent, the impacts of these characteristics can be mitigated by partial cooling of the recycle, as decreasing the granulation temperature reduces solubility. Cooling both product and oversize material has an added benefit: carrying out crushing at a lower temperature, well below the melting point, helps reduce crusher build-up.

Importantly, the dryer must be operated at a much lower temperature as the melting point of these high mole ratio mixtures is well below that of DAP. The resulting reduction in the drying rate means longer drying residence times are necessary. In plants designed to produce these NP grades as well as DAP, a two speed dryer able to provide the longer dryer residence time necessary is required.

Due to the extremely low CRH of these NP grades, high dryer airflows are often required to ensure that relative humidity of the dryer exhaust is far below the CRH of the product being dried. Additionally, all ductwork and cyclones must be carefully insulated and additional heat provided in the form of heat tracing. For the dust extraction system, direct injection of hot air into the equipment and ductwork is also necessary. Dehumidification of the storage building is also highly recommended.

Fig. 4: **The critical relative humidity (CRH) of MAP and DAP vs two NPK grades**



Source: Worley

High urea NPK grades

The typical **high mole ratio grade** in this category is 19-19-19, which again contains about 30 percent urea in the formulation. Process conditions and behaviour are similar to those described for high urea NP grades, except that their CRH is even lower. Combining urea with potash also lowers the melting point further as they form eutectic mixtures.

The very low CRH values for urea-based NPK grades, relative to MAP and DAP, are shown in Figure 4. The graph also illustrates the strong dependence of CRH on temperature – this explaining why higher airflows are necessary to lower product moisture content and so avoid caking.

Conclusion

NPK fertilizers can be produced via different process routes and from a variety of raw materials. Chemical granulation produces the best product quality but requires the highest capex. Granulation plants need to be tailor-designed to produce NPK fertilizers. The plant design is heavily dependent on the specific NPK fertilizer grades required and the available raw materials. ■

Author's note

A version of this article was presented at SYMPHOS 2017, the 4th International Symposium on Innovation and Technology in the Phosphate Industry, Benguerir, Morocco, 8-10 May 2017.

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Casale's NPK production technologies

Single and dual pipe reactor technologies provide a safe, flexible and efficient way of producing solid NPKs. Casale's **Jean François Granger** describes their design features and main advantages.

PHOTO: SAOIRSE2013/SHUTTERSTOCK.COM

Fertilizer granulation plant.

In 2014, Casale acquired from Borealis (formerly GPN) the complete set of process technologies for the production of compound fertilizers (NPKs), superphosphates (SSP, TSP, USP), nitric acid (NA), ammonium nitrate (AN) and urea ammonium nitrate (UAN) solution.

The transfer of these technologies to Casale was supported by a dedicated internal project to master all of the necessary technical know-how. Key professionals from Borealis were also recruited as part of the technology and knowledge transfer process.

Consequently, Casale now has a complete portfolio of fertilizer manufacturing technologies – and has an unrivalled ability to seamlessly integrate these into a fertilizer complex, based on our deep knowledge of every single process.

GPN's technology has a widespread presence throughout the global fertilizer industry, thanks to more than 30 years of developmental and operational experience in NPK plant design.

Indeed, GPN's long tradition in designing NPK plants dates back to the mid-1970s, when the first Grande Paroisse NPK plant with dual pipe reactor technology started-up in France. Since then, GPN has designed a range of NPK units with capacities ranging from 110 t/d to more than 2,800 t/d.

The dual pipe reactor process, as a production technology, offers distinct advantages in terms of flexibility, safety and cost (both capex and opex). Nevertheless, Casale can also design NPK plants with a single pipe reactor or revamp plants equipped with pre-neutralisers.

Compound NPKs

There are two main categories of NPKs depending on how their constituents are combined. They can be produced, for example, by physically mixing together separate granules of AN, MAP and MOP in a process known as bulk blending.

Compound fertilizers can also be produced using a granulation process to combine all three nutrients homogeneously within a single granule. Compound NPKs are generally preferred over NPK blends as they do not segregate during storage and transportation, helping to ensure that nutrients are spread evenly during field application.

Compound NPKs can be manufactured using a range of different raw materials.

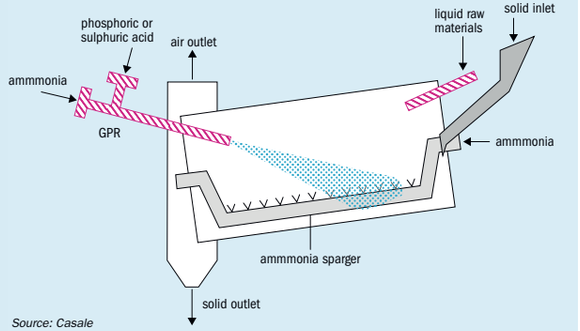
The nitrogen (N) source is usually a mix of ammonia with either AN or urea. Ammonium sulphate (AS) can also be used, being sourced as an external product or manufactured on-site from sulphuric acid and ammonia.

Phosphorus (P) can be sourced via the phosphate rock or phosphoric acid route. Using phosphate rock as the P source is a big disadvantage as its calcium content acts as diluent, preventing the production of some fertilizer grades such as MAP and DAP – unless it is treated separately to generate CAN as a side product. Phosphoric acid, while costing slightly more as a P_2O_5 source, reduces shipment and storage requirements at those production sites without access to a local source of phosphate rock.

Standard potassium chloride (MOP) is typically used as a potassium (K) source although the premium product potassium sulphate (SOP) is occasionally selected in special cases where the market values this.

The Casale granulation process for NPK production is described below. This is based on phosphoric acid and potassium chloride as raw materials for P and K, respectively, while the N source used is ammonia with either AN or urea.

Fig. 1: **Granulation pipe reactor**



Source: Casale

General concepts

Casale's NPK process uses the phosphoric acid route. As suggested above, the main advantages of this route are that:

- It can be operated at all sites located at any distance from a phosphate mine
- It manufactures the best quality products, particularly when compared to NPK bulk blends
- It offers flexibility in terms of the different fertilizer grades which can be marketed
- Generates a high analysis fertilizer product with high nutrient levels, as the calcium content associated with phosphate rock is avoided.

Some phosphoric acid routes involve a pre-neutraliser while others – such as Casale's process – are based on pipe reactors. These offer a number of advantages:

- Less equipment is required
- Neutralisation energy is not lost
- Granulation loop capacity is lower than required for a pre-neutraliser
- Less changeover time is required when a plant shifts production between different grades, enabling some operators to produce three different NPK grades in a single day
- The raw materials required can be sourced from the international market.

History

The Casale granulator pipe reactor process has a history stretching back almost 50 years, having originally been designed and owned by Grande Paroisse (GP). GP designed its first granulator pipe reactor (GPR) in 1970 and its first dryer pipe reactor (DPR) in 1974. Both types of pipe reactors were subsequently incorporated – without any pre-neutraliser – into two new NPK plants at GP's own manufacturing sites later in the 1970s.

Single pipe reactor process

In the single pipe process, the granulation plant comprises:

- A single granulator pipe reactor (GPR) (Figure 1)
- A drum granulator
- A drum dryer
- Screens and crushers
- Cooling equipment
- A coating drum, if required.

Additional transportation equipment is also necessary along with gas scrubbers to reduce emissions.

Solid raw materials are fed directly to the granulator along with the solids recycled from the process.

Most of the liquid raw materials, in contrast, are fed to the pipe reactor where the phosphoric acid is neutralised by ammonia. The molar ratio (MR) between phosphoric acid and ammonia is an important parameter for tuning the pipe reactors. For the granulator pipe reactor (GPR), the MR is usually kept at 0.7-0.8 or 1.2-1.4 so that the fluidity of the slurry is at a maximum.

For NPKs containing a high quantity of sulphate (SO_3), this is provided by premixing sulphuric acid with phosphoric acid in the feed to the GPR. Casale – thanks to its extensive experience – can design a GPR to cope with and neutralise almost any proportion of sulphuric acid. In situations where the heat of reaction raises the slurry temperature to a high level, the pipe reactor can be constructed from special materials to prevent corrosion.

Some ammonia is also fed to and distributed throughout the granulator via an ammonia sparger. This assists the granulation process and also helps to adjust the fertilizer's composition. Casale's ammonia sparger injects ammonia inside the rolling bed of granules. It is equipped with a brace-shaped moving arm, enabling it to be lifted outside of the bed if necessary, such as when there is a plant stoppage.

The granulated product exits the granulator through a chute to enter the dryer. The chute is a critical operational part of the plant as it can easily get chocked. Casale's chutes are designed to limit this risk. They are constructed from a special flexible material and incorporate an automatic hammering system that prevents granules from sticking to chute walls.

Granules are dried in a rotary drum using a co-current flow of hot air. The drum is fitted with optimised lifters to ensure maximum contact between the granules and the hot air. Residence time is adjusted, when required, by a ring at the outlet.

A lump screen at the outlet of the dryer separates large agglomerates and directs these to the lump breaker. This device protects the elevator located at the outlet of the dryer from the risk of blockage and damage.

The elevator lifts granules to the top of the plant and feeds these to the screening devices. Two deck screens move in a circular motion being fitted with an unbalanced shaft. These separate the granule stream into three parts:

- Undersize granules flow down directly to the recycling belt conveyor
- Oversize granules flow down to the crushers, where their size is reduced before they join the undersized granules on the recycling belt conveyor
- The desired on-size granules are fed to the cooling system.

Granules on the recycling belt conveyor are recycled to the granulator where their size is increased by adding new feed materials.

One of three different types of cooling system can be selected, depending on client preferences as well as site and ambient conditions:

- Fluid bed cooler
- Rotary drum cooler
- Bulk flow cooler.

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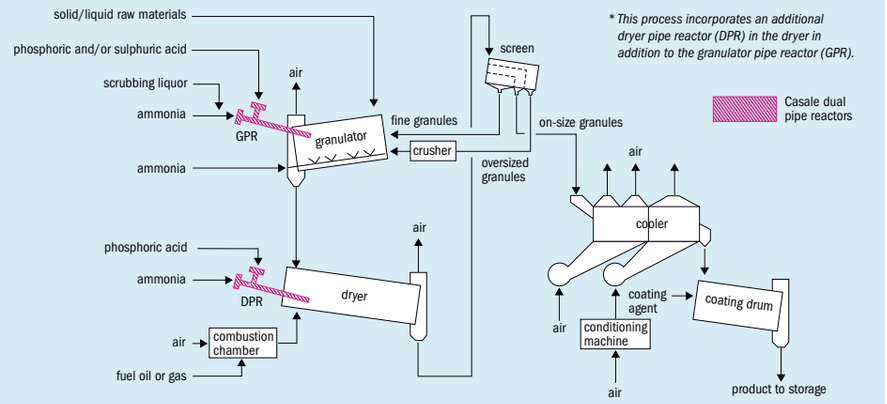
Fig. 2: **Casale's dual pipe reactor NPK process***



Source: Casale

Selection is made on a case-by-case basis, weighing up the pros and cons of each system. Fluid bed and rotary drum coolers use air as a cooling media. Humidity can therefore affect product quality in tropical conditions unless it is removed. Bulk flow coolers, meanwhile, are high-standing equipment and usually need an additional elevator, a factor which can affect product quality.

The product is usually coated, once it has been cooled down, before going to storage or a packaging unit.

A lot of air is consumed in NPK production. It is used for both drying and for de-dusting plant equipment. Air is also often used as cooling media, depending on the choice of cooling system.

This process air can be contaminated with chemicals (particularly ammonia, acids and fluorine) and dust and therefore needs to be treated before it is released back to the atmosphere.

Scrubbers (usually venturi types) are used to collect chemical contaminants. The Casale process is able to recycle these from scrubbing liquors and is a zero liquid effluent process under normal conditions.

Dual pipe reactor process

Casale also acquired the dual pipe reactor process as part of its package of technology purchases from Borealis. This optimises the granulation process by installing a second pipe reactor – the dryer pipe reactor (DPR) – into the dryer, in addition to the GPR (Figure 2).

The DPR works in almost the opposite way to the GPR as it designed to produce a solid rather than a slurry. Being located in the dryer, and to avoid clogging, the mole ratio needs to be kept to around one during operations so that the DPR produces only solid monoammonium phosphate (MAP). This also means that no sulphuric acid is used in the DPR.

Otherwise, all of the other components of the NPK plant remain the same.

The dual pipe reactor process allows plant operations and output to be optimised.

Any increase in plant capacity typically requires the introduction of more raw materials. A large part of this additional feed will be liquid, so introducing more liquid into the granulator. Therefore, more solids also have to be recycled to the granulator to balance this and keep control of the granulation process. This generally means that full loop capacity (granulator, dryer, elevators, screens, crushers etc.) has to be increased too.

In the dual pipe reactor process, most of the phosphoric acid and the ammonia are fed directly to the DPR where they react to form MAP which is then recycled to the granulator. Essentially, the DPR – by supplying the granulation loop with extra MAP and allowing some N and P feed to be introduced directly as a solid – allows plant output to be raised without the need for extra loop capacity.

Also, because the neutralisation of phosphoric acid by ammonia is exothermic and takes place within the dryer, the heat produced by the DPR contributes to the drying of material. This contribution is so great that the DPR provides all of the heat for drying in some plants.

Operating experience

Casale's NPK process was not only licensed but also operated by Grande Paroisse for more than 30 years. Thanks to its great flexibility, the use of the Casale process at one particular 2,000 t/d plant has successfully produced more than 200 different NPK grades in a single year.

In total, more than 80 Casale licensed pipe reactors have been designed and operated worldwide. These have been installed in revamped as well as at grass-root plants. Revamps typically involve:

- Replacement of the pre-neutralizer with the GPR or dual pipe reactor process
- Addition of a DPR to a plant already equipped with a GPR
- A DPR was even added to a plant running with a pre-neutraliser, in one particular case.

Valuably, the shutdown times needed to implement the above revamp solutions are very short compared to the alternative option – the modification of the granulation loop. ■

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EuroChem's potash ramp-up

Aerial view of the VolgaKaliy mine site.

PHOTO: EUROCHEM

EuroChem Group's $2.1 billion Usolskiy project in Russia's Perm region is now fully operational, while work continues at its sister project, the $2.9 billion VolgaKaliy mine in the Volgograd region, to enable it to enter production in late 2020. We provide an update on the first phase of both projects and their scheduled ramp-up in production.

2018 saw EuroChem Group deliver on its ambition to break into the potash market as a world-scale producer.

In a landmark moment, the company's $2.1 billion Usolskiy mine and beneficiation complex in Russia's Perm region began test production in March last year. Some 253,000 tonnes of marketable product emerged from the mine during the course of 2018, as Usolskiy was successfully commissioned and production ramped-up.

Usolskiy is now fully operational and sales volumes have risen to almost 500,000 tonnes in the first half of 2019. EuroChem is projecting output of 1.14 million tonnes for the full year. Latin America has emerged as a major market for Usolskiy's potash output, accounting for just under two-thirds of this year's product sales. The site is forecast to ramp-up to its full nameplate capacity of approximately 2.3 million tonnes in 2020. The strong sales performance in Latin America reflected improvements in EuroChem's distribution capabilities and a surge in demand from second season planting.

EuroChem's even larger sister project, the $2.93 billion VolgaKaliy mine in the Volgograd region, remains on track to reach first production late in 2020. Work to develop the mine continues apace, despite geological difficulties, with the above ground production complex being on the verge of becoming fully operational. Small test batch production is already underway. These have proved that the plant is capable of producing the correct product grade.

Potash self-sufficiency and export goals

Developing the Usolskiy and VolgaKaliy potash mines is central to EuroChem's future growth ambitions. The company's strategic goals have been two-fold: firstly, to be self-sufficient in potash and, secondly, become a major global fertilizer producer and potash exporter. EuroChem also plans to maximise the benefit of owning an in-house, integrated supply of potash by channelling this into the manufacture of value-added/premium NK, NPK and SOP (sulphate of potash) fertilizers and other potassium-based products.

With more than 10 billion tonnes of potash ore reserves at its disposal, EuroChem's initial aim is to develop 4.6 million t/a of new 'greenfield' potash capacity in Russia with the first project phases at its two mines. The ultimate goal is to bring 8.3 million t/a of potash capacity on-stream by the end of 2025 through a second development phase at both Usolskiy and VolgaKaliy, equivalent to around 10 percent of world production.

A landmark year

EuroChem's breakthrough achievements in 2018 were highlighted by chairman Alexander Landia in the company's recently published annual report.

"Several notable milestones were passed during the year. With test production of potash underway at our Usolskiy mine in the Perm region, I am delighted to be able to say that we now have capacity across all three primary nutrient categories," said Landia. "We also began test production of potash at our VolgaKaliy site in the Volgograd region. Another highlight was the start of production from Russia's only urea ammonium sulphate facility at our Novomoskovskiy Azot plant."

Clark Bailey, head of EuroChem's mining division, added: "We are building a leading position in potash production through our two mines, which will yield some of the world's most competitively priced product and add a new dimension to our international presence."

Bailey continued: "The plant at Usolskiy made specification product right from the start. Customers have commented that the quality of the product is exceeding expectations, which is good to hear."

Employee numbers have been rising fast as a result of EuroChem's large-scale capital investment in new production capacity, both in Russia and the EU. The company now employs more than 26,000 people: "In 2018, we welcomed nearly 800 new colleagues across our Usolskiy, VolgaKaliy, and Kingisepp projects," observed Landia.

Mine development plans

Mining at Usolskiy takes place some 500 metre below the surface in a well-known Russian potash region, while the VolgaKaliy mine will operate at depths greater than 1,100 metres in a virgin potash deposit. In terms of geology, Usolskiy is targeting potash within a salt layer, whereas VolgaKaliy's development involves drilling and blasting down through a dolomite formation to the underlying potash deposit.

EuroChem's VolgaKaliy and Usolskiy mines have broadly similar development plans – despite their different depths and geology. EuroChem is developing both projects in two phases. The first development phase required the construction of cage shafts for mining crews and equipment and skip shafts to haul ore from the underground potash layer to the surface. A subsequent second phase expansion at both mines requires the construction of an additional skip shaft.

Potash mining equipment at both mines is also the same. *Ural-20R* mining machines, transfer hoppers and shuttle cars will be used to transfer ore to the main line conveyor systems at both mines:

- ***Ural-20R* mining machines:** these cut an arched roof 3.1 metres high and 5.1 metres wide. Each machine is approximately 12 metres long and weighs 100 tonnes. They are crawler-mounted and electrically-powered, each with an average annual capacity of around 600,000 tonnes.
- **Transfer hoppers:** these operate immediately behind the *Ural-20R* machines. Being electrically-powered, and approximately 8.4 metres long and 2.3 metres wide with a capacity of 16 tonnes, they are equipped with a conveyor system to transfer ore to waiting shuttle cars.
- **Shuttle cars:** these bring ore to the conveyor system, which in turn transports the ore to the shaft where it is lifted to the surface. The cars operates using a 220 metre-long trailing cable on a cable reel, allowing them to travel a distance of up to 400 metres. Each shuttle car is approximately 9.0 metres long and 2.6 metres wide, weighs 19 tonnes, and has a 17 tonne payload capacity.

Usolskiy project progress

The sinking of Usolskiy's 473-metre deep cage shaft and skip shaft was originally completed in October 2013 and August 2014, respectively. Mining crews finally entered the mine's two potash layers in October 2017 following fit-out, including the installation of hoists and headframes. Eight continuous mining machines then began working underground to excavate permanent drifts in early 2018.

The Usolskiy and VolgaKaliy mines both use *Ural-20R* continuous mining machine manufactured by **Kopeysk Machine-Building** in Russia's Chelyabinsk region. Each of these machines is capable of mining an impressive 600,000 tonnes of ore annually. Usolskiy currently employs 20 *Ural-20R* units and will add more over time to keep up with the proposed ramp-up and feed the mill.

A large-scale underground material handling system was installed at Usolskiy as mine development progressed. The system – which comprises of conveyors, loading bins and four large skips – is capable of hauling 30 tonnes of material per skip to the surface in around two minutes.

2018 also saw the completion of above ground construction work on the three main sections of beneficiation complex – grinding and flotation, drying and compaction, and thickening. The mine's water supply, heating and ventilation systems have been completed and certified. Boilers and other heating systems were also commissioned in readiness for winter in 2017/18.

Usolskiy was set to become operational at the end of 2017, slightly ahead of schedule, with the start-up of the first of its four production (flotation) trains. But the start of commissioning of the first flotation train was delayed by around two months, following a fire at the beneficiation complex in December 2017. However, fire damage repairs were completed quickly by mid-January 2018. This allowed the beneficiation system to be successfully filled with ore and brine by February last year.

Usolskiy's current status

Usolskiy entered production in March 2018 and by the end of last year capital expenditure on the project stood at $2.1 billion. All of the potash ore and the first of several finished product storages buildings were completed, as was the on-site rail loadout area. With production underway, wagon trains are being loaded with finished product and despatched from the station at Palashery.

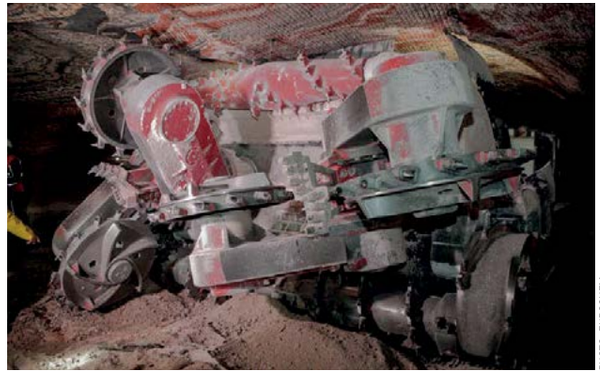

PHOTO: EUROCHEM

Ural-20R mining machine in operation at Usolskiy.

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Usolskiy project snapshot, Perm region

Key characteristics

- Proven and probable reserves: 420 million tonnes
- Mine life: +35 years
- Deposit depth: ~500 metres
- Deposit grade: 30.8 % KCl
- Distance to port: ~1,600 kilometres
- Test production was successful with marketable product becoming available in 2018

Phase I (completed)

- Full production capacity of 2.3 million t/a by 2021
- Involved the construction of cage shaft, skip shaft, beneficiation plant and associated infrastructure
- 2018/19/20 potash production targets are 250,000/1.14 million/2.3 million tonnes respectively

Phase II: (expected)

- Additional capacity of 1.6 million t/a
- Involves the construction of an additional skip shaft and expansion of the beneficiation plant
- Total estimated investment of $3.21 billion in both phases ■

VolgaKaliy project snapshot, Volgograd region

Key characteristics

- Proven and probable reserves: 492 million tonnes
- Mine life: +40 years
- Deposit depth: 1,147 metres
- Deposit grade: 39.5% KCl
- Distance to port: 500 kilometres
- Current production set to start in late 2020

Phase I (nearing completion)

- A gradual ramp-up in production capacity to 2.3 million t/a by 2025
- Involves construction of a cage shaft, skip shaft, beneficiation plant and associated infrastructure
- EuroChem expected VolgaKaliy to produce 130,000-140,000 tonnes of potash in 2020

Phase II: (expected)

- Additional production capacity of 2.0 million t/a
- Involves construction of third shaft and a second beneficiation plant
- Total estimated investment of $4.16 billion in both phases ■

EuroChem ordered 700 new wagons for Usolskiy from United Wagon towards the end of last year. These state-of-the-art wagons have already been delivered.

Each wagon has a volume of more than 100 cubic metres and is fitted with heavy-duty 25-tonne-axleload bogies, enabling it to carry approximately 77 tonnes. Their larger volume also lowers the centre of gravity of the wagons, making them more stable and difficult to overturn.

Wagon hatches are stamp-welded, improving durability and rigidity, and fitted with wear-resistant moulded rubber strip seals. The inside of each wagon is also protected from corrosion using a two-component polymer coating. The new wagons can be used for up to eight years, or one million kilometres (620,000 miles) between overhauls, says United Wagon. That compares with just two years or 110,000 kilometres (68,000 miles) for conventional wagons.

Fifteen continuous mining machines were in operation at Usolskiy by the end of last year, being deployed for both mine development work and potash production. In total, Usolskiy mined 1.38 million tonnes of ore and produced just over 250,000 tonnes of MOP (muriate of potash, KCl) in 2018.

Usolskiy's four production (flotation) trains have been commissioned in stages to ensure a continuous and smooth ramp-up. In a progress update, EuroChem confirmed that all four flotation trains are all now fully operational and that nine mining machines are extracting ore for production, as of August 2019. All three of Usolskiy's compaction lines have also now been completed and tested, and the final unit is now being commissioned.

Usolskiy's MOP capacity is projected to rise to around 1.14 million tonnes in 2019. 467,000 tonnes of MOP was produced and 389,000 tonnes delivered, as of the end of June, mainly to customers in the Americas and Europe. EuroChem now expects Usolskiy to reach its first phase design capacity of 2.3 million t/a by 2020. The company also says that – with minor equipment upgrades – the mine should achieve an output of 2.9 million t/a of MOP in the next two years.

EuroChem is committed to investing a further $1.1 billion in Usolskiy over the next five years. The project's second phase will add an additional 1.6 million t/a of potash product capacity – taking total MOP capacity to roughly 3.9 million t/a – and will require the construction of a third shaft, used primarily for skips.

VolgaKaliy project progress

EuroChem's VolgaKaliy project to mine the Gremyachinskoe potash deposit in Russia's Volgograd region has also continued to advance, both on the surface and underground. With proven and probable reserves of 492 million tonnes, the mine is predicted to have a useful life of over 40 years. The majority of the MOP produced at VolgaKaliy is destined for export – and will therefore be transported 500 kilometres (310 miles) by rail to EuroChem's Tuapse bulk cargo terminal on the Black Sea for onward shipment.

EuroChem is sinking three, seven-metre diameter shafts at Volgakaliy to a depth of more than a thousand metres – these providing the mine with a cage shaft and two skip shafts when completed. The two skip shafts will each be equipped with two 55 tonne skips able to convey potash to the surface at a hoisting velocity of sixteen metres per second. Each of the skip shafts will have a total annual hoisting capacity of 7–10 million tonnes. The mine's cage shaft has the capacity to hoist and lower 80 people or 25 tonnes of material.

Both skips shafts were fully excavated and connected in 2017, having reached their base level of 1,099–1,147 metres below ground. The two skip shafts will work in combination as a cage and skip during the first phase of the mine's development.

Following an inflow of water in the cage shaft in 2015, operational freeze plants are maintaining an ice wall around this shaft to a depth of about 820 metres. EuroChem subsequently extended the freeze wall in the cage shaft down to 838 metres in 2018 by drilling a second ring with additional freeze holes. The company will complete this extra protective barrier in early 2020.

Water ingress reoccurred in the cage shaft last December, according to EuroChem's 2018 annual report. This inflow is being eliminated by the drilling of a second ring of wells to deepen and strengthen the freeze wall.

Potash ore is currently being mined at the site but only in small batches, as shaft development continues and the site expands to actual production panels. Based on current progress, VolgaKaliy expects to begin continuous production in late 2020 or early 2021, according to the company.

By the end of 2017, crews at VolgaKaliy had excavated over 37,700 m³ of rock as part of the mine development process. More than 24,000 tonnes of potash ore had been excavated and placed in surface storage, as of February 2018. Above ground, the flotation plant reached the commissioning stage and produced its first concentrate in July 2018. EuroChem had expected VolgaKaliy to produce its first marketable potash by mid to late 2018, but difficulties in developing the underground mine through some dolomite layers slowed the pace.

VolgaKaliy's current status

Work to bring the VolgaKaliy mine into production continues apace. EuroChem recently reported that 35,000 tonnes of ore had been extracted underground and placed into surface storage, as of the end of June 2019, this translating into an equivalent 12,000 tonnes of finished MOP product.

VolgaKaliy's production plant is also now ready to enter operation. The front-end crushing and flotation units have both been commissioned, and are currently working in test mode to ensure product grade and quality criteria are being met.

Underground, the skip shaft is now complete, with hoists and skips installed, while the second shaft remains in use for mine development and for the transport of equipment and people. VolgaKaliy's shaft and plant design capacities for the first phase of operations remain as previously reported, at 10-12 million t/a of ore and 2.3 million t/a of finished product, respectively.

Due to geological difficulties, underground mine development at VolgaKaliy has been "somewhat slower than planned", admits EuroChem. Detailed analysis of 3D seismic surveys, plus the deployment of additional equipment and crews, are expected to improve the rate of mine development before the year is out.

EuroChem has invested $2.93 billion in VolgaKaliy to date and plans to invest a further $1.23 billion in the project over the next five to six years. The first phase of the project will see a gradual ramp-up to its full capacity of 2.3 million t/a of MOP by 2025. The planned two million t/a expansion of VolgaKaliy, as part of the project's second phase, will require the completion of the cage shaft and the construction of a new beneficiation plant. EuroChem says the newly installed freeze wall should allow VolgaKaliy's third shaft to be completed in 2025, increasing the project's potash ore mining capacity to more than 14.6 million t/a.

"The water inflow in the third shaft is not expected to significantly delay the current implementation of the project. The third shaft is not connected to the mine, so the water inflow will not cause flooding of the mine or any loss of reserves," comments EuroChem in its latest annual report. ■

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