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Fertilizer INTERNATIONAL

High performance nitrates

Innovation showcase

Ammonia and sulphur market report

P & K grinding equipment

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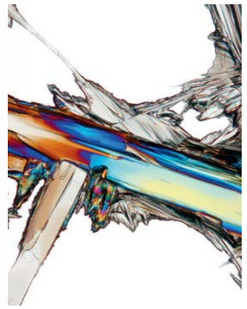

Cover: Microscopic view of potassium nitrate crystal. buccaneership/iStockphoto.com

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Becoming more inhibited

In 2019, the EU fertilizer market was valued at around €17 billion, with France, Germany and former member state the UK together representing 40 percent of this total.

These three countries also provide significant demand for urea, collectively consuming four million tonnes in 2019. Although modest by global standards, Western Europe still offers lucrative opportunities for urea producers, importers and traders. Indeed, the region as a whole consumes nine million tonnes of urea annually.

Yet some are asking whether clean air policy – namely the EU's 2013 Clean Air Programme and the UK's 2019 Clean Air Strategy – could eventually spell the end for standard commodity urea within Europe.

"There is no doubt among agronomists and fertilizer producers that enhanced urea fertilizers and urease additives will play a bigger role in arable farming because of the need to reduce ammonia losses under Europe's clean air goals," Julian Meehan, managing editor for fertilizers at ICIS, commented last year. "But not every market observer is convinced."

Germany has led the way. Despite consuming 2.2 million tonnes of urea in 2019, the EU's powerhouse economy has introduced a new fertilizer ordinance (Düngeverordnung) outlawing its straight use. This stipulated that, from 1 February 2020, urea could only be spread as a fertilizer if a urease inhibitor was added or worked in.

The new ordinance is designed to increase nitrogen use efficiency and reduce ammonia emissions. Its introduction has already changed fertilizer trade patterns in Germany by favouring calcium ammonium nitrate (CAN) over urea.

Germany's imports of CAN rose by 24 percent year-on-year (y-o-y) to 766,000 tonnes during July-November 2020 – the first five months of the European agricultural year. Urea imports, meanwhile, decreased by 18 percent y-o-y over the same period to 120,000 tonnes.

Now post-Brexit UK may be about to follow Germany's lead and ban the use of straight urea too. The UK's environment department Defra launched a three-month consultation on reducing ammonia emissions from urea in November last year. This set out three policy options for England:

- An outright ban on solid urea, the preferred option
- Only allowing urea treated with a urease inhibitor
- Restricting the application period for urea.

> **Fertilizer producer profits, in contrast, could potentially receive a £5 million boost from UK sales of inhibited urea, if this was mandated.**

Collectively, Britain's farms generate ammonia emissions on a large scale. Around 87 percent of UK ammonia emissions come from agriculture of which 18 percent is attributable to mineral (inorganic) fertilizer use. Solid urea also releases more ammonia than any other mineral fertilizer – contributing some eight percent to total UK ammonia emissions.

In 2019, the UK's Agriculture and Horticulture Development Board (AHDB) carried out its own scientific review of the nitrogen losses associated with urea use.

"Nitrogen losses from solid urea application can range from 10-58 percent," said Dr Sajjad Awan, a resource management scientist at the AHDB. "Urease inhibitors can be added to urea to slow down this process and consequently reduce volatilisation."

Reducing nitrogen losses from urea has the added benefit of making more nitrogen available to crops, thereby improving nitrogen use efficiency. In an economic analysis, the AHDB concluded that inhibited urea offered UK farmers a financially viable option for nitrogen fertilization, with a crop production cost (per kilo of grain) equivalent to ammonium nitrate.

The UK government calculates that mandating the sale of inhibited urea would add £70 million to nationwide farming costs over the period 2022-2030. This works out at an average cost per farm of £1,085, or just over two percent of average farm income. Fertilizer producer profits, in contrast, could potentially receive a £5 million boost from UK sales of inhibited urea, if this was mandated.

The UK consumes just under 600,000 tonnes of urea annually. The British government expects that England's farmers would mainly switch to ammonium nitrate (AN) if a total urea ban was imposed.

The UK imported £207 million worth of urea in 2018, with most of this sourced from Germany, Egypt and Russia. In the short term, the extra demand for AN created by banning urea would be partly met by reducing Britain's AN exports, these being valued at £27 million in 2018.

The UK consultation on ammonia emissions closed at the end of January and the government's response is currently awaited. Whatever the decision, the UK and EU member states are likely to continue their shift away from standard urea to nitrates (page 28) and/or enhanced efficiency fertilizers (page 20).

Simon Inglethorpe, Editor

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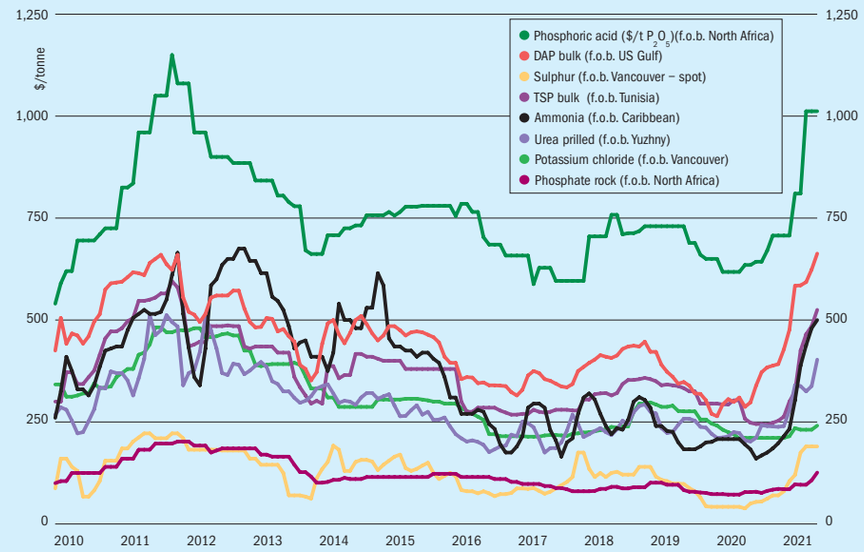
Market Insight

Historical price trends $/tonne



Source: BCInsight

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: Much of the urea market was on hold in late June as prices from the Indian RCF tender were awaited. Rumours that offer prices were all above $500/t cfr suggests the wait will have been worthwhile for suppliers. If confirmed, this would mark a new upward step in prices and reflect China and Middle East f.o.b levels above $470/t.

West of Suez, buyers are also expecting a new round of price hikes, despite the market having been inactive. This is due to another jump in freight rates from ports of origin in the Middle East, FSU and Mediterranean, as well as higher f.o.b. prices.

Key market drivers: availability for the RCF tender in India, government pressure to curtail exports in China and recent flat prices in Brazil.

Ammonia: Hopes of a slowdown in the price rally over next few weeks were confounded by a $50/t rise in the Tampa contract price for July shipments. Cargoes continue to be lined up from suppliers in the west for shipment to customers short of product in east Asia. Buyers remained out of the market towards the end of June while they weighed up their options and the prospect of the current tightness continuing into August.

In the absence of official information about how long exports will be affected by Ras al Khair's shutdown in Saudi Arabia, traders are preparing for the Middle East region to be below capacity until August. This would leave Saudi buyers needing to buy more spot ammonia, a situation which is supporting delivered offers above last business done.

Key market drivers: the rise in the Tampa ammonia contract price to $585/t cfr, the continuing Middle East outage and Ukraine exports being under threat.

Phosphates: New sales to major end markets have continued despite liquidity slowing towards the end of June. Indian DAP prices jumped following a sale by Saudi Arabia's Ma'aden at $590/t cfr. Indian importers remain constrained, however. Comparatively low domestic prices are setting the break-even price for imported DAP at $560s/t cfr. Bangladesh increased the volume of its private sector DAP purchase tender by 100,000 tonnes to 850,000 tonnes. China is expected to supply all of these lots.

Brazilian MAP prices firmed to $753-758/t cfr – up by around $8/t – on sales of Russian and Moroccan MAP. Barge prices in the US remained flat in the latter part of June.

Key market drivers: JPMC signing a supply agreement until 2022, China's January-May DAP exports hitting new highs and another jump in raw material prices.

Potash: Granular MOP prices in Brazil and the US rose significantly in late June, while those for standard MOP edged up in southeast Asia. These increases occurred despite the market being partly on hold – Europe almost entirely so – as the outcome of EU deliberations over Belarus sanctions was awaited. Offers dried up as producers stepped back from the market on hopes of making gains from tight supply.

Key market drivers: the EU's economic sanctions on Belarus, Nutrien's further output increase and Salt Lake Potash preparing for August SOP exports.

NPKs: The prospect of EU sanctions on Belarus dominated NPK market discussions in late June. Most producers abstained from offering product as they awaited exact details of the sanctions. At present, the consensus is that their arrival will make potash shortages inevitable for a number of NPK manufacturers in the EU, and that potash prices in Europe will rise as a result. This, in turn, will push up NPK production costs and potentially tighten NPK supply.

The global NPK market remains firm with news of the sanctions adding to existing bullish sentiment. Prices have continued to rise following a fresh 15-15-15 sale by PhosAgro to Brazil at $485/t cfr, this netting in the low/mid- $440s/t f.o.b. This agreed price is up by $25/t from the firm's previous sale to Brazil in early June. Acron recently sold more than 10,000 tonnes of 16-16-16 to southeast Asia at $510-515/t cfr, up from $460-490/t cfr earlier in June.

Key market drivers: the continued rise in raw material prices and expectation of Brazilian demand remaining strong through August.

Sulphur: Quarterly supply contract negotiations are continuing with most parties still engaged in talks. Initial numbers quoted to traders were at $170/t f.o.b. for Middle East tonnages. At late June's elevated freight rates, this would work out at around $217-219/t cfr south China and $222-225/t cfr river.

Some third-quarter contract tonnages for the Brazilian market were concluded in the range $221-235/t cfr. These are thought to have been sourced from the Middle East and the FSU.

Eastern markets have recently seen a slowdown in demand and easing of supply, while the west remains in tighter balance. Contracted exports from both Kazakhstan and Russia will be limited in the forthcoming quarter. This is expected to increase east to west trade flows, albeit at higher freight costs.

Key market drivers: reports of Middle East third-quarter price levels and emerging Brazilian third-quarter cfr numbers.

OUTLOOK

Urea: Supply tightness for July makes further price increases likely, especially east of Suez. A lull is expected in other parts of the market as prices catch up to the levels set in India and North Africa at the end of June. Price support is likely to be found again in late July when Indian tenders resume.

Ammonia: August should provide some opportunity for respite and lower pricing – if Saudi production starts to ramp-up again. While the outlook through to the end of August remains generally firm, there is scope for prices to stabilise as markets in the east and west become more balanced.

Phosphates: A variety of factors continue to fuel DAP price sentiment. These include fears of an export tax in China, rising Bangladesh purchase volumes and remaining Indian buying. West of Suez, buyers are hoping to see the upwards price momentum slow. But further price increases remain likely in coming weeks due to tight supply and producer discipline. The sizeable tonnages needed by Argentina and Brazil during the third-quarter are expected to support prices. The latest surge in crop prices could also drive up MAP prices further in Latin America.

Potash: The potash market remains firm. The combination of tight supply and patient suppliers has left buyers chasing MOP. Consequently, sellers are in a strong position to dictate prices in upcoming sales. Market conditions also likely to prompt a rise in SOP prices for third-quarter business.

Prices will continue to rise globally, though at different rates. There is some evidence that demand erosion is already taking place at current price levels. This could relieve some of the persistent supply tightness by causing sales levels to plateau.

NPKs: Suppliers will continue to raise NPK prices while there is no sign of the upwards trend in raw material prices relenting. Suppliers may find their options narrowing, however, as buyer resistance to rapidly increasing prices is growing. For now, several markets are accepting higher price levels due to concerns about future price hikes and potential product shortages.

Sulphur: Rising freight rates continue to be a complicating factor. This has resulted in the conclusion of lower-priced f.o.b.-based business on Middle East cargoes in recent weeks. Fundamentals do, however, remain largely supportive, despite this slight downward correction to f.o.b. pricing. This correction is expected to balance out the market by accounting for freight costs increases. The upshot is a soft-to-stable market at somewhat lower f.o.b. levels – while cfr levels will vary depending on freight costs. ■

Market price summary $/tonne – End June 2021

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	485-525	-	f.o.b. E. Europe 140-165	f.o.b. US Gulf	656-685	-	-
f.o.b. Yuzhny	490-530	390-435	-	f.o.b. N. Africa	535-650	500-550	960-1,063
f.o.b. Middle East	550-610	435-470**	-	cfr India	575-600	-	998*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	202-280	-	cfr US Gulf	135-185	f.o.b. Vancouver	180-200	-
f.o.b. Middle East	230-285	-	-	-	f.o.b. Arab Gulf	183-200	-
f.o.b. Western Europe	-	490-550	-	-	cfr N. Africa	170-200	-
f.o.b. Baltic	220-290	-	-	-	cfr India	206-232+	-

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.*

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KENYA

African renewable power-to-fertilizer plant

Preliminary engineering work has started on a renewable power-to-fertilizer plant in Kenya.

The plant is being built by three Maire Tecnimont subsidiary companies – MET Development, Stamicarbon and NextChem – at the Oserian Two lakes Industrial Park, near Lake Naivasha, 100 kilometres north of the capital Nairobi. It will have the capacity to produce 550 t/d of calcium ammonium nitrate (CAN) and/or NPK fertilizers, as required.

According to Maire Tecnimont, the plant will support low-carbon growth in Kenya and boost the country's agricultural output by providing fertilizers for local smallholder farmers and communities. It is expected to create over one hundred direct jobs in the Lake Naivasha region.

The project's announcement in May coincided with Stamicarbon's launch of its new Stami Green Ammonia Technology package. This will eliminate carbon from fertilizer manufacturing and promote sustainable and green production by substituting renewable resources for fossil fuels.

Stamicarbon is providing both its new Stami Green Ammonia technology and existing nitric acid technology as an integrated package for this innovative, first-of-its-kind fertilizer plant. The pioneering small-scale Kenyan project will also be modular in construction and design.

NextChem plans to start the front-end engineering design (FEED) on the project by the end of this year. MET Development is also setting up a development consortium for the project currently with local and international partners. The ultimate aim is to finish the plant and start commercial production in 2025.

The production plant, which is located next to Kenya's largest geothermal energy basin, will require around 70 MW of renewable power. It will also be partly powered by on-site solar electricity generation. Switching to production based on renewable power is expected to cut carbon emissions by 100,000 t/a, compared to an equivalent gas-based fertilizer plant.

On completion, the plant's fertilizer output should reduce Kenya's import dependency on nitrogen fertilizers by around 25 percent, as well as improving fertilizer affordability domestically.

Pierroberto Folgiero, Maire Tecnimont's CEO, said: "We are very pleased to announce the start of this exciting project… with a pioneering player such as Oserian Development Company. We aim to unlock the potential of decarbonising the fertilizer industry using renewable energy as a feedstock. Kenya has a unique potential to provide renewable energy, making it an ideal location for local green power-to-fertilizer production, replacing imports of nitrogen fertilizer."

Folgiero added: "With this very promising initiative, we confirm our expertise in project development in green energy, by acting as an end-to-end developer and technological integrator capable of connecting the key factors which are necessary to industrialize the green economy globally".

Stami Green Ammonia Technology is the outcome of an exclusive cooperation deal by Stamicarbon to commercialise the small-scale ammonia technology package offered by Argentina-based Raybite S.R.L. The agreement means that Stamicarbon is now an ammonia technology licensor for small-scale plants. This new capability for ammonia adds to and complements its existing urea and nitric acid technology portfolio.

As well as being suitable for new builds, Stami Green Ammonia Technology can be installed at currently operating plants as a hybrid solution to help make existing fertilizer production more sustainable. Fertilizer producers will have the choice of using the technology in combination with either urea and/or nitrate fertilizer production.

"The world is demanding accelerated cooperative climate action to reduce emissions and Stamicarbon is determined to be part of the solution," said Pejman Djavdan, Stamicarbon's managing director. "Our new Stami Green Ammonia Technology plots a clear course towards green fertilizer production from nature's elements – solar, wind energy, hydrogen from water – instead of fossil fuels and nitrogen from the air. It represents a significant leap forward for sustainability within the fertilizer industry, while also offering exciting opportunities for collaboration between the fertilizer and energy markets."

The technology condenses ammonia without the need for a large dedicated refrigeration compressor. This should improve plant reliability and deliver substantial capex savings. Four plants are currently operating with this innovative, small-scale technology, in addition to the newly-announced renewable power-to-fertilizer plant in Kenya.

RUSSIA

Shchekinoazot partners with Stamicarbon on sustainability

Russian chemical company Shchekinoazot and Stamicarbon are collaborating on sustainable fertilizer production.

In a memorandum signed in May, the two companies have agreed to "jointly explore, develop and implement green technologies at Shchekinoazot's existing and new enterprises in the Russian Federation, with the common goal to contribute to sustainable fertilizer production", Stamicarbon said in a statement. Both parties have pledged to assist one another in the development and commercialisation of green technologies.

Installing sustainable technologies at Shchekinoazot's urea and other fertilizer plants in Russia will be the main priority. These could potentially include Stamicarbon's Ultra-Low Energy technology, *MicroMist*™ Venturi Scrubbing systems and its new Stami Green Ammonia technology (see above).

Pejman Djavdan, CEO of Stamicarbon, said: "We are committed to the development of technologies for green fertilizers, decreasing the environmental footprint of fertilizer production and use. In partnership with Shchekinoazot, I'm sure we will greatly contribute to the implementation of these new technologies and intensification of sustainable agriculture."

Pierroberto Folgiero, the CEO of Stamicarbon's parent company Maire Tecnimont, added: "Stamicarbon is at the forefront of innovation in the fertilizer industry, and as such it is best positioned and equipped to set the pace for the development of technologies to support the energy transition. I am glad that an industry leader such as Shchekinoazot has selected Stamicarbon as the partner of choice to industrialize sustainable fertilizer production."

Boris Sokol, Shchekinoazot's president, also welcomed the new partnership: "We attach greater importance to environmental issues, by minimizing our environmental impact, reducing the carbon footprint of our activities and taking care of the local environment. The signed memorandum will allow us to take another step towards state-of-the-art technologies and approaches aimed at the preservation of natural diversity and a healthy planet for future generations."

UNITED ARAB EMIRATES

Abu Dhabi to build blue and green ammonia plants

ADNOC is pursuing plans to build a large-scale 'blue' ammonia plant at its Ruwais complex in Abu Dhabi.

Blue ammonia combines the conventional manufacture of ammonia from natural gas with carbon capture and storage. ADNOC's one million t/a capacity project, which has now moved to the design phase, will be located at the new Ta'zizz industrial and chemicals hub at Ruwais. Wood Group has been engaged to perform the pre front-end engineering and design (FEED) work for the blue ammonia plant.

ADNOC is already a major regional hydrogen and ammonia manufacturer, producing more than 300,000 t/a of hydrogen at its Ruwais complex.

The new project is part of ADNOCs' strategic move into the hydrogen-based economy and hydrogen infrastructure. In November 2020, the United Arab Emirates' Supreme Petroleum Council gave ADNOC the mandate to pursue opportunities in hydrogen and hydrogen carrier fuels, including blue ammonia, with the aim of positioning the UAE as a market leader. ADNOC has moved swiftly to sign a number of provisional hydrogen supply agreements with potential customers in recent months.

The construction of a green ammonia production plant at the Khalifa Industrial Zone in Abu Dhabi (KIZAD) has also been announced. This project will generate hydrogen from solar power for sale into both regional and international markets.

Once completed, the project will produce 200,000 t/a of green ammonia from 40,000 t/a of green hydrogen. Helios Industry, a privately-owned investment company, will invest more than $1 billion in the plant's construction over several years, according to KIZAD.

CANADA

BHP delays Jansen final investment decision

Australian mining giant BHP has put back the final investment decision (FID) for its partially completed Jansen mine project.

An announcement on whether to fully implement the potash mega project, located in Canada's Saskatchewan province, had been expected mid-year. However, the decision has now been postponed while the company reviews two potential port options. BHP says it will firstly decide which port to choose "in the coming few months", *Reuters* reported, before taking the Jansen project to its board for the long-awaited FID.

"We are considering two options in terms of the port. One is a commercial option at the port of Vancouver, one is a greenfield option," said Ragnar Udd, president of BHP Minerals America. "We would

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like to have those locked in before we take them to the board."

BHP has yet to fully commit to completing construction of the Jansen project. This is despite having already invested $4.5 billion sinking two mine shafts to a depth of 1,000 metres.

If approved, turning Jansen into a fully functioning 4.4 million tonne capacity potash mine, under the project's first phase of development, is expected to cost a further $5.7 billion. Given the current uncertainty over its future, Jansen is unlikely to enter production and start adding to global potash supply until 2026 or 2027 at the earliest.

The announcement of a delay in the final investment go-ahead for Jansen followed news that BHP, the world's biggest miner, was in talks with Canadian fertilizer giant Nutrien about a potential partnership for the massive Saskatchewan potash project.

Reuters reported in May that the two companies were discussing two options. These included Nutrien either becoming Jansen's operator – and selling the potash through its existing channels – or taking an investment stake in the mine to help fund its completion. However, these discussions have not been officially commented on or verified by either company.

Nevertheless, a BHP-Nutrien deal could help create greater price certainty for major potash producers, according to analysts. "[It] keeps new tonnes marketed within the existing global structure," Bloomberg Intelligence analyst Jason Miner told *Reuters*. "A potential Nutrien deal could lift the cloud BHP's Jansen mine has long cast over this market."

Nutrien has been a vocal critical of the Jansen project previously, warning that its development could flood the market with excess potash. Chuck Magro, Nutrien's previous CEO, said last year that building a new potash mine did not make economic sense and that the Jansen project would be a "sure-fire way to destroy shareholder value".

New incoming CEO Mayo Schmidt, in contrast, has struck a more emollient tone. He has stated that future rises in potash demand should be able to soak up new large-scale supply sources like Jansen, if producer discipline was maintained.

"I think… they [BHP] are a disciplined organisation that operates around the world as we [do] – and we approach these markets in a thoughtful way," Schmidt said recently. "We really think that the growth in [potash] demand is going to take up any … disciplined approach to the market."

He added: "We see [demand] growth of about 2 to 3 percent over the next ten years. So if you do the math on that, it is about 14 to 23 million metric tonnes of additional demand over the course of the next ten years."

BHP's leadership still views potash as potentially integral to its future business plans.

"We continue to like potash. We think the long-term demand and supply fundamentals for potash are attractive," BHP's CEO Mike Henry told a conference in May. "We've always said we're open to partnering, but the project doesn't need a partner to proceed."

New sulphur-enhanced urea plant

Northern Nutrients has started constructing a sulphur-enhanced urea plant at its premises in Saskatoon, Saskatchewan.

The plant will use Shell's proprietary *Thiogro* process to incorporate micronised elemental sulphur into urea. Construction began in July with completion expected early next year. The plant's production capacity was not disclosed.

Northern Nutrients is co-owned by Ross Guenther, the company's president, and Matt and Rob Owens of Saskatchewan-based Emerge Ag Solutions. The company has been importing sulphur-enhanced urea for several years and widely distributing this to retailers in Western Canada. The new production plant will provide Northern Nutrients with the capability to produce this product domestically from next year.

"The adoption of the product and the anticipated increasing demand has convinced us to manufacture our own form of the sulphur-enhanced urea in Canada," said Ross Guenther.

Matt Owens added: "We first tried the sulphur product three years ago, and all our growers who have tried it have increased their acres and moved all of their sulphur requirements over to the Shell micronized sulphur urea product. They like the product (11-0-0-75) because it is readily available to the plant early and throughout the growing season, it mixes well in any dry blend, and it has a low salt index compared to other forms of sulphur."

Rob Owens was excited to be bringing sulphur-enhanced urea to dealers and farmers in the west of Canada. "The lower salt index is important in our area, and I also like that it is much less dusty than ammonium sulphate," he said.

Curtis Bowditch, a farmer from Tisdale, Saskatchewan, has been using the sulphur-enhanced urea for three years. He was also enthusiastic: "The seed safety of the product was a game changer for our farm and allows us to get both our phosphorus and sulphur in the seed-row for the first time. Logistically it was a huge time saver."

AZERBAIJAN

New Caspian Sea fertilizer terminal

The port of Baku in Azerbaijan has started constructing a new fertilizer terminal at Alat on the Caspian Sea.

The strategic terminal is being jointly financed by the port and the government of Azerbaijan. It is expected to be commissioned by the end of 2022. The port authority plans to lease the terminal and is currently negotiating with potential bidders over a long-term concession.

The new terminal will have the capacity to handle 2.5 million t/a of fertilizers and includes two warehouses with a total capacity of 60,000 tonnes. It will also incorporate state-of-the-art conveyor systems to load/unload fertilizers directly to warehouses or into rail hoppers at a newly designed wagon loading station.

The investment decision and go-ahead for the project came after a feasibility study revealed significant potential for transhipment of fertilizers from landlocked Central Asian countries to western markets via Azerbaijan.

Three Central Asia states – Turkmenistan, Uzbekistan and Kazakhstan – all generate high volumes of fertilizers from large scale production plants. The three countries have a combined annual production capacity in excess of 6.6 million tonnes for commodities such as urea, sulphur and potassium carbonate. This includes the recently inaugurated Garabogaz fertilizer plant on the eastern shore of the Caspian Sea in Turkmenistan. Garabogaz alone produces 1.2 million t/a of urea, with more than 90 percent of this output intended for export.

"The volume of Central Asian – primarily Turkmen – fertilizers transshipped via the port of Baku has increased more than 13-fold between 2018 and 2020, from 48,339 tonnes to 630,000 tonnes – and the trend is accelerating," said Taleh Ziyadov, the port of Baku's director-general. "In the first 5 months of 2021, we handled more than 450,000 tonnes of fertilizers. A new terminal will ensure reliability in Central Asia's fertilizer supply chain and allow us to increase volume from Turkmenistan, Kazakhstan and Uzbekistan."

AFRICA

Acron develops NPKs for the African market

Russia's Acron Group has developed four new complex NPKs tailored for cereal crops grown in West and East Africa

The new formulations (23-10-5+S+Mg+Zn, 23-9-6+S+Ca+Mg+B, 22-20+S+Ca+Zn, and 20-10-10+S) are perfectly suited for growing most cereals in the region, according to Acron, particularly maize, wheat, and barley.

The new NPKs were developed following a comprehensive review of African farming methods. They are being manufactured at Acron's Veliky Novgorod site in Russia. The company has already shipped more than 25,000 tonnes of the new formulations to countries in the region, as of the end of April.

Acron's NPK fertilisers are designed to release nutrients quickly to the soil, despite the arid African climate, ensuring excellent crop yields. The new NPKs provide balanced nutrition by offering additional secondary nutrients (calcium, magnesium, and sulphur) alongside micronutrients (zinc and boron). They also have minimal effects on soil acidity, an important consideration in many African countries where soil acidity is already high.

Dmitry Khabrat, Acron's overseas vice president, linked Acron's product development process with changing African farming practices and increasing demand.

"As farming methods in Africa evolve, and Acron's product portfolio expands, we will continue to develop new brands of complex fertilisers to meet highly specific local demand," Khabrat said. "Our company has supplied products to the African market for many years and I believe that – as new complex fertiliser brands with extra nutrients and microelements emerge – we will expand our sales geography on both coasts of the African continent."

WORLD

Dry bulk freight rates surge

Freight rates for dry bulk fertilizers have continued their year-long upwards surge, hitting new heights in the last week of June.

The average freight rate for fertilizers jumped to $48.34/t, Argus reported in late June, a rise of $3.50/t in one week. The Argus average rate is based on a basket of 19 selected fertilizers. These are spread across major shipping routes for urea, phosphates, NPKs, potash and sulphur.

The average freight rate has almost doubled since the start of 2021, Argus noted, having increased by $23.95/t. Rates have, in fact, been rising since the middle of 2020, more than reversing the slide of the previous six months. They continued to surge throughout 2021's first-quarter, driven upwards by factors such as improving global trade, iron ore demand in China and icy conditions in Baltic ports, according to Argus.

Rates subsequently dipped in mid-March, then stabilised in mid-April, before rallying again to new highs in June. Grain exports from Latin America and the US Gulf have propped up Atlantic rates. East of Suez, demand from northern China for Australian iron ore shipments has also pushed rates higher, suggested Argus, in combination with coal-vessel fixings and increased bunker fuel prices. ■

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People

The International Fertilizer Association (IFA) elected **Svein Tore Holsether** as its new chair on 14th June. He replaces **Mostafa Terrab**, the chairman and CEO of OCP Group. IFA said Holsether, who is the president and CEO of Yara International, would continue the fertilizer industry's commitment to sustainability.

"I am honored to be appointed Chair of IFA because the fertilizer industry has a key role in finding sustainable solutions to some of the greatest challenges the world is facing," Holsether said. "As an industry, we need to lead the way to decarbonise food and build resilient and fair food systems."

IFA also confirmed a number of other appointments and changes to its executive board. **Dmitry Konyaev**, the chair of Uralchem, is the association's new vice chair. He will serve alongside Svein Tore Holsether on IFA's executive board of directors. The executive board also welcomed two new appointments: **Jeanne Johns**, managing director and CEO of Incitec Pivot Ltd, and **Tony Will**, president and CEO of CF Industries. Mostafa Terrab, as the immediate past chair, will remain on IFA's executive board, as will **Zhai Jidong**, vice president international for Kingenta, and **Alzbeta Klein**, IFA's director general.

The following five new board directors were also elected by IFA's membership:

- **G David Delaney**, CEO, Itafos
- **Ahmed El-Hoshy**, CEO, OCI NV
- **Shakeel Ahmad Khan**, CEO, Petronas Chemicals Marketing
- **Suresh Krishnan**, managing director, Paradeep Phosphates Ltd and Mangalore Chemicals and Fertilizers
- **Mayo Schmidt**, president and CEO, Nutrien.

Jumana Saleheen.

IFA members also re-elected **Raviv Zoller**, the president and CEO of ICL Group, to the board of directors.

Dmitry Mazepin took over as the CEO of Uralchem on the 12th May. Mazepin was previously Uralchem's chairman, a position he has held since 2007. He replaces **Sergey Momtsemlidze** who has become the company's nitrogen production director.

"A fundamentally new stage in the development of Uralkali and Uralchem has begun. Our traditional business is being modernized and I would like to lead these changes to ensure an effective strategy for the long-term growth of Uralchem and Uralkali. Returning to direct control of the entire chain of operations will allow me effectively and as quickly as possible to join forces to promote Russian fertilizers on the world stage, as well as to form a convenient platform for providing a full range of agrotechnical and climate-neutral services in the Russian market," Mazepin explained.

In a coordinated move, **Dmitry Konyaev**, the previous deputy chairman and former CEO, was appointed as Uralchem's new chairman.

London-based commodity research company CRU launched a new sustainability division in mid-June. Named CRU Sustainability, it will focus on four areas: climate policy and regulation; carbon emissions and markets; the clean energy transition; and the circular economy.

"CRU is bringing together all its sustainability expertise into one division and, in so doing, launching a unique service designed to give clients in the industries CRU serve, the much-needed data and insights to accelerate their journey to net zero," CRU said in a statement.

The new division will be led by **Jumana Saleheen**, who will also remain in her current post as CRU's chief economist. Dr Saleheen brings over two decades of experience to her role as head of CRU Sustainability – having previously worked at the Bank of England and the Federal Reserve Bank of Boston.

"I am pleased to appoint Jumana as Head of CRU Sustainability. As Chief Economist at CRU Group, Jumana has become an important voice in the industry. Her background in policy making and data analysis makes her the ideal person for this role. CRU Sustainability will play a vital role in enabling all stakeholders in the commodity industry to take bold action, and successfully transition to a low-carbon world," said Robert Perlman, CRU's executive chairman. ■

Calendar 2021

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

SEPTEMBER

20-22

TFI World Fertilizer Conference 2021, BOSTON, USA
Contact: Mariana Gallo
Tel: +1 202 962 0490
Email: mgallo@tfi.org

20-23

CRU Sustainable Fertilizer Production Technology Forum – **Virtual event**
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

27-29

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

OCTOBER

20-22

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

NOVEMBER

15-17

IFA Strategic Forum, KIGALI, Rwanda
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

MARCH 2022

21-23

Argus/CRU Fertilizer Latino Americano 2022, MIAMI, Florida, USA
Contact: Argus Media
Tel: +44 (0)20 7780 4340
Email: conferences@argusmedia.com

Sleepwalking to failure?

One year on from the launch of its Farm to Fork Strategy, the European Commission is still failing Europe's farmers, says **Igor Shmidt**, EuroChem Group's head of public affairs.

The European Commission is sleepwalking towards a sustainable-farming failure.

Unless the Commission revises its Farm to Fork Strategy, launched in May last year, by offering farmers real incentives to adopt smart fertilization practices, it will have no hope of achieving its stated goal of reducing agriculture's impact on the environment. The slow pace of Common Agricultural Policy reform has made the need for progress even more urgent.

The much-trumpeted Farm to Fork Strategy will be a dead end for Europe's agricultural sector if it continues on its current path. All hopes are pinned on the willingness of Member States to pass the Commission's vague and uncertain recommendations on mitigating nutrient losses into national laws. This is a fundamental flaw.

Reliable information on nutrient losses

Mitigating nutrient losses is a noble and valid goal – one that the large majority of Europe's farmers support, as it would mean reducing the inefficiencies of existing fertilizers. Maximising the amount of nutrients taken up by plants, while reducing the amount that escapes into the water table or into the air, clearly benefits both farmers and the environment.

Nevertheless, the interplay between fertilizer uptake and environmental escape is hugely complicated – varying significantly between different landscapes, soil types, ecosystems and agricultural production systems. Because of this, only a few EU Member States are reliably measuring their nutrient losses at present. These include countries such as France, Italy, and Germany which also farm the most efficiently.

If the European Commission wishes to pass EU-wide legislation to reduce nutrient losses, while at the same time maintaining the economic viability of Europe's agricultural sector, these proposals need to be backed by reliable information. Specifically, the Commission must undertake detailed data gathering studies. These are required to determine the appropriate and exact level of nutrient loss reduction for each Member State. It also needs to come forward with solutions for achieving this objective and agree to provide the necessary support.

Avoiding negative economic impacts

Regrettably, the European Commission has shied away from presenting its own comprehensive impact assessment of the Farm to Fork Strategy, while being critical of other institutions, such as the US Department of Agriculture (USDA), that have willingly undertaken such studies. Worryingly, the USDA study found that the European Commission's proposals will result in severe negative economic impacts.

As things stand, the European Commission is conveniently washing its hands of any responsibility for gathering baseline data or providing farmers with practical solutions. Instead, current plans to provide Member States with a set of vague recommendations will have perverse and unfortunate consequences. The Commission is, in effect, punishing those farmers wishing to achieve high levels of nutrient use efficiency, while giving free rein to those unwilling to take action to avoid over-fertilization. After one year of intense debate, Europe's farmers still have more questions than answers about the Farm to Fork Strategy.

The need for leadership and action

The European Commission is still able to bring about real change for every one of the bloc's 10 million farmers – if it acts now with leadership and certainty to address nutrient losses. An appropriate first step would be to work with farmers to identify and promote smart farming practices, including the use of enhanced efficiency fertilizers (EEFs) with financial incentives to boost their adoption. This would garner significant support from the farming community.

Two specific actions that would make many of the farmers we work with change their behaviour tomorrow are:

1. **Undertake a comprehensive impact assessment** of the entire Strategy, as previously promised by the European Commission. This would allow Europe's farmers to gain a much better understanding of how they will be affected by the Strategy – so enabling them to begin adapting their operations to mitigate any potential downsides.
2. **Implement a financial incentives programme for farmers** to boost their use of enhanced efficiency fertilizers (EEFs). This would help meet the Strategy's objectives and be informed by the impact assessment. Farmers could, for example, be encouraged to purchase EEFs by slashing VAT on these products. Additionally, the Commission could rewards farmers with climate credits under carbon farming programmes to encourage the uptake of inhibitors or other smart fertilization technologies.

Still time to wake up

The European Commission has already shown its willingness to listen to the concerns of Europe's farming community by changing some of the original proposals in the Farm to Fork Strategy. For example, we applaud its decision to drop the blanket proposal for a fixed quantitative reduction in fertilizer use. Almost inevitably, this would have led to the conversion of pristine land into arable land to maintain food supply levels.

We are simply asking the European Commission to show the same flexibility and dynamism on the issue of nutrient losses and fertilizer efficiency. The fertilizer industry is willing to work collaboratively with the Commission to develop an informed, balanced and wholly practical approach – delivering policies that address climate concerns *and* benefit Europe's farming communities.

By being alert to the solutions already on the table – as well as being agile enough to adopt them – the European Commission still has time to awake from its somnambulism and steer European agriculture towards a sustainable future. ■

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CRU Sustainable Fertilizer Production Technology Forum

During this time of disruption, keeping connected and informed has never been more important. While the in-person events the industry usually relies on are not possible, CRU's virtual Sustainable Fertilizer Production Technology Forum, 20-23 September, offers exceptional information sharing and networking opportunities.

Across the industry, technology is transforming how fertilizers are being produced by reducing the carbon footprint and environmental impacts associated with their manufacture. With this in mind, CRU Events is pleased to announce the Sustainable Fertilizer Production Technology Forum – a new virtual event entirely devoted to driving sustainability through technology.

The forum, which runs from 20-23 September 2021, will focus on the technical aspects of sustainability and the role of environmental, social and corporate governance (ESG) in fertilizer production. It will bring together technical and sustainability experts from across industry together for the first time.

Delivering net zero and the circular economy

The four-day programme will highlight new innovations and advances in decarbonisation, emissions reduction, energy savings and production sustainability – and will cover both nitrogen and phosphate fertilizer manufacturing.

Launching the forum, CRU Events said: "The fertilizer industry is at a defining moment, facing the need to accelerate advances in emissions abatement, energy efficiency and environmentally sustainable production, in order to deliver net-zero carbon production and embrace the circular economy.

"This cross-nutrient event will cover the production of nitrogen, syngas and phosphates. Content will be primarily technical, focusing on new innovations in sustainable fertilizer production, as well as showcasing existing and updated technologies that improve energy efficiency and environmentally sustainable production in existing production assets."

"Alongside the technical content will be thought-provoking presentations from industry experts and CRU's analysis and consulting teams, outlining the key drivers including economics, regulation, policy and investment.

"This is a fantastic opportunity to showcase your organisation's products, services and expertise in this emerging space."

TECHNICAL AGENDA

The forum's technical programme will encompass two key themes:

- **Investing in innovation:** This will explore the future of sustainable fertilizer production and the industry's role in the energy transition, decarbonisation and the circular economy.
- **Greening existing assets:** This will focus on the deployment of new technology at existing production plants to boost energy efficiency, reduce emissions, and improve water and waste management.

CRU is welcoming presentations on the following subjects:

- Green and blue ammonia/hydrogen technology
- Carbon capture utilisation and storage (CCUS)
- Advances in energy efficiency
- Water and effluent treatment technology
- Phosphogypsum management and recycling technology
- Ammonia- and hydrogen-to-power technology
- Emissions abatement technology
- Water resource management.

Tried and tested virtual platform

CRU will be running the forum using its successful and immersive virtual platform. This tried and tested format will bring together technical and sustainability professions from around the globe to connect, learn and share knowledge. As well as providing valuable up-to-date intelligence, the forum will offer multiple opportunities for interaction including live networking and 'meet the experts' sessions.

CRU's expertise in sustainability and fertilizers

CRU's fertilizer team is renowned for its insight and understanding across the fertilizer value chain, spanning pit to port to field. This includes in-depth knowledge and expertise on carbon emissions. CRU's recent extensive research into green and blue ammonia will feature in the new *Green Ammonia Market Outlook* being launched in October 2021.

For more information on CRU's Sustainable Fertilizer Production Technology Forum, visit: sustainableferttech.com

Ammonia and sulphur market trends

Ammonia and sulphur, as essential raw materials, underpin and drive fertilizer production costs. A steep and sustained rally has seen prices for both commodities reach new heights in recent months.

The prices of fertilizers and fertilizer raw materials continues to surge. In the second of week of June, CRU's fertilizer price index saw its largest weekly increase since 2008. Urea, UAN, ammonia, DAP/MAP, potash and sulphuric acid prices all posted double-digit increases in what is turning out to be an extraordinary year for commodity prices.

This latest June surge marks a new acceleration in prices, confounding previous predictions that these would start to soften during the second-quarter of 2021. Instead, urea prices rose at the end of May on the back of the latest Indian import tender, while phosphate prices west of Suez reached 10-year highs. The political crisis engulfing Belarus, meanwhile, helped push potash prices higher in the US and Brazil. Sulphur and sulphuric acid prices also continued to climb.

Below, we examine the current state of the sulphur and ammonia markets, highlighting the key trends and major drivers.

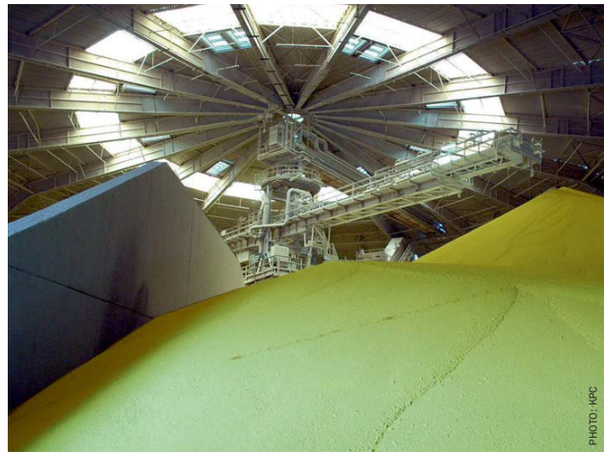
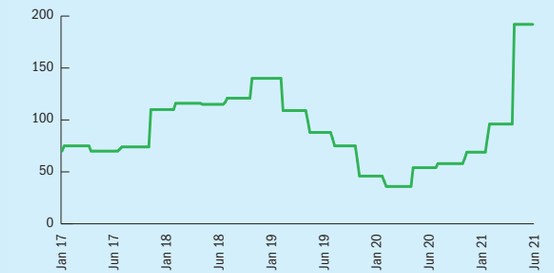


PHOTO: NPC

Sulphur storage at Mina-al-Ahmadi, Kuwait.

SULPHUR

Fig. 1: **Tampa cfr sulphur benchmark, January 2017 – mid-June 2021**



Source: The Mosaic Company

Prices more than triple year-on-year

Sulphur prices have been on a steep upwards trajectory in recent months, having more than doubled over the course of 2021 and tripled year-on-year. The Tampa contract price, for example, stood at $192/t cfr mid-June – compared to $83/t cfr in early January and $54/t cfr 12 months ago (Figure 1). Elsewhere, f.o.b. benchmarks such as the Vancouver and Arab Gulf sulphur prices have seen similar rises, with prices reaching heights last seen in early 2014.

The explanation? Well, since March last year – when the Tampa contract price, for example, reached a nadir of $36/t cfr – supply downturns have combined with healthy demand to rapidly push up sulphur prices.

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In particular, disruption to the oil market from Covid-19 has had a dramatic knock-on effect by reducing sulphur availability. These Covid-related sulphur shortages were then further compounded by supply tightness in 2020's fourth-quarter due to the winter closure of Russia's river transport routes and depleted Chinese port inventories.

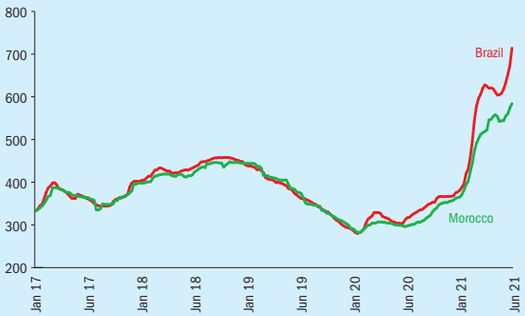
"All of these factors combined… led to the first inklings of a price run-up back in the fourth quarter. And …still, there's no sign of a price ceiling being reached," Meena Chauhan, Head of Sulphur and Sulphuric Acid at Research at Argus, commented in February[1].

Indeed, the sulphur price rally has continued well into the second-quarter of 2021, a sign that the prevailing tight supply-demand balance has yet to ease. Nevertheless, analysts are expecting to see a downward price correction during 2021's second-half.

"[For] the second half of the year, the outlook is for slightly softer prices – also from the downstream processed phosphate sector as well. That, I think, provides some direction for the short-term view for sulphur. But, of course, Covid-19 is still that wild card factor for the market overall," commented Chauhan[1].

Phosphates market conditions will ultimately be key. The strong link between sulphur prices and downstream phosphates prices is unsurprising, given that more than 90 percent of global sulphur trade is consumed in phosphate production.

Fig. 2: **Morocco DAP f.o.b. benchmark and the Brazil MAP cfr benchmark, January 2017 – mid-June 2021**



Source: The Mosaic Company

At the time of writing, the DAP Morocco benchmark stands at $584/t f.o.b., up by more than 95 percent year-on-year, while the Brazil MAP price stands at $714/t cfr, 125 percent higher than a year ago (Figure 2). Phosphate prices at these levels – which represent eight- or nine-year highs – will undoubtedly continue to support sulphur prices, at least in the short-term.

"We are expecting [phosphate] prices after this year to start to correct downwards and experience pressure, particularly 2022 to 2023. While the market returns to normal, it'll have to get used to absorbing new [DAP] capacity from OCP and India. We're seeing new [MAP] capacity in Brazil as well," says Claira Lloyd, Phosphate and Phosphate Rock Research Manager at Argus, commenting in May[2].

Table 1: **New sulphur projects, 2020-2023**

Country	Plant	Operator	Sector	Status	Sulphur capacity ('000 t/a)	Start date	Progress update
Kuwait	Mina Al Ahmadi	KPC	Oil	Committed	130	2020	Commissioning
Kuwait	Mina Abdullah	KPC	Oil	Committed	450	2020	Commissioning
Kuwait	Al Zour	KPC	Oil	Committed	1,320	2020	Delayed to 2021
Qatar	Barzan	Ragas	Gas	Operating	800	2020	Commissioning
Saudi Arabia	Jazan	Saudi Aramco	Oil	Committed	730	2021	Delayed to 2021
Saudi Arabia	Al Fadhili	Saudi Aramco	Gas	Operating	1,320	2020	Commissioned in Q1 2020
UAE	Shah	ADNOC	Gas	Committed	1,600	2023	Delayed to 2023
India	Assam	BPCL	Oil	Probable	100	2020	Construction delays in 2020
Malaysia	RAPID	Petronas	Oil	Committed	660	2021	Delayed to 2021
China	Zhejiang	Zhejiang Petrochem	Oil	Operating	480	2020	Commissioned in Q1 2020
China	Shenghong	Shenghong Petrochem	Oil	Probable	600	2021	Delayed to Q4 2021
China	Zhanjiang	Sinopec	Oil	Operating	400	2020	Commissioning
China	CDB (Phase II)	PetroChina	Gas	Probable	550	2023	Delayed to 2023

Source: Various

Sulphur supply hit by Covid-19 shocks

The demand shock to the oil market inflicted by the pandemic last year also hit sulphur availability, especially in those markets that rely heavily on oil-based sulphur recovery. In the US, for example, the fall in oil refinery run rates led to the loss of around 600,000 tonnes of sulphur supply in 2020, estimates Argus[1]. Western Europe too has been similarly affected by lower run rates and the consequent tightening of sulphur supply and availability.

Looking ahead, significant sulphur capacity additions are expected over the next 2-3 years, countering the Covid-related supply disruptions of 2020 (Table 1). CRU expects the slump of 2020 – which saw sulphur output decline by 0.9 percent – to be reversed by a strong project-driven production rebound, both this year (+3.7%) and next (+5.2%).

Argus is forecasting just over three million tonnes of capacity additions in 2021, primarily in Gulf states, such as Saudi Arabia, Qatar and Kuwait, supplemented by the arrival of additional capacity in China. In Saudi alone, the ramp-up of the new Al Fadhili gas project this year is expected to add more than one million tonnes to Middle Eastern sulphur supply (Table 1). Covid-19 has delayed the arrival of some new sulphur capacity, however, most notably the 800,000 t/a capacity Barzan project in Qatar. Its commissioning has now been pushed back to this year.

Demand

Ups and downs in the phosphate market over the course of the Covid-19 pandemic have undoubtedly affected sulphur demand. Lockdowns in the first half of 2020 saw phosphate plant closures in China, alongside reductions in phosphoric acid production in countries such India – with a consequent downturn in sulphur demand. Operations did subsequently restart, however, supported by strong government backing for agriculture and food supply/security (*Fertilizer International* 496, p18).

Overall, sulphur demand fell by about 800,000 tonnes in 2020 versus 2019, estimates Argus.

"When we look at the whole [sulphur] demand picture – fertilizers and all other end uses – we did see a decline. But this was not uniform across all regions. Africa saw growth, so did Latin America and Southeast Asia also. As well, global demand for sulphur from the phosphoric acid sector actually grew marginally last year, supported by a Moroccan uptick in phosphoric acid production," commented Meena Chauhan[1].

Trade – Africa rises as China falls

One major sulphur market development last year was the three million tonnes year-on-year plunge in Chinese imports in 2020. This was also accompanied by a fall in Chinese sulphur stock levels. China is currently the world's largest sulphur importer, although that status may not last, given that its decline in imports looks set to continue over the short-term and possibly beyond.

"We are not forecasting any recovery in Chinese imports. In fact, we're actually looking at China potentially losing its leading importer ranking in that medium-term forecast as well. So, this trend is set to continue," concluded Chauhan[1].

This fall in Chinese sulphur imports is being driven by increased domestic supply, with four scheduled projects likely to add more than two million t/a to Chinese sulphur capacity over the near term (Table 1). Indeed, Argus expects Chinese sulphur production to increase by almost 40 percent out to 2025 – putting a permanent damper on import expectations.

This is likely to provoke a change in sulphur trade flows with Africa – Morocco in particular – taking up some of the slack. The continuing ramp-up in OCP's phosphates production capacity should also prompt a significant rise in Moroccan sulphur imports.

Looking ahead, Argus is expecting extra sulphur capacity in both Canada and Middle East to make its way onto the global export market. This is linked to the entrance of a plethora of new Middle Eastern sour gas and oil projects (Table 1). The emergence of several new forming projects in Western Canada could also boost sulphur trading out of Alberta. ■

AMMONIA

Prices – from sub $200/t to plus $500/t in a year

As with sulphur, the ammonia market has reached new heights in the last six months. After what analysts Profercy called a "crisis year" in 2020, ammonia prices have surged upwards this year, driven higher by a tightening market as strong demand collided with limited supply.

The market conditions 12 months ago could not have been more different. The spread of the Covid-19 pandemic across the globe in 2020 had a highly negative effect on industrial ammonia demand and energy/feedstock prices. The upshot was a marked downturn in ammonia prices.

One key price barometer for ammonia – the Yuzhny (Black Sea) f.o.b. benchmark – eventually bottomed out in the $170s/t in mid-2020. Around that time, Trinidad product was dumped in Turkey at below $145/t f.o.b., while Middle East ammonia prices also fell below $150/t f.o.b., reported Profercy[3]. As for feedstocks, global gas prices were also depressed with European, Far East LNG and US gas all falling to around $2mmBtu.

Extreme weather and outages hit supply

The ammonia price rally that followed began to gather pace in mid-February. The combination of unexpected worldwide outages, extreme US cold weather and heavy Baltic sea ice (*Fertilizer International* 501, p8) conspired to create what Profercy called "the hottest market for ammonia since mid-2018"[3].

Plant outages triggered by February's North American freeze affected as much as seven million t/a of US ammonia production capacity. The resulting disruption added to a string of unplanned outages across the globe – affecting plants in Trinidad, Egypt, Northwest Europe, the Middle East, Southeast Asia, Japan and Australia.

This widespread catalogue of problems was almost unparalleled, reported Profercy, adding fuel to a market that was already on fire. The Yuzhny ammonia price responded by rising to $350/t f.o.b., twice the level seen in mid-2020.

No respite was in sight as 2021 entered the second-quarter. Ammonia prices kept climbing into March with prices eventually hitting $500/t.

"$500/t ammonia is now a reality, from the US to China. This week already high

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Asian prices for ammonia hit $500/t cfr, just one week after $520/t cfr was paid in the US," reported Profercy in mid-March[4]. "There is no sign of the market easing in April as global demand is running at a strong pace with buyers unable to get ahead of the curve."

On the supply side, production outages remained a major issue during March. Production was cut back in Trinidad, while Algeria was unable to operate at full rates.

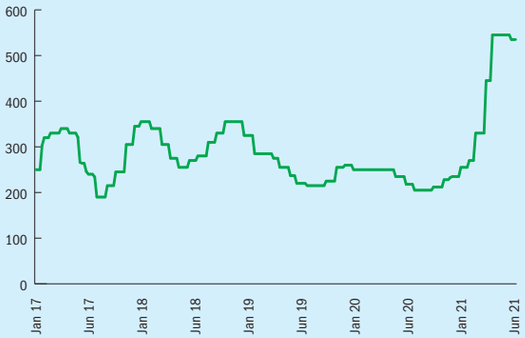
Although Profercy does not expect the current ammonia price run-up to be sustained during the third-quarter, it predicts that the 2021 floor price should remain "vastly ahead" of the sub-$200/t f.o.b. levels of 2020[4].

While major plant outages and unscheduled shutdowns, by disrupting supply, have acted as catalyst for significant price increases in the first-quarter of 2021, analysts ICIS initially expected the return of normal production schedules during second-quarter to reverse those price hikes (*Fertilizer International* 501, p20).

However, ammonia supply continues to be plagued with unexpected production outages. "[There is] more grim news for ammonia buyers as shutdown of the 1.2 million t/a SAFCO IV plant at Al-Jubail in Saudi Arabia threatens to force prices higher," commented Richard Ewing, senior editor for ammonia at ICIS, on 10th June. "Nearby, Ma'aden is still assessing the impact of a fire at a 1.1 million t/a plant, but has dismissed talk it may be offline until August or September."

The trajectory of the Tampa ammonia benchmark illustrates the rollercoaster fall and rise in ammonia prices seen over the last 12 months. The Tampa cfr price initially fell to a low of $205/t in mid-June 2020 before recovering to $255/t by the year's end. Since then, it has rocketed to $545/t – a year-on-year increase of 150 percent (Figure 3).

Fig. 3: **Tampa cfr ammonia benchmark, January 2017 – mid-June 2021**



Source: The Mosaic Company

Eventual price softening?

Ammonia benchmarks in Europe and the US did show signs of softening during April and May. The Yuzhny contract price for example, fell by $40/t from March highs to $415-$455/t cfr following a sale to OCP. Better availability in the Baltic, meanwhile, saw f.o.b. prices there fall by up to $5/t in April to $466-$467/t[4].

At the end of April, Mosaic agreed a Tampa cfr price of $545/t with Yara for May shipments. This Tampa contract price, a rollover of the previously agreed April price level, followed eight consecutive monthly increases. Remarkably, this price run included a hike of $115/t in March (Figure 3) – one of the largest single month-on-month increases of the last decade[4].

Elsewhere, ammonia prices in China and Southeast Asia remained firm overall.

Looking ahead, ratings agency Fitch recently raised its ammonia price assumptions for 2021 and 2022 (Black Sea f.o.b.) – from $220/t to $270/t and from $230/t to $260/t, respectively. The agency also increased its long-term price assumption beyond 2024 by $10/t to $260/t. These buoyant price levels for ammonia reflected expectations of strong agricultural demand globally and a rebound in industrial demand led by Asia.

"We expect supply to remain restricted in the short and medium term. Feedstock prices (gas) rose due to cold weather in the US, which resulted in supply curtailments for multiple US nitrogen plants. This coincided with Trinidad and Tobago's country-wide capacity curtailments. Utilisation rates at ammonia plants have already been high, and we expect further incremental increases," commented Fitch.

Supply and demand

The Covid-19 pandemic in 2020 underlined the market's fundamental overcapacity. Producers on both sides of Suez shuttered several ammonia units in 2020, as the economic fallout of the deadly virus hit the bottom line for producers (*Fertilizer International* 501, p20).

These ammonia supply cuts did help balance the drop-off in demand in 2020. Trinidad cut production capacity by 500,000 tonnes in 2020, reducing its annual exports to 3.9-4.0 million tonnes. Russian production curtailments also supported the market, with 2020 exports at 4.4 million tonnes some 300,000 tonnes lower year-on-year.

Last year's ammonia market downturn – and the attendant collapse in prices – hit Caribbean production particularly hard. Yara, for example, took one of its two ammonia plants in Trinidad offline in August 2020 (*Fertilizer International* 498, p10). The decision to temporarily idle the 1.5 million tonne capacity Tringen 1 ammonia plant followed a $50/t decrease in the US Gulf/Caribbean f.o.b price over the preceding three months to $150-170/t. Yara had been running Tringen 1 and its sister plant on the island, the 495,000 tonne capacity Tringen 2 plant, at reduced operating rates.

Yara's plant shutdown followed a similar decision by Nutrien to take two of its four ammonia units on the island offline until the market recovered (*Fertilizer International* 499, p10). The Canadian fertilizer subsequently announced that one of these plants, the PCS-03 unit, would be closed indefinitely.

Trinidad's ammonia industry had been struggling to compete, being squeezed by cheaper gas in rival regions such as the US and Europe. Previously, Yara had closed Yara Trinidad in 2019, its oldest and smallest plant on the island, due to its high production costs.

Global ammonia trade to rebound

Demand for ammonia from international fertilizer and chemicals users bounced back strongly in early 2021. Black Sea exports of ammonia look set to remain higher than in previous years, with a continuation of the 2020 jump in Ukrainian output expected. The restart of Fertial's Algerian plants will also add more tonnes to the merchant ammonia market (*Fertilizer International* 501, p20).

In its prediction for the year ahead, Argus was forecasting a rebound in global ammonia trade to 19.3 million tonnes in 2021. This follows the estimated year-on-year fall in trade of 800,000-900,000 tonnes to 18.7 million tonnes in 2020.

Global ammonia demand, particularly from industry, fell significantly last year. India, one of the largest global import regions, saw its ammonia demand fall by around 200,000 tonnes to 2.5 million tonnes in 2020. Other regions, particularly Morocco and China, bucked the trend by maintaining steady demand last year.

Industrial demand in markets east of Suez was starting to recover at the end of 2020, while the outlook west of Suez remained uncertain. India and Morocco combined are forecast to require an extra 500,000 tonnes of ammonia demand this year.

Green ammonia projects accelerate

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

The recent flurry of green ammonia/hydrogen project announcements is, however, significant as it demonstrates an acceleration of interest from investors. Major fertilizer industry players like Yara, CF Industries, Nutrien and Fertiberia have all pledged to invest large sums in green ammonia projects (*Fertilizer International* 499, p8) – a trend that can only harden as 2021 progresses. ■

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Innovation showcase

A selection of innovative products and technologies that have recently been brought to market.

2021 has been an excellent year for product innovation. In March, for example, the next generation of fertilizers were highlighted in a two-day webinar on slow- and controlled-release and stabilised fertilizers (SCRFs) – an event *Fertilizer International* supported as media partner.

The initial outcome of *Next Gen Fertilizer Innovations Challenge*, a competition sponsored by the US Environmental Protection Agency, The Fertilizer Institute and others, was also unveiled in March. Some 16 enhanced efficiency fertilizers (EEFs) have now advanced to the next stage. The competition process is designed to identify commercial products that can reduce the environmental release of nitrogen and phosphorus from corn and other row crops in the US.

Fertilizer producers such as Borax, IFFCO and K+S have also released innovative new products in recent months.

Below, we highlight some of the major product innovations of the last 12 months.

New fertilizer technology prize fund

Last year, The Fertilizer Institute (TFI) joined together with the US Environmental Protection Agency (EPA) and the US Department of Agriculture (USDA) to launch two competitions as part of a new multi-partner *Next Gen Fertilizer Challenge* initiative. Winners will receive up to $10,000 in prize money or help with greenhouse and field trials.

According to TFI, the aim is to "accelerate the development of innovative fertilizer product technologies and to increase the use of existing enhanced efficiency fertilizers (EEFs) that maintain or increase crop yields and reduce environmental impacts to air, land, and water".

Lara Moody, TFI's former vice president, explained the thinking behind the initiative[1]: "There were several drivers. First, there is growing evidence of the effectiveness of these products in advancing agronomic and environmental benefits on the farm. Additionally, we see a need to increase use of these products on the farm. And finally, it is important to further support emerging product development and innovation within the fertilizer industry."

The two competitions launched by the EPA and its partners in August 2020 are:

- Firstly, the *EEFs: Environmental and Agronomic Challenge*. This will identify existing EEFs currently on the market or near-market. These will need to meet – or exceed – certain environmental, agronomic and economic criteria.
- Secondly, the *Next Gen Fertilizer Innovations Challenge*. This will identify con-

New dawn for fertilizer efficiency?

Dawn over the Vale of Aylesbury, England.

Slow- and controlled-release and stabilised fertilizers (SCRFs) were the focus of a two-day webinar held on 15-16th March. The event – organised by *New Ag International* and supported by *Fertilizer International* as media partner – highlighted the latest improvements in fertilizer efficiency from BASF, Koch Agronomic Services, ICL Specialty Fertilizers, Milliken and Saviolife.

Speaking to *New Ag International*, Taylor Pursell, chairman of Pursell Agri-Tech, said: "We need to find ways to get the more efficient controlled release technologies used in specialty markets applicable in broad acre agriculture. The key will be reducing the costs to levels that have financial paybacks to farmers for adoption.

"What I hope to see in my lifetime is a shift to more nutrient efficiency resulting in higher yields, healthier foods that contain essential micronutrients, and at a low enough cost that it is a no brainer for the farmer to adopt."

Mandatory use of inhibitors

Michael Basten, senior agronomist at Koch Agronomic Services highlighted the environmental benefits of urease inhibitors. In his view, these can play a vital role in meeting the targets of the EU's *Farm to Fork* strategy. Germany and Denmark have both made the use of urea treated with urease inhibitors mandatory – a move which other EU member states are also considering.

Urease inhibitors deliver significant reduction in ammonia and CO_2 equivalent emissions, as well as improving nitrogen use efficiency (NUE). Their broader adoption has dual benefits, suggests Basten, being able to improve the farmer's return of investment for urea and lower the external costs of fertilizer use.

Embedded growth enhancers

The use of controlled-release fertilizers (CRF) in field-grown agriculture and forestry crops is on the rise, according to **Ronald Clemens**, global marketing manager at ICL Specialty Fertilizers.

Placement of CRFs in the planting hole of perennial crops, such as fruit trees and forest seedlings, is a cost-effective single fertilizer treatment that results in quicker development and growth – thereby shortening the time to maturity. Coated fertilizers also release nutrients predictably and consistently. This makes them an ideal tool for reducing nutrient losses and optimising nutrient use efficiency (NUE).

Using proprietary *V-Factor* technology, ICL has developed a unique range of *Agroblen* CRFs featuring embedded growth enhancers. These have been shown to improve root establishment and seedling growth. In eucalyptus, spruce and grape vine, for example, these novel CRFs improved growth by up to 20 percent in controlled experiments.

Maximising crop output, reducing climate impacts

Nitrous oxide is a very potent climate gas formed by soil bacteria involved in the nitrification process. Fortunately, treating urea with nitrification inhibitors can reduce these N_2O emission significantly, says **Markus Schmid** the head of BASF's nitrogen management business, and also increase crop yield and quality.

BASF invented the nitrification inhibitor 3-4 dimethylpyrazole phosphate (DMPP) and remains its leading producer. This inhibitor is notably used by Compo Expert and EuroChem in their respective *Novatec* and *Entec* fertilizer product ranges. BASF also offers ready-to-use DMPP formulations. These are marketed for mineral fertilizers under the *Vibelsof*® brand and for organic fertilizers under the *Vizura*® brand.

BASF's also offers the established and well-known urease inhibitor product *Limus*®. This combines two active ingredients – 75 percent N-(n-butyl)thiophosphoric triamide (NBPT) and 25 percent of a new compound N-(npropyl) thiophosphoric triamide (NPPT).

"Nitrogen fertilizers stabilised with urease- and nitrification inhibitors can play a key role in optimising the crop output per unit of fertilizer used," says Markus Schmid[1]. "They are the only technologies that directly reduce the impact from fertilizers on climate warming."

Schmid adds: "Over 120 field trials on all continents and in a broad range of crops show that *Limus*® is 40 percent more effective than NBPT. That means at the same application rate of NBPT, *Limus*® delivers 2.1 percent higher yield.

"Alternatively, customers can achieve the same performance they have come to expect with NBPT by using *Limus*® at 60 percent of the NBPT use-rate."

Pioneering slow-release technology

Thanks to an innovative manufacturing process, *Sazolene* slow-release nitrogen (SRN) products deliver a radical improvement in methylene-urea technology, says **Federico Guaraldi**, the commercial director of Saviolife. The Italian company is a leading manufacturer of both granular and liquid SRN products.

Sazolene® *39G* is a slow-release nitrogen fertilizer comprised of polymer chains obtained from the condensation of urea molecules. By varying the chain length, Saviolife offers three different formulations (shorter, balance and longer) with nutrient release times ranging from 12 weeks to more than 10 months.

The liquid nitrogen fertilizer *Sazolene*® *SC* contains about 60 percent nitrogen in methylene-urea form. The product is suitable for open-field, horticultural, fruit-bearing and nut crops – and can improve absorption, translocation and re-mobilisation of nitrogen, according to Saviolife. It can be used as a foliar fertilizer or in fertigation and can also be applied to soils. *Sazolene*® *SC* is also compatible with most water-soluble fertilizers and other agrochemical solutions. ■

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US Borax operates California's largest open pit mine in Boron, California.

PHOTO: US BORAX

Table 1: **Commercial EEF products and technologies selected for greenhouse trials in the second stage of the US *Environmental and Agronomic Challenge* competition.**

Company	Product
CHS Inc.	Trivar
Timac Agro USA	Top-Phos
Koch Company Services, LLC	SUPERU
The Andersons	Struvite DG
Renuvix LLC	Renuvix CRF
Pursell Agri-Tech LLC	PurYield
AgroLiquid	Pro-Germinator
Harrell's LLC	POLYON
Corteva Agriscience	Optinyte
MicroSource	Hi-Test
Nutrien	ESN
EuroChem Agro GmbH	ENTEC
Timac Agro USA	Duo Maxx
Koch Company Services, LLC	CENTURO
SABIC	BCRU
Verdesian Life Sciences LLC	AVAIL

Source: US EPA

cepts for novel fertilizer technologies that are not yet near-market. These will need to show great potential for reducing the environmental effects of modern agriculture, while maintaining or increasing crop yields. They may include EEFs and other product technologies used alongside or in combination with commercial fertilizers.

Winners of the *Next Gen Fertilizer Innovations Challenge* will receive a cash prize of at least $10,000 from a total prize purse of $65,000. They will also be invited to a showcase event to share ideas and spur innovation.

There is no cash prize for winners of the *EEFs: Environmental and Agronomic Challenge*. Instead, they will receive recognition from the EPA and USDA and benefit from a full scientific evaluation. They will also receive help in proceeding to greenhouse trials and eventually field trials, subject to positive results and available funds.

The two competitions were developed with input from corn grower representatives, individual fertilizer companies, university researchers, and environmental and industry groups. As well as working with TFI and USDA, the EPA is also collaborating with the International Fertilizer Development Center (IFDC), The Nature Conservancy (TNC) and the National Corn Growers Association (NCGA).

Lara Moody explained the initial focus on corn[1]: "This stems from its importance and scale as a crop and for its use of nitrogen and phosphorus fertilizer. In the United States, corn is the largest user of phosphorus and potassium. And, as a commodity crop, economics of production are important. It's likely that solutions that advance nutrient use efficiency in corn would be feasible and applicable to other cropping systems."

The EPA unveiled the finalists from the first stage of *EEFs: Environmental and Agronomic Challenge* competition in March. A judging panel recommended that 16 EEF products and technologies move forward to greenhouse trials in the second stage of the competition (Table 1).

Winners of the two competitions will be announced in winter 2021. Identifying which products and technologies will emerges as winners is, however, hard to predict at this stage.

"Beyond traditional slow- and controlled-release and stabilised products, I think we could see entries from emerging biostimulants, organic matrices, multi-nutrient combinations and maybe even some type of EEF-biostimulant combination," comments Lara Moody[1]. "I can't predict where the most exciting and potentially successful technologies will come from – for me, that's part of the fun and excitement of the challenges."

US Borax launches two new fertilizer products

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

Anhybor® and *Zincubor*® have both been created for fertilizer manufacturers wishing to produce micronutrient-enriched compound fertilizers. The products are designed to address the micronutrient deficiencies faced by agricultural producers and meet increasing market demand for boron and zinc.

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

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

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

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

IFFCO launches nanotechnology fertilizer

The Indian Farmers Fertilizer Cooperative Limited (IFFCO) has delivered its first commercial consignment of a new nanotechnology fertilizer.

The first batch of the company's new nano urea liquid was supplied to farmers in Uttar Pradesh in the first week of June. The patented technology behind this first-of-its-kind product was developed at IFFCO's Nano Biotechnology Research Center in Kalol in Gujarat.

IFFCO will mass produce half-litre bottles of the new liquid from three under-construction production plants – Kalol, Gujurat and Aonla and Phulpur in Uttar Pradesh. Initially, these sites will provide enough capacity to produce 140 million bottles, although IFFCO plans to ramp up annual production to 320 million bottles by 2023. The company calculates that producing nano urea at this scale will be enough to replace 13.7 million t/a of standard urea production.

India looks set to consume around 35 million tonnes of domestically-produced and imported commodity urea in 2020/21. Nutrient use efficiency is, however, surprisingly low. Only 30-50 percent of nitrogen applied to soils as urea prills or granules ends up being utilised by crops. Instead, the majority of the nitrogen contained in urea

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is lost to the environment due to leaching, volatilisation, run-off and other processes.

Currently, India farmers also have a financial incentive to overuse urea as it attracts significantly higher government subsidies relative to other types of fertilizer.

IFFCO's new nano urea liquid, in contrast, is a much more efficient nitrogen product. Each bottle – which contains 40,000 ppm of nitrogen – delivers enough crop nutrients to replace at least one 45 kilo bag of standard commodity urea, according to IFFCO.

The urea particles present are around 30 nanometres in size (one nanometre = one billionth of a metre). Because of this, the surface area to volume ratio of nano urea is about 10,000 times higher than conventional granular urea.

Nano urea is a foliar product applied to plant leaves. "Due to the ultra-small size and surface properties, nano urea gets absorbed by the plants when sprayed on their leaves. Upon penetration these nanoparticles reach parts of the plant where nitrogen is required and release nutrients in a controlled manner," IFFCO said in a statement.

IFFCO has tested the efficacy of nano urea by carrying out 11,000 field trials on more than 94 crops across India. These trials have shown that providing urea in nano form is an effective way of meeting crop nitrogen requirements . On average, it was found to increase crop yields by eight percent.

IFFCO believes its new nano urea product can avoid many of the environmental problems associated with the use of standard granular urea, such as nitrous oxide and ammonia emissions, soil acidification and water eutrophication.

As well as cutting environmental losses, IFFCO says nano urea is more sustainable in other ways: "It will reduce the input cost to farmer. Due to its small size, the bottle can be kept in the pocket and will significantly bring down the cost of logistics and warehousing also."

The new nano urea liquid is also competitively priced, with each bottle costing 240 rupees – 10 percent below the cost of an equivalent standard bag of urea.

Nano fertilizers have been heralded as a potential game changer for the market, although this does hinge on their acceptance by farmers. IFFCO is therefore planning a massive nationwide campaign to demonstrate and train farmers about the usage and application of nano urea.

Enhanced efficiency fertilizers, including urea treated with urease and/or nitrification inhibitors, are being applied to broad acre crops such as wheat (pictured). These can boost crop yields while reducing nitrous oxide and ammonia emissions (see page 21).

Shri Dilip Shangani, IFFCO's vice chairman, said: "Nano urea is a product of the 21st Century, and the need of the hour is to keep the environment – soil, air and water – safe for future generations while securing food for all."

IFFCO has also started field trials for a nano diammonium phosphate (DAP) product it has developed.

Two new speciality products from K+S

Germany's K+S is continuing to diversify its fertilizer portfolio. The major potash producer recently introduced two new speciality products to the market – *Roll-Kali* and *K+BooZter*.

Through its 'Project S' initiative, the company is also developing a novel potassium fertilizer that incorporates sulphur and is enriched with magnesium and essential micronutrients.

Roll-Kali (48% K_2O, 4% MgO, 10% SO_3) provides a source of highly concentrated potassium, alongside valuable magnesium and sulphur supplied by the natural mineral kieserite. All three nutrients are completely water-soluble and directly available to plants, independent of soil pH.

The product was launched in 2019 and is specifically designed for high quality bulk blends and precision farming. According to K+S, it makes an excellent potassium fertilizer for chloride-tolerant crops which also require magnesium and sulphur.

Its most special feature, however, is its spherical shape. Because drum granulation is used instead of compaction-granulation, *Roll-Kali* consists of highly uniform and perfectly round granules. The resulting product, with a bulk density of around 950 kg/m³ and an average diameter (d50) of 3.5mm, is ideally suited for bulk blending with nitrogen or phosphate fertilizers.

Roll-Kali granules have been designed to match other constituents of fertilizer blends (e.g., CAN, ASS, SSA or TSP) in terms of their shape, size and bulk density. This avoids segregation during transport, storage and application. Indeed, field application tests have shown that *Roll-Kali* spreads very evenly alongside other blend constituents at the desired mixing ratio, even at broadcasting widths of up to 30 metres. This ensures the optimal distribution of nutrients across the field.

Roll-Kali, although designed as a bulk blend component, also offers advantages in direct application. Its round shape is far less sensitive to wind, enabling fertilizer grains to be spread with great accuracy. The product can be applied to fields with an extremely precise lateral distribution even at spreading widths of over 40 metres.

K+S also recently introduced the potassium-based speciality fertilizer *K+BooZter* (54% K_2O, 1% B and 1% Zn). This innovative new product is enriched with zinc and boron in both fast- and slow-release forms. Uniquely, these micronutrients are incorporated and compacted within each single granule. Because of this, *K+BooZter* offers both higher nutrient use efficiency and better broadcasting precision in the field, compared to similar products on the market.

K+BooZter is suitable for a wide range of chloride-tolerant crops, including soybean, oilseed rape, cereals, corn and sugar beet. The product can be broadcasted directly or used as part of a blend with nitrogen and phosphate fertilizers. It is able to improve biomass generation in crops by increasing root formation and simultaneously improving the nutrient and water use efficiency of the plant. *K+BooZter* also helps to ensure plant health, by boosting resistance to abiotic and biotic stresses, as well as enhancing seed and fruit quality.

In recent decades, soil nutrients have been depleted worldwide by intensive agriculture and have often fallen below deficiency thresholds – especially in areas where nutrients are not being replenished by fertilizer applications.

Sulphur is a key nutrient at particular high risk of depletion. On one side, due to flue gas desulphurisation, soils are no longer being replenished by sulphur deposition from the air. On the other side, sulphur is absent from many commonly used high-analysis fertilizers. As a result, sulphur deficiency – and correspondingly agricultural demand for sulphur – is rising in many areas worldwide.

Sulphur has well known agronomic benefits. It improves plant photosynthesis, for example, and increases both the protein content and oil quality of crop products. It also improves plant health by strengthening resistance to abiotic and biotic stresses. This ultimately benefits crop yields and quality.

K+S Minerals and Agriculture GmbH has launched 'Project S' to address the widespread problem of soil sulphur deficiency and satisfy increasing market demand for sulphur fertilizers. The project is developing a new type of potassium fertilizer that can supply crops with sufficient sulphur. It will also be enriched with valuable magnesium and essential micronutrients. The target market for this new product areas where high protein and high oil content crops are cultivated such as soybean, maize, oilseed rape and sunflower.

The new product is being designed to fulfil the following requirements:

- **Rapidly replenish the potassium needed for plant growth**. This helps crops increase their nutrient and water uptake – which, in turn, is conducive to high biomass formation and yield improvements.
- **Incorporate both slow- and fast-release sulphur**. This guarantees sulphur availability to plants during the whole season, from the initial growth stage to the generative (flowering and fruiting) stage.
- **Consist of round, homogenous granules**. This ensures even and efficient dispersion of nutrients across the field during broadcasting. The physical properties of granules also need to compatible with other fertilizers when used as part of a blend.

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Technologies for boosting nitrogen use efficiency

The European Union is seeking to create a climate-neutral and circular economy through its flagship Green Deal policy. The fertilizer industry can support these objectives by adopting inhibitor treatment technology (ITT) and controlled-release fertilizers (CRFs) based on biodegradable polymers. These two innovations have a vital role to play in improving nitrogen use efficiency and the shift towards more sustainable resource use, says **Dr Matthias Potthoff** of thyssenkrupp Fertilizer Technology.

Fertilizers exert a dual pressure on the environment. On one hand, the world's population is constantly growing, diets are shifting towards higher meat consumption, as at the same time the area of arable land becomes less and less. The result is higher fertilizer demand and usage.

On the other hand, the agricultural sector contributes 10-12 percent towards worldwide greenhouse gas emissions, out of which about two percent is attributable to fertilizer production (CO_2, NOx, N_2O). Understandably, the pressure to reduce such emissions is growing constantly.

Moreover, the nitrogen losses from the application of urea – the mostly widely applied nitrogen fertilizer with a 75 percent market share – are known to be considerable. A fact that makes the focus on improving the nitrogen use efficiency (NUE) of urea particularly important.

The European Union is one region that has taken action on this issue – by implementing a ban on the application of untreated urea fertilizers from 2022. At the same time, fertilizer producers, faced with a highly competitive market environment, are seeking to expand their portfolios and diversify into higher margin products.

Against this backdrop, the fertilizer industry needs to manage its product offerings and innovate in preparation for future market needs. In this context, two successful technologies for improving the NUE of granular urea are proposed:

- Inhibitor treatment technology (ITT), jointly developed by BASF and thyssenkrupp Fertilizer Technology
- Controlled release fertilizers (CRFs) which coat urea granules with biodegradable polymers such as polylactic acid (PLA).

We summarise each of these innovative technologies below.

Inhibitor treatment technology (ITT)

Regulators around the world have recognised the problem of ammonia volatilisation from surface-applied urea. The result has been by an increasing number of stringent regulations and restrictions governing the application of urea.

Urease inhibitors are one answer. These reduce ammonia emissions, improve NUE and increase yield performance. They also provide farmers with a higher degree of freedom in terms of their fertilizer application strategy. Urease inhibitors need to be present when urea is applied to soils. The easiest way to achieve this is by incorporating the urease inhibitor within urea granules during their production.

With this in mind, new inhibitor treatment technology (ITT) provides a highly efficient way to treat granular urea with a urease inhibitor at large scale in the quantities required globally. ITT is flexible too – being available as a plant add-on for both existing and new *UFT*® fluid bed granulation plants. This saves cost and space, since no additional coating equipment is necessary. Furthermore, ITT is less labour intensive, and also provides scope for additional surface treatments further down the value chain (e.g. for micronutrients).

There is a need to ensure that the urease inhibitor formulation and the application technology are completely compatible and correctly and specifically match one another. To achieve this, BASF and thyssenkrupp Fertilizer Technology (tkFT) have cooperated closely together on a new ITT project.

Under a formal agreement, the two project partners have now successfully developed an application-specific version of BASF's proprietary *Limus*® urease inhibitor formulation for use in the *UFT*® fluid bed urea granulation process. No additional investment is required beyond a simple dosing system.

ITT has been thoroughly tested and validated at pilot plant scale. It was also recently verified for the first time at a full-scale industrial *UFT*® fluid bed urea granulation plant. The results and the stability of the inhibited urea product produced at industrial scale are currently being evaluated. ITT is then expected to become fully commercialised in late 2021.

Controlled-release fertilizers (CRFs)

Under unfavourable conditions, conventional fertilization can result in big nutrient losses to the environment – up to 70 percent or more in the case of nitrogen. These losses are directly responsible for nitrate pollution of groundwater and soils in countries where agricultural fertilization is extensively practiced, including EU countries.

Consequently, legislators have reacted by imposing restrictions. The amounts of fertilizers applied need to be decreased, as does the number of applications over the crop growing season. Additionally, standard commodity fertilizers such as urea need to be replaced with so-called enhanced efficiency fertilizers (EEFs) – also known as stabilised fertilizers (SFs) – to decrease these losses.

Having recognised this trend, thyssenkrupp Uhde has been working to develop SFs and controlled-release fertilizers (CRFs) together with their associated production processes. One successful outcome has been the development of an innovative polymer-coated urea (PCU), a special type of CRF. This focused especially on the application of biodegradable polymers such as polylactic acid (PLA) as a coating material (Figure 1).

These polymers can be produced from renewable materials and decompose naturally in soils without producing environmentally-harmful substances. This guarantees that the whole production and application process can be sustainable.

These type of CRFs ensure the availability of nutrients over the entire growing season (Figure 2). They are also more efficient as they supply nutrients in the exact quantities required by the crops. This provides the option to either increase crop yields by up to 10 percent or apply less fertilizer, with scope to also combine these two positive effects.

CRF production can be integrated within an existing ammonia/urea complex, or set up as a standalone plant, and is offered in a wide range of production capacities. The application of a polymer coating helps minimise the nitrogen losses associated with urea and improve its NUE. This technology can also be successfully applied to K-, P- or S-fertilizers to provide similar benefits and positive effects.

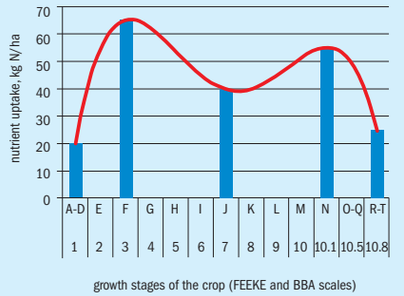
Conclusion

The innovative fertilizer technologies described here increase nitrogen use efficiency (NUE). They also make a valuable contribution to new environmental requirements encouraging the sustainable use of resources. Both these technologies, which are readily available for commercial implementation, provide new product options that will help ensure fertilizer producers are well-positioned to satisfy changing market demand. ■

Fig. 1: **Electron microscope image of a PLA-coated fertilizer granule**

Source: thyssenkrupp Uhde Industrial Solutions

Fig. 2: **Crop nutrient needs (winter wheat) over the whole growing season**



Source: thyssenkrupp Uhde Industrial Solutions

PRODUCT TECHNOLOGY

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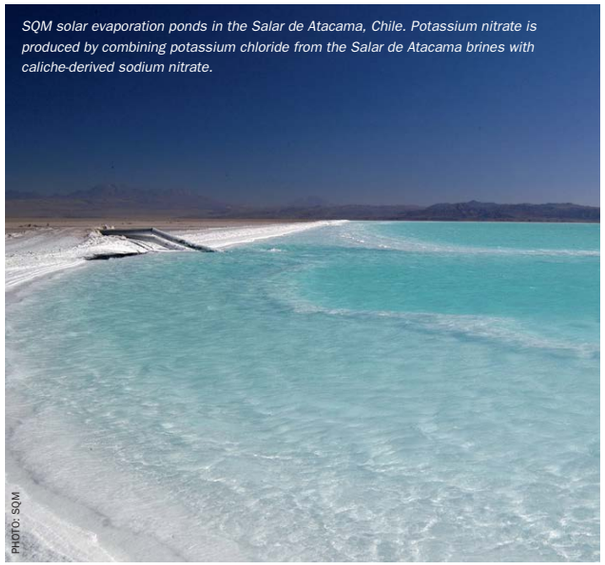
High performance nitrate-based fertilizers

The delivery of nitrogen in nitrate form can deliver superior yields and quality in arable, fruit and vegetable crops. Because of this, production and consumption of the principal nitrate fertilizers – ammonium nitrate (AN), calcium ammonium nitrate (CAN), urea ammonium nitrate (UAN), potassium nitrate (NOP) and calcium nitrate (CN) – continue to grow.



SQM solar evaporation ponds in the Salar de Atacama, Chile. Potassium nitrate is produced by combining potassium chloride from the Salar de Atacama brines with caliche-derived sodium nitrate.

PHOTO: SQM

Nitrate fertilizers have a deserved reputation as efficient sources of agricultural nitrogen. Indeed, their superior performance over urea – in terms of yield and quality – has been demonstrated in numerous agronomic trials for fruit, vegetables and arable crops.

Nitrates also have a much lower environmental impact relative to urea-based fertilizers. This is due to their ability to avoid volatilisation losses. Their production can also have a lower carbon footprint.

In the EU, for example, ammonium nitrate production is associated with average carbon emissions of 1.112 kg CO_2e/t versus 1.611 kg CO_2e/t for urea. Furthermore, urea will release an additional 0.733 CO_2e/t of captured emissions when applied in agriculture.

Supplying nitrogen in nitrate form has the following advantages:

- Nitrate can be readily absorbed by plants via efficient direct uptake from soil
- Nitrogen is supplied in a non-volatile nitrate form with no need for incorporation into the soil
- Avoids the soil acidification associated with the nitrification of ammonium fertilizers
- Higher nitrogen use efficiency improves yields and prevents unwanted nitrogen losses to the environment
- Avoids root damage and toxicity associated with high ammonium concentrations
- Generally highly soluble in water and easily dissolved and therefore ideal for fertigation and foliar application
- Compatible in tank mixes with most other fertilizers and agrochemicals
- Ability to combat excess chloride in soils and irrigation water
- Promotes the uptake of other valuable plant nutrients (K, Ca, Mg)

Nitrates – soluble, readily available, less volatile

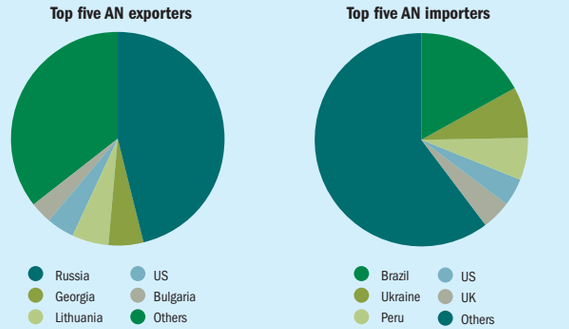
Ammonium nitrate is a popular nitrogen fertilizer in North America, Europe and Russia. Notably, it supplies nitrogen in both ammonium and nitrate form. Its extremely high solubility (1,900 g/L) also makes it ideal for fertigation and foliar spraying.

The nitrate component of AN is readily available for plant uptake. Once dissolved, it moves easily from the soil solution into the roots. Its ammonium content, meanwhile, is either partly taken up by roots or gradually converted to nitrate by soil microorganisms.

AN is more stable than urea, being less prone to volatilisation, and overall nitrogen uptake is also generally quicker.

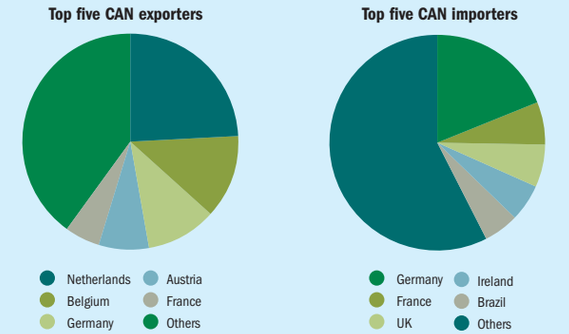
These characteristics make AN well-suited to countries and regions in northern latitudes with shorter growing seasons, such as Canada, parts of Europe and Russia. The fact that AN releases 90 percent less ammonia to the atmosphere than urea means it is finding favour in the EU where reducing ammonia emissions has become a priority.

Fig. 1: **Top five exporting countries (left) and import destinations (right) for ammonium nitrate. Total world trade was 9.4 million tonnes in 2019**



Source: IFA

Fig. 2: **Top five exporting countries (left) and import destinations (right) for calcium ammonium nitrate (CAN). Total world trade was 9.5 million tonnes in 2019**



Source: IFA

Ammonium nitrate use does have downsides. Urea's ability to deliver nitrogen in more concentrated form – with 42 percent N content versus 33-34% for AN – makes it the preferred nitrogen fertilizer in India, China and South America. A number of countries have also imposed outright bans on the sale of straight AN following a series of terror-related and factory and warehouse explosions (*Nitrogen+Syngas* 367, p18; *Fertilizer International* 491, p15). Even when the sale of AN is permitted, its use is often highly circumscribed due to major safety concerns. Soil-applied AN can also be prone to leaching.

Tried and tested manufacturing route

AN is produced industrially from the acid-base reaction between ammonia and nitric acid:

$$HNO_3 + NH_3 \rightarrow NH_4NO_3$$

Because AN is synthesised from ammonia, as is nitric acid, production plants are typically co-located with ammonia and nitric acid production.

The AN generated via this manufacturing route is firstly obtained as a weak solution in water. Solid AN is then typically produced by concentrating this solution to a strength of 95-99 percent at high temperature (c. 150°C) in an evaporator or concentrator. This 'melt' is then passed to a prill tower to generate solid AN prills.

Prills of different density can be generated by varying the concentration of the ammonium nitrate melt. High-density (1.69) fertilizer-grade AN or (FGAN) prills are formed from a 99.5-99.8 percent AN melt. Low-density (1.29) 'technical' or 'industrial' grade AN (TAN/IGAN) prills, in contrast, are formed from a 95-97.5 percent AN melt. These prills are suitable for manufacturing explosives, being more porous and so able to absorb oil more easily.

Ammonium nitrate is also the starting point for other popular nitrate fertilizers (*Nitrogen+Syngas* 367, p18). Calcium ammonium nitrate (CAN), for example, is produced by mixing the AN melt with calcium carbonate (limestone). While urea ammonium nitrate (UAN) is produced by mixing non-concentrated AN solution, obtained directly from the reactor, with dissolved urea.

UAN solutions are generally offered in three different concentrations: 28 percent, 30 percent or 32 percent nitrogen content, respectively. The most popular form – 32 percent N – consists of a solution of 45 percent ammonium nitrate and 35 percent urea diluted with 20 percent water. UAN solutions are adjusted to neutral pH (7) using ammonia and nitric acid.

Production rises to meet growing demand

Global AN production reached 49.1 million tonnes in 2019, versus world production of 15.9 million tonnes for CAN and 25.6 million tonnes for UAN. Nitrate production globally continues to grow, particularly for UAN solutions. World output for AN and CAN grew by 19 percent and 17 percent, respectively, over the decade to 2019 – broadly similar to the urea growth rate – while global UAN output leapt upwards by around 70 percent over the same period.

The top five exporting countries and import destinations for AN and CAN currently are shown in Figures 1 and 2, respectively.

Major UAN producing countries include the US, Russia, Canada, Trinidad and Belarus. Around one-third of world UAN production was traded internationally in 2019.

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Countries in Europe and the Americas are the main import destinations (Figure 3).

Among the main regional producers of fertilizer-grade AN and its derivatives are:

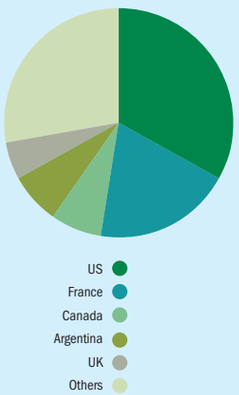
- Norway's **Yara International**, the world's largest NPK and nitrates producer, which produced 6.5 million tonnes of nitrates and 960,000 tonnes of UAN in 2020.
- **CF industries** which produced 6.8 million tonnes of UAN in 2020 from its Donaldsonville, Port Neal, Verdigris, Woodward and Yazoo City sites in the US and Courtright site in Canada. The company also produced 2.2 million tonnes of AN in 2020 from Yazoo City in the US and its Ince and Billingham UK sites.
- **Uralchem** – which has three million t/a of AN production capacity – alongside other major nitrate producers Acron, EuroChem and SDS Azot in Russia.
- Egypt's **Abu Qir Fertilizers** which operates a 792,000 t/a capacity AN plant and a 280,500 t/a capacity UAN unit.

Primary AN production has been growing on average at 4-5 percent p.a. over the last two decades, rising (on a nutrient basis) to around 21 million tonnes N in 2019 (*Nitrogen+Syngas* 367, p18). Of this total:

- 34 percent was manufactured as straight fertilizer-grade AN (FGAN)
- 29 percent as technical and industrial grade AN (TAN/IGAN) for commercial explosives
- 19 percent as calcium ammonium nitrate (CAN)
- 17 percent as urea ammonium nitrate (UAN) solutions.

A small proportion of output also goes into the manufacture of ammonium sulphate nitrate and other derivatives. CAN and AN are also used as sources of nitrogen in NPK blends.

Fig. 3: **Top five UAN import destinations for urea ammonium nitrate (UAN)**



Total world trade was 8.3 million tonnes in 2019

Source: IFA

Concentrated demand

The ammonium nitrate market was valued at $17.0 billion in 2019 – with the agricultural segment worth $11.9 billion (70%). Demand for AN is relatively concentrated with the top five consuming countries – the US, Russia, China, Ukraine and Australia – accounting for more than half of world demand (Figure 4).

Each regional market has a distinctly different pattern of use (*Nitrogen+Syngas* 367, p18). In Europe, for example, restrictions on the sale of straight AN – due to its potential for misuse – has created a sizeable market for CAN. Consequently, EU countries together with Turkey are now responsible for more than half of global CAN consumption (Figure 5).

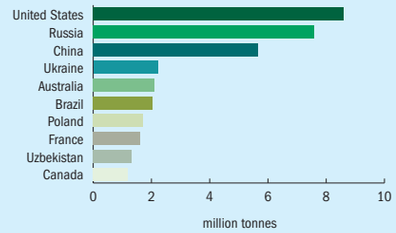
In the US, meanwhile, a preference for liquid fertilizers – when combined with tight regulations on the storage, transport and direct application of ammonia – has led to a rapid increase in demand for UAN solutions. As a result, the North American nitrates market is heavily skewed towards UAN.

Consumption of AN and its derivates has risen steeply in Russia and neighbouring countries – with Russian consumption of AN having more than tripled since 2000. CAN and UAN, in contrast, are not generally as favoured by the region's farmers.

The rise in Russian domestic consumption has helped alleviate another issue that has plagued global AN trade – the alleged dumping of product at below cost price to increase market share (*Nitrogen+Syngas* 367, p18). Both the US and EU maintained anti-dumping tariffs on sales of Russian-produced AN for many years, following the breakup of the Soviet Union in the early 1990s. These tariffs were linked to claims of unfairly subsidised Russian natural gas.

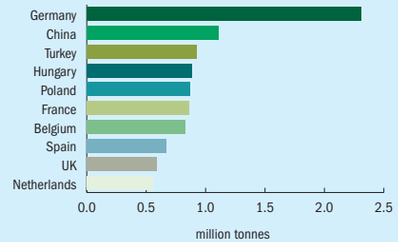
In recent years, greater liberalisation of the gas market globally, plus the pickup in Russian AN demand, has helped ease dumping concerns. The US reacted by removing its AN tariffs in 2016, with the EU subsequently moving to reduce its tariffs in 2018. Nevertheless, the EU's imposition of fresh tariffs on Russian UAN imports in 2019 shows that dumping remains a live issue. Russia was not singled out, how-

Fig. 4: **Apparent consumption of AN for the 10 leading consuming countries, 2019**



Source: IFA

Fig. 5: **Apparent consumption of CAN for the ten leading consuming countries, 2019**



Source: IFA

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ever, as these duties were also applied to UAN traded by Trinidad and the US.

Potassium nitrate

Potassium nitrate (KNO_3) is a soluble source of two major and essential plant nutrients. It is typically marketed as a speciality NK (13-0-45) fertilizer for high-value crops that prefer chloride-free potassium and the nitrate form of nitrogen. The fertilizer – also known as NOP (nitrate of potash) – is commonly sold in water-soluble crystalline form for fertigation and foliar use or as prills for soil application.

Potassium nitrate can be manufactured via a primary production process from naturally-occurring brines. It can also be generated using a secondary production route by reacting potassium chloride with an available nitrate source, such as sodium nitrate, nitric acid or ammonium nitrate.

KNO_3 offers chloride-free potassium (46.3% K_2O) alongside nitrogen (13.7% N). It is widely used as a water-soluble fertilizer in irrigation systems (fertigation) and as a foliar spray applied to crop leaves. Relatively high productions costs have tended to limit its use to higher-value cash crops.

Irrigation systems generally require nutrient-rich and highly-soluble fertilizers that have a low salinity index and are free of impurities and insoluble substances (*Fertilizer International* 486, p28). Potassium nitrate meets all of these requirements and has become a popular and market-leading fertigation product. It is also widely applied as a foliar spray to correct crop nutrient deficiencies.

Crystalline potassium nitrate is ideal for fertigation and foliar application, while prills are suitable for split applications to soil (basal and side or top dressing).

Agronomic benefits

Potassium nitrate is marketed on its ability to increase the quality and yield of harvested produce. It is said to promote stronger and healthier crops by increasing plant tolerance to abiotic and biotic stresses. Potassium nitrate offers the following advantages over other forms of potash:

- Improves tolerance to drought, frost, pests and diseases
- Increases water use efficiency
- Enhances organoleptic properties of fruit (colour, sugar content and aroma)
- Promotes the synthesis of lycopene to create a deep red colour in fruit, for example

Potassium nitrate producers target high-value segments of the market such as vegetables, fruits and flowers. This target market includes chloride-sensitive crops such as potato, strawberry, beans, cabbage, lettuce, peanut, carrot, onion, blackberry, tobacco, apricot, grapefruit and avocado.

Production and producers

The total value of the world potassium nitrate market – including both agricultural and industrial segments – reached $ 1.51 billion in 2018, and is projected to grow at more than three percent p.a. to reach $1.83 billion by 2024.

Potassium nitrate is a high-value niche product with a two percent share of the global potash market. World production capacity (primary and secondary) is around 1.3 million tonnes K_2O. On a product basis, the size of the global market for agriculture was estimated at 1.8 million tonnes in 2016. Production was forecast to grow at around four percent p.a. out to 2021.

> **Potassium nitrate producers target high-value segments of the market such as vegetables, fruits and flowers.**

Leading global producers and products include:

- **SQM**: *Ultrasol K* and *Ultrasol K plus and Qrop K*
- **Haifa Group**: *Multi-K*
- **Yara International**: *UNIKA PLUS* and *KRISTA K/ULTRASOL™ K PLUS*
- **Kemapco**
- **Uralchem**: *Solar* Potassium Nitrate
- **Kingenta**
- **Wentong Group**
- **Migao Corporation**.

Prayon also markets Kemapco potassium nitrate as part of its *Hortipray* product portfolio.

Chile's **SQM** is the world's largest producer of potassium nitrate (see companion article on page 56). The company is a primary producer with an annual potassium nitrate production capacity of 1.3 million tonnes. It sources nitrates from natural caliche ore and brine deposits in northern Chile.

Caliche is mined from surface deposits in the Atacama desert to derive products such as sodium nitrate and iodine. Underground brines in the Salar de Atacama (Atacama salt flat) are also pumped to the surface and transferred to large solar evaporation ponds to yield economically valuable lithium chloride, potassium chloride, magnesium chloride, boric acid and potassium sulphate.

Nitrates are produced by firstly leaching crushed caliche with water. Sodium nitrate is then obtained from the leached solution by crystallization. Potassium nitrate is subsequently produced by combining potassium chloride from the Salar de Atacama brines with the caliche-derived sodium nitrate. This mixture is purified by crystallisation, refining and drying to yield the final product. This primary production route generates up to 40 percent less greenhouse gas emissions compared to secondary production of potassium nitrate, according to SQM.

SQM's production complex at Coya Sur includes four potassium nitrate plants with a total capacity of 1.3 million t/a. Production lines at the site for crystalline product have a combined capacity of 1.2 million t/a, supplemented by a 360,000 t/a prilling plant.

SQM's agricultural sales volumes for potassium nitrate reached 673,400 tonnes in 2018. The company estimates that this volume accounts for around 56 percent of the global potassium nitrate fertilizer market. The completion of a new potassium nitrate plant at Coya Sur in 2011 increased SQM's potassium nitrate production capacity by 300,000 tonnes.

SQM's largest international competitor is Israel's **Haifa Group** with a potassium nitrate production capacity of around 300,000 tonnes p.a. The company is thought to have contributed about 13 percent to potassium nitrate fertilizer sales (outside China) during 2018.

Haifa Group is a secondary producer, manufacturing crystalline, prilled and special grades of potassium nitrate from ammonia and nitric acid. These are sold as standalone products and also incorporated into water-soluble NPKs and controlled-release fertilizers. Haifa helped pioneer the use of potassium nitrate in the fertilizer market and its high-quality *Multi-K* product portfolio remains a market-leading brand.

Jordan's **Kemapco**, a fully-owned subsidiary of the Arab Potash Company (APC), is a major primary producer, manufacturing 141,700 tonnes of potassium nitrate in 2018. The company's made sales worth $106 million that year. Its main markets are Europe, Mediterranean countries and Asia.

Kemapco successfully completed a $19 million expansion project in May 2018. This has raised its annual production capacity by nearly 30 percent, from 135,000 tonnes to 175,000 tonnes. A feasibility study for a second expansion to double Kemapco's current production is currently underway.

Uralchem is Russia's only potassium nitrate producer. The product is manufactured at its Azot complex at Berezniki in the Perm region, being partly derived from the site's 1.38 million tonnes of ammonium nitrate production capacity. The company markets *SOLAR* potassium nitrate for both greenhouse and open field fertigation of crops such as cereals, vegetables, fruit, and the flower and ornamental sector.

EuroChem recently embarked on a three-year project to build a potassium nitrate plant at its Nevinnomysskiy Azot production site. This will manufacture potassium nitrate from potassium chloride and ammonium nitrate melt, a process which will also generate ammonium chloride (a nitrogen fertilizer that contains at least 24% nitrogen) as a by-product.

China is a key market for potassium nitrate, with annual demand from agriculture estimated at 400,000-420,000 tonnes, although this is largely fulfilled by domestic producers. The country currently imports just 20,000-30,000 tonnes of potassium nitrate annually. China's tobacco growers and horticultural sector are the main consumers, with an annual requirement of around 130,000 tonnes and 120,000 tonnes, respectively.

The Qinghai Salt Lake Nitrate Industry Stock Co – part of Chinese chemicals conglomerate **Wentong Group** – is said to have a potassium nitrate production capacity of 400,000 tonnes. It was formed in 2016 from the merger of Qinghai Salt Lake Yuantong Potash Fertilizer Co with Qinghai Wentong Yanqiao Fertilizer Co.

The **Migao Corporation** operates an 80,000 t/a capacity potassium nitrate production plant in Sichuan and a 400,000 t/a capacity potassium nitrate/NPK plant in Yunnan. The company's secondary production process is based on combining potassium chloride with ammonium nitrate. SQM constructed a 40,000 t/a potassium nitrate production unit in China as part of a joint venture with Migao dating from 2008. This plant has been operational since 2011. ■

High-purity calcium nitrate (CN)

Standard CN products

Agricultural calcium nitrate (CN, 15.5-0-0+26.3CaO) products are typically manufactured from nitric acid and calcium carbonate (limestone). They are available as both liquid fertilizers [45% $Ca(NO_3)_2$] and in solid crystalline form [$Ca(NO_3)_2.4H_2O$]. Global output is estimated at around 2.3-2.5 million tonnes p.a. Yara through its *YaraLiva* range is the largest CN producer globally. The company's market-leading products include soil-applied *YaraLiva TROPICOTE* and the water-soluble greenhouse-grade *YaraLiva CALCINIT*.

CN is widely used in fertigation and hydroponic systems. Soil-applied products, meanwhile, due to their calcium content, can improve the texture of clayey soils, improve soil water retention and soil oxygenation, as well as help release exchangeable nutrients held by the soil. Calcium is a valued nutrient known to play a role in cell wall strength, so enhancing crop quality, yield and prolonging shelf life.

High-purity CN

Standard CN is relatively impure, containing around seven percent of total nitrogen in ammonium form. This level of ammonium, linked to the presence of ammonium nitrate, can be deleterious to the yield and quality of fertigated greenhouse crops. Uralchem and Prayon have both responded to this perceived problem by bringing high-purity anhydrous CN products (17-0-0+33CaO) to market.

Uralchem began producing what it says is the world's most concentrated calcium nitrate (CN) fertilizer, *Calcium Nitrate Concentrated*, in 2013. This is marketed by Uralchem as "the only fully water-soluble and readily available calcium source for plants". The company believes the quality of its CN fertilizer surpasses that of rival international products available on the market. To meet demand, the Russian producer has expanded production of this relatively-new product from a single line to three lines over the last five years, increasing its annual manufacturing capacity from 40,000 tonnes to 141,000 tonnes currently.

Calcium Nitrate Concentrated is produced to the following specification:

- Calcium content: 33 percent CaO minimum
- Total nitrogen: 17 percent minimum, 16.7 percent as nitrate-nitrogen, 0.3 percent as ammonium-nitrogen
- Insolubles: 0.1 percent maximum
- pH: 5.5-6.5, one percent solution
- Moisture content: three percent maximum

The product is around 98 percent pure, providing an extremely high concentration of calcium and nitrogen nutrients. It contains up to 25 percent more $Ca(NO_3)_2$ than some standard types of calcium nitrate, according to Uralchem.

The purity and high solubility of *Calcium Nitrate Concentrated* make it ideal for fertigation and foliar applications. In addition, the product's unique high-concentration formulation is said to boost the stress resistance of fruit crops, benefitting quality and extending shelf life. Providing nitrogen in the nitrate form, rather than as ammonium, also increases the uptake of other plant nutrients (Ca, Mg, K and micronutrients), claims Uralchem.

Belgium's **Prayon** also added a *Calcium Nitrate EXTRA* product to its *Hortipray®* range at the end of 2016. This highly-concentrated, water-soluble product boosts calcium content from 25 percent to 33 percent (CaO), compared to standard calcium nitrate. It also guarantees that at least 17 percent nitrogen content is available as nitrate.

"Compared to standard products, the crystals in *Calcium Nitrate EXTRA* contain fewer water molecules, resulting in a higher concentration of nutrients," explained Kurt Verhelst, Prayon's strategic account manager.

Calcium Nitrate EXTRA is being marketed as an ideal alternative to liquid calcium nitrate. The new product is free of impurities, such as sodium, and contains a negligible amount of ammonium, unlike other standard types of calcium nitrate.

"In some hydroponic crops, excessive ammonium can cause growing problems resulting in yield and quality losses. [That is why] a liquid version of calcium nitrate – containing no ammonium – has been introduced into modern horticulture. *Calcium Nitrate EXTRA* is the perfect solid alternative to this liquid calcium nitrate," concluded Verhelst. ■

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PHOTO: EUROCHEM

World-scale nitrogen projects

EuroChem has given the greenlight for the construction of Northwest 2 ammonia-urea plant. This will be constructed alongside Europe's largest ammonia plant, Northwest 1 (above) in Kingisepp, Russia.

We highlight the large-scale nitrogen projects that are currently under development across the globe – with a focus on ammonia and urea technology licensors and engineering contractors.

With urea prices currently hovering around the $450/t mark, farmers might be relieved to know that extra global urea supply is on its way. Indeed, across the globe, a wave of new urea projects are either in the final stages of construction or being commissioned.

Globally, the International Fertilizer Association (IFA) expects urea capacity to grow by around seven percent (14 million tonnes) during 2020 and 2021 to reach 223 million tonnes[1]. This short-term surge in capacity growth is being mainly driven by around a dozen new urea projects in just five countries – India, Nigeria, Russia, Brunei and Iran (Figure 1). These five countries collectively are expected to add around 12.6 million tonnes to global urea capacity.

However, analysts ICIS expect that, realistically, only 2.5-3.0 million tonnes of new urea supply will actually hit the market in 2021 – due to project delays arising from the Covid-19 pandemic and other factors (*Fertilizer International* 501, p20). According to ICIS, notable urea projects likely to be commissioned this year include:

- The new world-class **Dangote Lekki-I** plant and the second **Indorama (IEPL) Eleme** urea line in Nigeria. These are expected to become operational in mid-2021, although doubts about the exact timing of their arrival remain.
- New Russian production capacity, including units at **Acron (Novgorod)**, **Metafrax (Gubakha)** and **TOAZ (Togliatti)**, is also likely to come on-stream by the year's end.
- But only one of the four government-owned urea 'revival projects' in India, **RFCL Ramagundam**, is now expected to come on-stream in 2021 due to project delays.

Similarly, CRU is expecting the commissioning of up to six major urea projects in 2021:

- Brunei Fertilizer Industries (BFI), Sungai Liang, Brunei, 1.287 million tonnes capacity
- Dangote, Lekki-I, Nigeria, 1.271 million tonnes capacity
- RFCL, Ramagundam, India, 1.270 million tonnes capacity
- NavoiAzot, Navoi, Uzbekistan, 580,000 tonnes capacity
- Metafraz, Gubakha, Russia, 575,000 tonnes capacity
- Acron, Novgorod, Russia, 520,000 tonnes capacity.

These six projects combined would add around 5.5 million tonnes to global urea production capacity.

Below, we highlight some key ammonia-urea project developments over the last 12 months, with a particular focus on Australia, China, Egypt, India, Nigeria and Russia (Table 1).

AUSTRALIA

New urea plant for Western Australia

Australian gas producer Strike Energy is pressing ahead with a project to build an ammonia-urea production complex in Geraldton, Western Australia.

Project Haber, which includes a 800,000 t/a ammonia plant and a 1.4 million t/a urea plant, will consume natural gas sourced from Strike's Greater Erregulla development in the Perth basin. This will be transported to the site via a 120-kilometre pipeline. The proposed production complex will also include 300,000 tonnes of on-site urea storage, power, utilities, steam generation and rail sidings.

Strike is currently preparing to move Project Haber to the front end engineering and design (FEED) stage. Engineering partner Technip Energies is currently reassessing the project's capital cost estimate of $1.74 billion as part of this pre-FEED work. Strike has also retained JBS&G Strategen to start the planning process and seek the necessary environmental approvals for the project.

Strike intends to secure offtake agreements for up to 80 percent of the proposed plant's urea output before advancing the project to the FEED stage. Discussions have already begun with 12 potential domestic and international buyers on urea offtake contracts.

At present, Technip and technology partner Haldor Topsoe are also exploring ways to maximise green hydrogen input to the project's production process. Strike already intends to provide two percent of the plant's hydrogen requirements via its own 10 MW electrolysis unit.

Strike estimates that Project Haber, by reducing its emissions intensity, could ultimately reduce the carbon footprint of Australian urea consumption by 50-65 percent, due to the abatement of 650,000-795,000 CO_2 equivalent tonnes annually.

Pre-FEED studies and revised cost estimates are expected to be completed by the end of August. As a next step, Strike is planning to begin the process to finance the Project Haber later this year, although a final investment decision is not expected before the end of 2022.

Strike Energy has emphasised that Project Haber is at a preliminary stage, with successful development contingent on a number of factors. These include the proving of sufficient gas reserves, the outcome of FEED, access to finance and the securing of offtake agreements. If and when the green light is given, construction of Project Haber is expected to take 36 months.

Perdaman awards construction contract for Burrup urea plant

Perdaman Chemicals and Fertilizers Pty Ltd awarded the engineering, procurement and construction (EPC) contract for its Burrup urea project at the end of last year. The project is located at the Burrup Peninsula Industrial Area, some 20 kilometres northwest of Karratha, on Western Australia's coast.

The $2.4 billion EPC contract was secured by a 50:50 joint venture between Italy's Saipem SpA and local engineering and construction firm Clough Group. It covers engineering, the supply of equipment and materials, and the construction and commissioning of the 2.1 million t/a urea production plant. The building of a water treatment plant, a 100 MW power plant are also included in the contract, as are urea storage, loading and unloading facilities.

Saipem will provide *Snamprogetti* technology for the urea plant, while Haldor Topsoe will license its *SynCOR*™ technology to build the world's largest single-train ammonia plant.

Fig. 1: **Likely start-up of key global ammonia-urea projects, 2020-2021***

*Uncertainties remain about exact timings with some projects facing delays of up to six months.

Source: IFA

NITROGEN PROJECT REPORT

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Table 1: **Nitrogen project listing 2021 for Australia, China, Egypt, India, Nigeria and Russia***

Contractor	Licensor	Company	Location	Product	mt/d	Status	Start-up date
AUSTRALIA							
SNC Lavalin	Haldor Topsoe	Perdaman	Karratha, WA	Ammonia	3,500	CA	2024
SNC Lavalin	Saipem	Perdaman	Karratha, WA	Urea	2 x 3,100	CA	2024
Technip FMC	n.a.	Strike Energy	Garaldton, WA	Ammonia	2,400	DE	2025
Technip FMC	n.a.	Strike Energy	Garaldton, WA	Urea	4,200	DE	2025
CHINA							
n.a.	Casale	Yichang Xingxing	Yichang, Hubei	Ammonia	1,250	UC	2022
n.a.	Casale	Fujian Shen Yuan	Fuzhou	Ammonia	1,200	UC	2021
n.a.	Casale	Henan Xinlianxin	Jiangxi	Ammonia	2,000	UC	2022
n.a.	Stamicarbon	Henan Xinlianxin	Jiangxi	Urea	2,330	DE	2024
n.a.	Casale	Jiangsu Jinmei	Xuzhou	Ammonia	2,000	UC	2022
n.a.	Casale	Chongqing Yihua	Chongqing	Ammonia	900	UC	2022
n.a.	Saipem	Shanxi Qingshui	Yulin, Henan	Urea	3,300	UC	n.a.
Hualu Engineering	Stamicarbon	Jiujiang Xinlianxin	Jiujiang, Jiangxi	Urea	2,330	C	2021
Wuhuan Engineering	Stamicarbon	Hubei Sanning	Hubei	Urea	2,330	C	2021
EGYPT							
Tecnimont	KBR	Kima	Aswan	Ammonia	1,200	C	2020
Tecnimont	Stamicarbon	Kima	Aswan	Urea	1,575	C	2020
thyssenkrupp Uhde	thyssenkrupp Uhde	NCIC	Ain Sokhna	Ammonia	1,200	UC	2022
thyssenkrupp Uhde	Stamicarbon, TKFT	NCIC	Ain Sokhna	Urea	1,050	UC	2022
thyssenkrupp Uhde	thyssenkrupp Uhde	NCIC	Ain Sokhna	Nitric acid	500	UC	2022
thyssenkrupp Uhde	thyssenkrupp Uhde	NCIC	Ain Sokhna	Ammonium nitrate	635	UC	2022
thyssenkrupp Uhde	thyssenkrupp Uhde	NCIC	Ain Sokhna	CAN	835	UC	2022
Tecnimont	KBR	EHC	Ain Sokhna	Ammonia	1,320	CA	2023
n.a.	Stamicarbon	Abu Qir Fert	Abu Qir	Urea	2,370	RE	n.a.
INDIA							
Engineers India Ltd	Haldor Topsoe	RCFL	Ramagundam	Ammonia	2,200	C	2020
Engineers India Ltd	Saipem	RCFL	Ramagundam	Urea	3,850	C	2020
n.a.	Casale	Zuari AgroChem	Goa	Ammonia	1,050	RE	2022
TechnipFMC/L&T	Haldor Topsoe	HURL	Sindri	Ammonia	2,200	UC	2021
TechnipFMC/L&T	Saipem	HURL	Sindri	Urea	3,850	UC	2021
TechnipFMC/L&T	Haldor Topsoe	HURL	Barauni	Ammonia	2,200	UC	2021
TechnipFMC/L&T	Saipem	HURL	Barauni	Urea	3,850	UC	2021
n.a.	KBR	HURL	Gorakhpur	Ammonia	2,420	UC	2021
n.a.	TEC	HURL	Gorakhpur	Urea	3,850	UC	2021
n.a.	Saipem	NFL	Vijaipur	Urea	2 x 1,515	RE	n.a.
n.a.	Saipem	Coromandel	Gadepan	Urea	1,650	RE	n.a.
n.a.	Casale	Deepak Fertilizers	Paradip	Nitric acid	970	C	2020
Wuhuan Engineering	KBR	Talcher Fertilizers	Talcher	Ammonia	2,200	UC	2023
Wuhuan Engineering	Stamicarbon	Talcher Fertilizers	Talcher	Urea	3,850	UC	2023
NIGERIA							
TEC	KBR	Indorama	Port Harcourt	Ammonia	2,300	C	2020
TEC	TEC	Indorama	Port Harcourt	Urea	4,000	C	2020
Saipem	Haldor Topsoe	Dangote Fertilizer Ltd	Agenbode	Ammonia	2 x 2,200	C	2021
Saipem	Saipem/TKFT	Dangote Fertilizer Ltd	Agenbode	Urea	2 x 3,850	C	2021
n.a.	n.a.	OCP	n.a.	Ammonia	3,300	P	2024
RUSSIA							
Tecnimont	Stamicarbon	KuibishevAzot	Togliatti	Urea	1,500	UC	2021
GIAP	Casale	KuibishevAzot	Togliatti	Nitric acid	1,350	UC	2021
GIAP	Casale	KuibishevAzot	Togliatti	Ammonium nitrate	1,500	UC	2021
NIIK	Casale	JSC Metafrax	Gubakha	Ammonia	1,000	UC	2021
NIIK	Casale/MHI	JSC Metafrax	Gubakha	Urea	1,700	UC	2022
Casale	Casale	Togliatti Azot	Togliatti	Urea	2,200	UC	2022
Tecnimont	KBR	EuroChem	Kingisepp	Ammonia	3,000	UC	2024
Tecnimont	Stamicarbon	EuroChem	Kingisepp	Urea	4,000	UC	2024
Uralchem	Stamicarbon	Uralchem	Perm	Urea	+900	RE	On Hold
n.a.	KBR	Kemerovo Azot	Kemerovo	Nitric acid	500	UC	2021
Acron	GIAP	Acron	Dorogobuzh	Ammonia	2,100	C	2020
NIIK	Stamicarbon	Acron	Novgorod	Urea	2,000	C	2020
CNCCC	Haldor Topsoe	ShchekinoAzot	Pervomayskyy, Tula	Ammonia	1,500	DE	2022
CNCCC	Stamicarbon	ShchekinoAzot	Pervomayskyy, Tula	Urea	2,000	DE	2022

*Note This is an extract from the full global 2021 nitrogen project listing published in our sister magazine Nitrogen+Syngas in June this year (*Nitrogen+Syngas* 371, p26).

KEY

BE: Basic engineering
C: Completed/commissioning
CA: Contract awarded
DE: Design engineering
FS: Feasibility study
n.a.: Information not available
P: Planned/proposed
RE: Revamp
UC: Under construction
Conversion:
1 t/d of hydrogen = 464 Nm³/h
1 t/d of natural gas = 1,400 Nm³/d

SAIPEM: New ammonia industry milestones

Saipem, with its reputation as a tier-1 engineering, procurement and construction (EPC) contractor, is fully committed to the energy transition and the sustainable and innovative approaches needed to deliver this. This is illustrated by the following three projects:

The Perdaman project, Western Australia

Perdaman's ammonia-urea project is located at the Burrup Strategic Industrial Area (BSIA), approximately 10 kilometres from Dampier on Western Australia's north coastline. Known as the Destiny Project, it will take natural gas from an LNG plant as a feedstock and convert this into large quantities of granular urea for export. This world-scale urea plant has an overall design capacity of 6,200 t/d, while the 3,507 t/d ammonia plant will be the world's largest with a single converter.

The EPC project awarded to the Saipem-Clough joint venture includes:

- 3,507 t/d ammonia unit licensed by Haldor Topsoe A/S (HTAS)
- 6,200 t/d urea units licensed by Saipem and 6,200 t/d urea granulation units licensed by thyssenkrupp Fertilizer Technology (tkFT)
- Air separation unit able to produce 2,200 t/d of oxygen
- A combined cycle gas turbine (CCGT) power plant to produce electricity and steam from natural gas
- All associated utilities and offsite export facilities – including storage, ship loaders and conveyors at Dampier Port.
- The innovative construction approach will also involve extensive use of modularisation.

The state-of-the-art technologies selected for the project will ensure high quality products are produced in a highly efficient and environmentally-friendly manner. Haldor Topsoe's *SynCOR*™ technology, in particular, meets the international best practice benchmark for energy efficiency in ammonia-urea production. Consequently, the project will achieve a much lower average greenhouse gas (GHG) intensity compared to other more conventional fertilizer projects. To reduce the project's carbon footprint even further, a dedicated solar power plant will generate about five percent of total net electrical power requirements.

This milestone project – due to its scale and by setting a new benchmark for low energy consumption – established new standards for the fertilizer industry and will become an exemplary reference plant for the burgeoning blue ammonia industry.

Haifa project, Israel

Saipem is providing Israel's Haifa Chemicals with an efficient and low emissions solution for small-scale ammonia production. The new ammonia unit has a nominal rated capacity of 300 t/d and incorporates Haldor Topsoe's Low Energy Ammonia Technology design.

Around 70-75 percent of the ammonia produced will be consumed by Haifa's on-site nitric acid plants. The remaining 20-25 percent will be transported off-site in tankers by road. Any surplus ammonia will be refrigerated and stored on site at atmospheric pressure.

The project includes the installation of a carbon dioxide purification unit. This 75 t/d capacity unit will generate high quality food-grade CO_2 from carbon dioxide recovered from the ammonia plant's vent stream. The unit will purify, then liquefy and store this before eventual sale into the merchant liquid CO_2 market.

The scale of this project makes it an important flagship reference for the emerging green ammonia industry.

Barents blue ammonia project, Norway

Saipem is pleased to announce the award of the concept study for Horisont Energi's ambitious Barents blue ammonia proejct in northern Norway. This 3,000 t/a capacity plant will incorporate Haldor Topsoe *SynCOR*™ technology capable of achieving a 99 percent carbon capture rate. ■

Stefano Cao, Saipem's CEO, said: "We congratulate Perdaman Industries for the achievement, and we are grateful for the confidence demonstrated towards our Saipem-Clough JV. This project – one of the largest and environmentally efficient urea plants in the world – will strengthen our leadership role in the gas monetisation market and will contribute to further diversify our geographical footprint."

EGYPT

KIMA 2 enters commercial production

KIMA's new $770 million ammonia-urea plant at its Aswan complex in Upper Egypt commenced production in May last year. This followed the completion of construction by contractor Tecnimont and commissioning trials in the first-quarter of 2020.

The KIMA 2 plant has a capacity to produce 1,200 t/d of ammonia and 1,575 t/d of urea. The ammonia production unit incorporates KBR *Purifier* technology, while the urea melt unit is based on Stamicarbon's *Pool Reactor* technology.

EHC ammonia plant construction contract

Maire Tecnimont has secured a $350 million engineering, procurement and construction (EPC) contract with Egypt Hydrocarbon Corp (EHC) for a new ammonia plant at Ain Sokhna near Suez.

The contract, finalised in May last year, covers the construction of a new 1,320 t/d capacity ammonia plant at the site, as well as providing extensive utilities and offsite facilities. Output from the new plant will feed EHC's existing ammonium nitrate plant at Ain Sokhna.

The project is scheduled for completion 36 months after financial closure. Project finance is being arranged by the Italian export credit agency SACE and US EXIM Bank.

Basil El-Baz, EHC chairman, said: "This contract is another outstanding opportunity to work with Maire Tecnimont, a company we trust with best in class expertise and experience. The EHC expansion project is a vote of confidence in the Egyptian economy and the reforms that have been undertaken to date. The project will serve as a catalyst for the mining sector, attracting foreign investment and increasing employment opportunities and providing the raw materials needed for the sectors activities."

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STAMICARBON: Focus on sustainability

Stamicarbon, the innovation and license company of Maire Tecnimont Group, has been at the forefront of fertilizer industry innovation since its establishment almost 75 years ago. The company is committed to increasing its investment in innovation and sustainable fertilizer production. Examples include:

- Ultra-Low Energy technology to reduce plant steam (energy) consumption.
- *MicroMist*™ venturi scrubbing systems to significantly lower emissions.
- Stami Green Ammonia technology to enable sustainable and green fertilizer production by using renewable resources and eliminating carbon.
- The development of a renewable power-to-fertilizer plant in Kenya, based on Stamicarbon's green ammonia and nitric acid technologies (see page 8).
- The partnership with Shchekinoazot to develop and bring green technologies to Russia (see page 8).
- Participation in the European INITIATE project to create a symbiosis between the steel and fertilizer industry – by re-using captured carbon dioxide and carbon-rich off-gasses from steel mills.
- Contributing to the European PROMETEO green development project to reduce CO_2 emissions.

Energy saving

Stamicarbon's innovative Ultra-Low Energy design for urea plants – which recycles heat three times instead of two – offers unrivalled energy savings. The design also substantially reduces urea plant operating costs by significantly reducing both steam and cooling water consumption. As well as being suitable for new plants, the Ultra-Low Energy design can also be incorporated in plant revamps – being applicable to both CO_2 stripping plants and conventional urea plants.

The first two Ultra-Low Energy design plants with a capacity of 2,334 t/d went into operation this spring in China, while two others are under construction, one in Turkey and one for the same client in China.

Green ammonia

With the launch of Stami Green Ammonia technology, Stamicarbon has become a licensor for small-scale ammonia plants.

With four plants in operation, this capex-competitive technology already has a solid reference base, offering high reliability (thanks to a multi-service reciprocating processor) with a proven design. It can also be installed in currently operating plants, as a hybrid technology solution, to make existing fertilizer production more sustainable.

Other applications include the production of renewable energy carriers such as shipping fuels, for example, or the generation of renewable feedstocks for other processes.

Overall, Stami Green Ammonia technology offers a complete solution for carbon-free and sustainable ammonia production.

Pierroberto Folgiero, the CEO of Tecnimont's parent company Maire Tecnimont, added: "With this achievement we are proving once again the great resilience of our core business in a particularly challenging period for the whole market. We are also really proud to play a strategic role in the development of the fertilizer industry in Egypt with an entrepreneurial client such as EHC."

Stripper fabricated for NCIC urea melt plant

Major equipment items have been completed for NCIC's new urea melt plant in Ain Sokhna, Egypt. Stamicarbon was preparing to ship the plant's high-pressure stripper in June last year, after this was successfully fabricated by Schoeller-Bleckmann Nitec in Austria.

The 1050 t/d capacity urea melt plant is an integral part of NCIC's under-construction Ain Sokhna fertilizer complex in Egypt's Suez governorate. This is currently being built by a consortium of Germany's thyssenkrupp Industrial Solutions (tkIS) in partnership with the Egyptian company Petrojet. The complex, which is scheduled for completion next year, will have the capacity to produce 440,000 tonnes of ammonia, 380,000 tonnes of urea and 300,000 tonnes of calcium ammonium nitrate (CAN) annually.

In a news update in June last year, Peter Lang, Stamicarbon's project manager, said the Ain Sokhna project was running smoothly with all equipment on schedule.

Stamicarbon to revamp Abu Qir urea plant

Stamicarbon has signed a contract with Egypt's Abu Qir Fertilizers to revamp the Abu Qir 3 urea melt plant in Alexandria.

The revamp of Abu Qir 3 will increase urea production capacity to 2,370 t/d. That compares to its current nameplate capacity of 1,750 t/d and design capacity of 1,925 t/d.

The existing urea plant dates from 1996 and uses Stamicarbon's CO_2 stripping process. Stamicarbon is providing both the license and the process design package for the revamped plant. This is expected to become operational in 2025.

The revamp is based on Stamicarbon's *EVOLVE CAPACITY*™ design with medium-pressure (MP) add-on technology. This allows capacity to be expanded, but without investing in high pressure equipment or a high-pressure CO_2 compressor, while simultaneously reducing energy consumption. The revamp will also reduce emissions to meet local norms.

INDIA

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

Four more 1.3 million t/a capacity 'revival' projects are scheduled to be commissioned over the next 4-5 years, as follows:

- RFCL's Ramagundam plant, Telangana, in 2021
- HURL's Gorakhpur plant, Uttar Pradesh, in 2022

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- HURL's Barauni plant, Bihar, and Sindri plant, Jharkhand, in 2023.

As of mid-2020, construction progress at the RFCL, Gorakhpur, Sindri and Barauni plants had reached 99 percent, 77 percent, 70 percent and 69 percent, respectively, according to local media reports.

Although the remaining 'revival' project, the Talcher urea plant in Odisha, is scheduled for completion in 2023, the plant remains at the design stage currently.

Ramagundam plant enters production

The renovated Ramagundam urea plant in Telangana edged closer to commercial production in March.

Urea production at the newly renovated plant, owned by Ramagundam Fertilizers and Chemicals Ltd (RFCL), had originally been due to start at the end of March last year, but this was delayed by India's Covid-19 lockdown. Commercial production has been rescheduled several times since then.

RFCL did, however, successfully complete a prilling tower trial run at the plant at the end of February. Nirlep Singh Rai, RFCL's CEO, said: "An important technical-grade urea production trial run was held. In addition, [a] bagging unit trial run was also successfully completed."

He was also confident that commercial production would start in March: "Every day about 3,850 tonnes of urea and 2,200 tonnes of ammonia will be produced at the RFCL plant. In the coming days, there won't be any shortage of urea in Telangana."

The 1.27 million t/a capacity RFCL plant is a joint venture between five organisations. National Fertilizers Limited and Engineers India Limited are major partners, both owning a 26 percent stake. The Fertilizer Corporation of India (11%), the Telangana government (11%), the Gas Authority of India (14.3%) and the HTAS consortium (11.7%) own the remaining 48 percent.

Talcher urea plant selects Stamicarbon process

Stamicarbon was named in January as the technology licensor for the Talcher urea plant in Odisha. The company will deliver the process design package (PDP) for Talcher Fertilizers Limited's 3,850 t/d urea melt and prilling plant. The melt plant will incorporate Stamicarbon's *Pool Condenser* design, while the synthesis section will use *Safurex*® stainless steel.

The project is a strategic milestone for Stamicarbon, marking its return to the Indian market after more than 40 years. Other urea plants currently under development in India have generally opted for Saipem production technology.

NIGERIA

Dangote aiming for 2021 project start-up

Analysts expect Dangote's Lekki project to begin commercial production this year, although an official announcement from the company is still pending.

The project's first 1.3 million t/a capacity urea line underwent trials in June 2020, ICIS reported last year, with exports likely to begin in the first half of 2021.

"Realistically, we expect completion of the first Dangote line by the end of 2020, it is unlikely it will happen before. Commercial output should be available in second-quarter 2021 or possibly first-quarter," an international trader told ICIS.

Project contractor Saipem was also expecting commissioning to be completed by the end of 2020 with production starting in 2021. "We are picking up now that things are looking more stable and are currently very well advanced," Maurizio Coratella, Saipem's chief operating officer, said in mid-July last year. "We are in the commissioning stage of the first train; for the second, we will have that commissioning in six to seven months' time."

Saipem is making special arrangements to enable it to meet the completion deadline, Coratella said, including setting up dedicated flights for vendors and suppliers.

Saipem is the project's EPC contractor and is also supplying the urea technology for the plant. The petrochemicals complex, located in the Lekki district of Nigeria's capital Lagos, includes two urea trains with a combined capacity of 2.6 million t/a.

Although the plant was said to have been completed mechanically in the first-quarter of last year, initial test runs scheduled for March 2020 were held up when the Covid-19 outbreak prevented Saipem's engineers flying from Italy to Nigeria to help with commissioning.

While analysts expect the Dangote plant, and Nigeria's second under-construction urea project, Indorama's second 1.4 million t/a urea line at Port Harcourt, to both become operational soon – doubts about exact timings remain with no official word from either producer (*Fertilizer International* 501, p21).

RUSSIA

EuroChem gives go ahead for Northwest 2 project

EuroChem Group is proceeding with a project to develop the Northwest 2 ammonia-urea plant in Kingisepp.

Northwest 2 will have an annual production capacity of 1.4 million tonnes for urea and one million tonnes for ammonia. The new plant will be built alongside the existing one million t/a capacity Northwest 1 ammonia plant. This was commissioned in 2019 to provide ammonia to EuroChem operations in Belgium, Lithuania, and its adjacent phosphate fertilizer plant at Kingisepp. Yara also sources ammonia from the Northwest 1 plant, via the Estonian port of Sillamae, under an offtake agreement.

EuroChem recently secured the necessary finance for construction of the $1.6 billion Northwest 2 plant. Loans for the project were agreed at the St Petersburg International Economic Forum in early June. The lenders are Russian state development corporation VEB.RF and Russian banks Sberbank, VTB, Gazprombank, and Otkritie.

"This is the first time that EuroChem is implementing such a project with Russian banks, and for the first time a debt-to-equity ratio of 80:20 has been achieved," commented Vladimir Rashevskiy, EuroChem's CEO.

Although most of the ammonia produced by Northwest 2 will be consumed on-site, EuroChem plans to place around 300,000 tonnes on the market.

Carbon-abatement at Northwest 2 should reduce the environmental impact of production at the Kingisepp site. The new project will achieve this by consuming the CO_2 by-product from the adjacent Northwest 1 ammonia plant during its urea production process.

The new Kingisepp plant is an important project for EuroChem, says Vladimir Rashevskiy: "Northwest 2 is part of our drive to move beyond self-sufficiency in ammonia, a vital component of our fertilizer production needs. It will also boost our urea output capacity and market share in this critical commodity product. We are constructing a state-of-the-art plant in close proximity to our existing rail and shipping facilities, enabling easy transportation to production units and global markets."

CASALE: Boosting GIAP ammonia plant capacity

In the last 2-3 years, Casale has successfully completed the revamping of two GIAP plants for EuroChem Group in Russia. The projects successfully delivered the maximum possible increase in capacity while simultaneously minimising the investment cost.

The two EuroChem plants, located in Nevinnomyssk and Novomoskovsk, were originally designed with a nameplate capacity of 1,420 t/d. However, in practice, they were operated at production capacities ranging between 1,650-1,700 t/d prior to revamping, depending on the season.

The design of GIAP plants is similar to vintage MW Kellogg plants. The main differences are in the refrigeration section where – instead of a refrigeration compressor – aqua ammonia refrigeration packages (AARP) are used. These are based on ammonia absorption in water. The column internals in the CO_2 removal section of GIAP plants are also quite specific.

The following plant bottlenecks needed addressing:

- Air compressor limitations
- Unbalanced burning in the primary reformer affecting convection section performance
- CO_2 removal – especially incipient flooding in the absorber
- Syngas compressor and turbine load
- Ammonia synthesis converter
- AARP refrigeration section.

Prior to revamping, the top-fired superheating burners in the primary reformer were operated at maximum load due to the low superheating temperature of the high pressure (HP) steam. This was fixed by repurposing the boiler feedwater (BFW) coil as a low temperature process air coil. This allowed the burner load to be reduced by heating the flue gas before it entered the high temperature super heating coil. This was a straightforward modification requiring only a few items.

The CO_2 removal section was debottlenecked by switching to new Casale multipipe trays in the CO_2 absorber. With a much higher active area, these trays are twice as efficient as standard sieve trays. The revamped absorber is now capable of exceeding a production capacity of 2,000 t/d.

Casale's 'clean/dirty' separation concept was implemented to improve the performances of the nearby urea plant. This concept involves installing an external elevated vessel to operate as a solution flash drum at slightly higher pressure than the CO_2 stripper. The hydrogen content of the CO_2 feed to the urea plant was reduced to about 100 ppm thanks to this modification.

Welded plate exchangers were also installed in the CO_2 removal section to improve efficiency.

An ammonia washing unt was installed to dry the make-up gas (MUG) feed to the synthesis loop. The ammonia synthesis converter, meanwhile, was revamped by installing an axial-radial three bed configuration with one quench and one interchanger. The resulting improvement in efficiency significantly reduced circulation inside the synthesis loop, with correspondingly lower power consumption in the synthesis gas compressor.

Casale adopted two different strategies for the AARP-based refrigeration sections at the Novomoskovsk and Nevinnomyssk plants. A completely new AARP was installed at the Novomoskovsk plant with a cooling capacity of about 12 MW. At Nevinnomyssk, in contrast, as well as the original AARP units, the client had an additional second-hand AARP. Casale therefore revamped this existing configuration.

The start-up and commissioning of the two GIAP plants was carried out smoothly after a shutdown of about 30 days. The success of Casale's revamp project for EuroChem was confirmed by performances tests (below) – the revamps having transformed both sites into the most productive GIAP plants in Russia. ■

Table 1: **Performance test results for GIAP plant revamps**

	Production (t/d)	Energy saving (Gcal/t)
Before revamp	1,655	–
Revamp target	1,854	-0.11
Actually achieved	~1,900	N/A

Source: Casale

Previously, EuroChem had selected Maire Tecnimont to carry out early works for Northwest 2 under a memorandum of intent signed in October 2019. This work, carried out by subsidiaries Tecnimont S.p.A and Tecnimont Russia LLC, involved preliminary engineering and site surveying work at a brownfield site adjacent to EuroChem's existing Kingisepp ammonia plant.

Acron completes ammonia revamp

Acron completed the revamp of its Number 4 ammonia plant at Novgorod in April. The Ammonia-4 plant was successfully uprated to its new production capacity of 2,500 t/d, having passed guarantee test runs.

The plant was originally commissioned in 2016 at a cost $500 million. It was the first ammonia plant built domestically in modern times by Russian engineers without the support of foreign contractors.

The Ammonia-4 revamp was carried out by Acron in conjunction with Haldor Topsoe. The revised design incorporates Topsoe's heat exchange reformer (HTER), changes to the CO_2 removal section, plus other modifications.

A team of Acron engineers and Topsoe specialists, working hundreds of miles apart, completed the successful overhaul of Ammonia- 4 late last year, enabling the plant to reach its new design capacity.

"Haldor Topsoe and Acron have been in successful partnership for quite a while and the revamp project, delivered in November 2020, marks another milestone in our cooperation. We believe our partnership will develop further, to the benefit of both companies," said Peter Vang Christensen, managing director of Haldor Topsoe's Moscow office.

Aleksandr Popov, Acron's chairman, said: "Boosting the Ammonia-4 plant is an important project for Acron Group's investment program… [allowing] us to increase production of nitrogenous and compound fertilizers at our Novgorod site."

Dorogobuzh completes ammonia plant upgrade

PJSC Dorogobuzh, part of Acron Group, completed a five billion rouble upgrade of an ammonia plant at its nitrogen fertilizer complex in Russia's Smolensk region in August last year.

The upgrade has increased the plant's ammonia production capacity by one-fifth to 2,100 t/d. The revamp is being hailed as a landmark achievement. This is the

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first time in the whole of the post-Soviet era, according to Acron, that a Russian ammonia plant based on KBR technology has achieved this output level.

The Dorogobuzh ammonia plant, which dates from 1979, had an original design capacity of 450,000 t/a. Its annual ammonia output is now expected to increase by an extra 130,000 tonnes.

Dorogobuzh is the first ammonia plant in Russian to use KBR's *KRES* heat exchange reformer technology. The resulting energy efficiency improvements have reduced the plant's natural gas consumption by seven percent (per tonne of ammonia).

LLC Novgorodsky GIAP designed the ammonia plant upgrade. The project itself was carried out by 60 Russian contractors who brought in over 1,100 specialists and 50 pieces of equipment. Dorogobuzh and Acron employees also participated.

"The upgrades to the Dorogobuzh ammonia unit are an essential part of our technology development programme," commented Vladimir Kunitsky, Acron's CEO. "The increase in the unit's capacity will give us additional ammonia to use for new projects."

Gubakha project makes steady progress

Construction of the large Metafrax ammonia-urea-melamine (AUM) complex at Gubakha is making steady progress, Casale reported in an update last year. This was despite the serious hurdles caused by the Covid-19 pandemic and the need to guarantee the health and safety of all of those involved in the project, including Casale's own on-site team.

"At the onset of the pandemic, appropriate measures and strategies were quickly put in place. We have strictly complied with all norms and procedures enacted by Russian authorities. All this has given us the confidence not to actually increase the strength of our on-site team. Meanwhile, for all vendors, specific procedures have enabled remote working, with minimal disruption of the workflow and reduced impact on the schedule," Casale said.

The company added that it was confident that the project's ammonia unit would come on stream soon: "All equipment of all units was already delivered to site before the pandemic struck. Owing to this, the piping prefabrication and installation is underway."

Analysts expect Metafrax's 575,000 t/a Gubakha urea plant to enter production this year.

TOYO: Three large-scale urea projects near completion

Japan's Toyo Engineering Corporation is a leading urea process technology licensor and EPC contractor. The company owns the *ACES21*® proprietary urea synthesis technology and Spout Fluid Bed Granulation, a unique urea granulation technology.

Toyo continues to invest in innovation. It recently introduced innovative digital plant optimisation technology and novel urea plant maintenance techniques that enable the inspection of internal equipment.

In the past year, Toyo has been especially active globally in the construction, pre-commissioning and/or commissioning of the three large-scale and 'epoch-making' urea plants, as described below.

Indorama Train-2 project, Nigeria

In 2018, Indorama Eleme Fertilizer & Chemicals Limited (IEFCL) awarded a contract to Toyo to build one of the world's largest ammonia-urea complex. This Train-2 project, located at Port Harcourt in Nigeria, has a design capacity of 2,300 t/d for ammonia (KBR *Purifier*™ process) and 4,000 t/d for granulated urea. This under-construction project follows the successful completion of the Train-1 project for IEFCL in 2016.

HURL project, Gorakhpur, India

In 2018, Toyo was awarded the urea technology license and the EPC contract by Hindustan Urvarak and Rasayan Ltd (HURL) to build a new ammonia-urea complex in Gorakhpur, India. The plant has a design capacity of 2,200 t/d for ammonia (KBR *Purifier*™ process) and 3,850 t/d for prilled urea. Construction activities are continuing, despite the serious Covid-19 pandemic situation in India, with commissioning expected in due course. Operational staff at the plant will have the opportunity to train on Toyo's own operation training simulator (OTS) prior to the commissioning phase.

MSPIC project, Khuzestan, Iran

Toyo is the urea technology licensor for the under-construction Masjed Soleyman Petrochemical Industries Company (MSPIC) ammonia-urea plant. This project is currently being built by PDIEC in Iran's Khuzestan Province. Toyo was originally awarded the license for the 3,250 t/d capacity urea plant in 2016. The company subsequently completed the design package for MSPIC and also remotely supported the project's detailed design, fulfilling both requirements in a timely manner. With both construction and pre-commissioning now close to completion, the MSPIC plant is due to enter commissioning later this year. ■

CHINA

Stamicarbon licenses second ultra-low energy urea plant

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

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

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

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

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

Author's note

A complete and comprehensive breakdown of all current global nitrogen projects is provided in the **2021 Nitrogen project listing** published by our sister publication *Nitrogen+Syngas* in June (*Nitrogen+Syngas* 371, p26).

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Phosphate and potash grinding equipment

The crushing and grinding of mined phosphate rock and potash ore is a vital preparatory step for subsequent beneficiation and chemical processing. Although often overlooked, the efficiency of downstream P & K fertilizer production is heavily reliant on successful particle size reduction upstream.

PHOTO: METSO OUTOTEC

A new Metso Outotec grinding mill being lowered into place with millimetre precision at Yara's phosphate concentration plant in Siilinjärvi, Finland.

In most forms of mining, the mechanical crushing and grinding of ore is the immediate next step after its extraction. Known as comminution, this is required to adjust particle size and/or liberate target minerals prior to beneficiation and downstream processing.

Grinding is a highly energy-intensive process, with the energy required (per unit mass) increasing rapidly as the desired particle size decreases. Power requirements depend on factors such as initial ore size, hardness and the final particle size required. For Florida phosphate rock, for example, around 35-40 kWh (per tonne P_2O_5) of electricity is consumed during the grinding of phosphate ore concentrates.

Types of equipment

In the potash and phosphate industries, the main crushing and grinding equipment options include:

- Ball mills
- Jaw crushers
- Hammer, impact and cage mills
- Rod mills
- Roller mills.

Ball or rod mills are both heavy duty cylindrical devices able to reduce coarse-sized ore to a fine powder. Rod mills grind ore using the friction generated between particles and steel rods in a rotating drum, while ball mills, as their name suggests, rely on hard spheres as a grinding medium.

Ball mills can greatly increase the surface area and reactivity of materials and are usually operated as continuous processes in phosphate and potash grinding. Typical grinding media include ceramic balls, flint pebbles and steel balls. Forged steel and high chrome iron grinding balls are particularly common.

Phosphate grinding

Mined phosphate rock needs physical preparation before it is suitable for beneficiation and downstream chemical processing. Preparatory comminution and size separation are usually both necessary. This can involve crushing, grinding and screening plus air classification or hydrocyclone separation.

While froth flotation is widely applied as a beneficiation method within the phosphates industry, the pre-preparation of the phosphate rock differs significantly depending on the ore type.

In some sedimentary ores, crushing and screening are used to reject coarse hard siliceous material, while attrition scrubbing and desliming are used to remove fine clayey fractions. In Florida, the phosphate matrix is extracted with a dragline, placed into a pit and turned into a slurry with a water cannon. This slurry is then pumped to the beneficiation plant which can be located miles away from the mine.

Harder sedimentary ores, meanwhile, require a combination of primary crushing, secondary grinding and classification to liberate phosphate from the unwanted gangue. This comminution process is used to generate a suitable size fraction for froth flotation.

Much harder igneous phosphate rocks also need to be crushed and ground prior

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Potash crushing and grinding in Saskatchewan

Canadian potash deposits are concentrated in two distinct stratigraphic horizons. Mines in the Saskatoon area of Saskatchewan, for example, extract potash from the Patience Lake member, while those in the southeast of the province extract ore from the Esterhazy member.

Historically in Canada, around 90 percent of fertilizer-grade potassium chloride (muriate of potash, MOP) is produced by froth flotation (Figure 1), sometimes supplemented by heavy media separation.

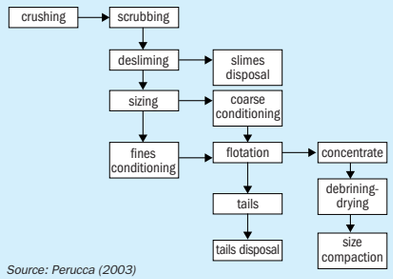
The crushing, grinding and sizing of potash flotation feed is a compromise, according to metallurgists[2]. Comminution needs to be carefully managed as, inevitably, there is trade-off between avoiding overgrinding – as the size of potassium chloride constituents need to be kept as large as possible for good flotation performance – while still effectively liberating halite and other insoluble constituents.

The run-of-mine ore produced by continuous mining machines is usually crushed underground with a jaw crusher to reduce the largest lumps to 15-20 centimetres in size. This minimises problems during underground transportation and skipping to surface[2].

Potash ore is a soft rock with typical Bond Work Index of 7-9 that can be prepared for flotation in wet or dry crushing plants. Dry crushing is generally carried out in a single stage using impactors in closed circuit with vibrating screens. More complex comminution circuits employ double-stage wet crushing in combination with wet screens and hydrocyclones. Dry crushing plants are simpler to operate but are often dirty due to poor dust collection. Wet crushing plants run much more cleanly and their screening is more efficient. They also remove insolubles more effectively[2].

Rougher flotation tails are usually re-crushed in a secondary wet crushing stage. The older circuit designs used rod mills for this purpose. Recent expansions and retrofitting of existing plants are replacing the old roll mills with rotating cage impactors. These are cheaper to operate, use much less space, have more capacity and generate less fines. ■

Fig. 1: **Schematic block diagram of a conventional potash flotation plant**



Source: Perucca (2003)

to froth flotation. This typically involves a primary crushing stage, followed by grinding in a rod mill in open-circuit and a ball mill in closed-circuit.

Beneficiated phosphate rock concentrates provide the feedstock for downstream phosphoric acid plants. Individual plants have distinct particle size requirements. These vary according to the reactivity of the phosphate rock feedstock and the type of process used. A fine powder with 60 percent less than 200 mesh (0.074 mm) is sometimes specified (*Fertilizer International* 434, p37).

The grinding of phosphate rock is generally essential for phosphoric acid production via the long-established and widely adopted dihydrate (DH) process. Rock grinding requirements are, however, less exacting for both the hemihydrate (HH) and hemi-dihydrate (HDH) processes, as a satisfactory reaction rate can be achieved with much coarser rock. Some phosphate rock feedstocks, such as those sourced from deposits in Jordan, Morocco, Senegal and Togo, are already fine enough for the HH and HDH processes without further grinding. The hemihydrate recrystallisation (HRC) process, meanwhile, requires a particularly fine rock grind (*Fertilizer International* 434, p37).

The primary purpose of comminution in phosphoric acid production is to create sufficient surface area to allow the rapid and complete digestion of the phosphate rock by sulphuric acid in the reactor. However, overgrinding, as well as wasting energy, can lead to hyper reactivity. It can also increase co-crystallisation losses due to formation of smaller and difficult-to-filter gypsum crystals.

The wet grinding of phosphate rock concentrates in ball mills is common practice in Florida and elsewhere (*Fertilizer International* 434, p37). Wet grinding keeps power consumption low and avoids dust generation.

Using gypsum pond water in wet grinding operations, to completely or partly replace service water, can generate further cost savings. Recycling pond water in this way avoids the substantial treatment costs otherwise required for its disposal or storage.

Recycled pond water is, however, acid and can cause excessive corrosion of the balls and metal liners during the wet grinding of phosphate rock. Consequently, the corrosion of forged steel or high chrome iron balls is a well-known phenomenon. Using water with a pH of at least 5.5 is therefore generally advised. pH can adjusted upwards by adding sodium hydroxide or ammonia, although this type of neutralisation adds to processing costs.

Metal grinding balls also undergo erosion, independent of pH, due to repeated abrasive contact with phosphate rock. The use of corrosion-resistant speciality steels and/or the neutralisation of pond water is therefore recommended to prolong the life of grinding media.

Wet grinding offers the following advantages over dry grinding:

- 30-40 percent reduction in energy consumption
- Eliminates the energy costs for rock drying
- Eliminates phosphate rock dust
- Reduces the size of grinding mills and their associated energy consumption.

Wet grinding can, however, create the following disadvantages at the phosphoric acid plant:

- Water in the slurry reduces P_2O_5 concentration in the reactor. This dilution effect subsequently requires larger evaporators and therefore raises evaporation costs.
- Any reduction in the volume of water available for washing the gypsum filter cake will result in higher water-soluble P_2O_5 losses.
- Overgrinding of soft, porous rock produces high viscosity slurries which are too fine. This 'hyper active' rock slurry yields very fine gypsum crystals which are difficult to filter.

Potash grinding

In conventional mining and modern beneficiation plants, potash ore is generally processed as follows[1]:

- The ore is firstly ground to the size which liberates the target mineral sylvite (KCl) from unwanted halite (NaCl)
- The ore is next 'deslimed' to remove insoluble material and fines
- Coarser sylvite particles are then separated and recovered by froth flotation
- Some potash plants also beneficiate the ore using dry electrostatic separation (the ESTA process) or wet heavy media separation
- The beneficiated potash is dried and partly compacted to increase its size
- Fines are generally leached and recrystallised.

For potash, the size reduction process starts underground. Ore is usually crushed to less than 10-15 centimetres before being loaded onto conveyors. Some operations use hammer or impact mills to reduce the ore to below five centimetres before it is hoisted to the surface and delivered to the mill[1].

PHOTO: JAMES ST JOHN/FLICKR

Permian-age potash-bearing rock, Carlsbad potash mining district, Eddy County, New Mexico. Potash ore needs to be crushed and ground to liberate the target mineral sylvite from unwanted halite.

Once above ground, the ore is typically milled to a much lower size (below 2-4 mesh, roughly 0.5 cm) using high-capacity hammer, impact or cage mills in preparation for further processing. These are operated in a closed circuit with vibrating screens which return the oversize to the mill. Finer grinding with ball, rod or cage mills is then often necessary to achieve the desired halite-potash liberation size in the froth flotation feed[1].

In the two-stage milling of potash, while coarser grinding is usually carried out dry, finer grinding is often a wet process. To avoid overgrinding, finer grinding mills operate in closed circuit with screens or particle size classification equipment.

DSM (Dutch State Mine) screens – elliptical, near vertical screens with wedge-shaped bars – have traditionally been used for coarse size separation in these potash slurry grinding circuits. Oversize particles slide off the screen's lower curved edge, while undersize particles and most of the brine fall through the screen. Hydrocyclones, hydroseparators and screw or rake classifiers are also used to remove slimes and for size classification of the flotation feed[1].

Equipment suppliers and projects

Leading manufacturers of phosphate and potash grinding equipment (*Fertilizer International* 434, p37) include:

- Bradley Pulverizer Company
- Comspain
- FLSmidth
- Köppern
- Ludman
- Metso Outotec
- Sandvik Rock Processing Solutions
- Sahut-Conreur
- Shanghai Jianye and Shanghai Zenith of China
- Terrasource (Gundlach and Pennsylvania Crusher).

Köppern is a leading supplier of potash compaction-granulation equipment. The family-run business, based in Hattingen, Germany, has been manufacturing briquetting, compaction and comminution machinery since 1898.

Granular potash is produced almost exclusively by the compaction-granulation process. Köppern has been supplying compaction and granulation equipment and plants to the fertilizer industry for more than 70 years. Its sales include several hundred roller presses in over 60 countries (*Fertilizer International* 501, p55).

Dusseldorf-based **Loesche GmbH** is a leading designer and supplier of milling plants based on vertical roller mill (VRM) technology. The company completed and commissioned a 650,000 t/a phosphate rock grinding plant for EuroChem at Zhanatas in southern Kazakhstan in 2016. The plant uses Loesche's *LM 24.2* model VRM mill for the primary treatment of phosphate ore from the Kok-Djon deposit in the country's Zhambyl region.

VRMs are suitable for the dry comminution of hard phosphate ore, according to Loesche, being able to produce "a consistent, dry product in a difficult environment".

Loesche has installed more than 2,500 VRM machines worldwide. These are typically used for the dry grinding of coal, cement raw materials, granulated slag, industrial minerals and ores. Loesche has often been the first company to introduce VRM technology into new industrial sectors – including several installations for grinding phosphate rock and phosphate rock concentrates.

EuroChem is developing the Kok-Djon deposit in two stages. The initial crushing, drying and grinding plant – which consumes phosphate rock mined from a nearby open pit – came on stream in 2016. This will ultimately supply a large-scale phosphate fertilizer plant. EuroChem signed an investment agreement with Kazakhstan's government to build and operate a new $1 billion fertiliser plant in the country's Zhambyl region at the beginning of last year.

TerraSource is the owner of the three flagship equipment brands Gundlach, Pennsylvania Crusher and Jeffrey Rader. Collectively, these brands have supplied many of the impact crushers, cage mills and roll crushers employed by the global potash industry.

Indeed, TerraSource has a long history of partnership with leading phosphate and potash producers. To the extent that the company has installed crushing equipment for all the major potash producers in North America as well as having a significant presence at potash operations in Russia, Australia, South America and the Middle East.

Gundlach, which has been an equipment supplier to the North American potash industry since 1967, offers both wet and dry crushing equipment. Notable potash industry models include the:

- *4000 Series* roll crusher for raw potash ore
- *2000 Series* roll crusher for breaking flake from the compactor

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CASE STUDY

Gundlach *Nanosiz-R*® roll mill

Jack Vivrett of TerraSource explains how the company is bringing innovation to the potash industry through its partnership with Intrepid Potash.

Intrepid Potash relies on TerraSource crushers at multiple operations. But the company's conversion to our Gundlach *Nanosiz-R*® roll mill at one of its Utah sites has helped make that operation one of the lowest cost potash production sites in the world – with the highest efficiency in the industry from compaction to final product.

The *Nanosiz-R* offers 'bi-modal' crushing for friable materials – as it functions through both shear and compression. Its modular design means that multiple units can be configured in series, if necessary, to achieve greater size reduction ratios.

For materials with a bulk density of 70 lbs/ft^3, the standard version of a *Nanosiz-R* can crush up to 65 short tons per hour (st/h), while the high-capacity version can crush up to 130 st/h, reducing feeds to a 2-4 mm size product.

At Intrepid's Utah plant, the company harvests potash from evaporation ponds, crushes this and then pumps this as a slurry some eight kilometres back to a mill for further processing.


PHOTO: TERRASOURCE

Raw potash product, Intrepid Potash, Utah.

For this process to work productively and seamlessly, Intrepid needed machinery capable of crushing 3,500 t/d of very wet mill feed from its raw size of 12-19 mm down to 1-2 mm size.

Although many impact crushers can produce material this fine, these types of machines typically produce too much oversize. In contrast, the precise hydraulic adjustment of rolls possible with *Nanosiz*-R machines – which offer a roll gap accuracy of a thousandths of an inch – enables operators at Intrepid Potash to fine tune the very tight roll gap they need. These Gundlach machines also efficiently eliminate the large size materials that can create a lot of rolling resistance in a slurry line. ■

- *Cage-Paktor* cage mill for polishing oversize material from screens
- *Nanosiz-R* roll mill, which is used for sizing oversize potash material discharged from screens (see case study).

Jeffrey Rader *Flextooth* hammer mills are also used to break down raw ore. Their energy efficient design and longer wear life makes them ideal for high-capacity crushing at low speeds. *Flextooth* mills work in tandem with proprietary *Slant-Flow* screen grates. These deliver a more uniform product size, evacuate material faster and minimise clogging, all with less wear on grates.

Pennsylvania Crusher has installed more than 6,500 crushers in 79 countries. The company's double toggle jaw crusher is ideally suited to bigger and harder grades of phosphate rock. This effective and rugged compression crusher offers a power-efficient method for the sizing of hard or abrasive materials that can cause excessive wear with other types of crushers. Being designed with balanced moving parts, these machines do not require massive and costly foundations, unlike other types of compression crusher.

TerraSource equipment has a reputation for durability and efficiency. They are also well known for their ability to precisely size a wide variety of raw materials, whatever their hardness, composition and moisture content. Every installation is backed by in-depth engineering and application know-how and rapid-response service support. Comprehensive materials testing and analysis capabilities are also provided by the company's innovation centre in South Carolina.

Metso Outotec installed a custom-built mill at Yara's Suomi phosphate mine in Siilinjärvi, Finland, in 2018. The finished rod mill was installed at the site's phosphate concentration plant during its annual shutdown.

The new 4x6 metre rod mill was designed so that it could be installed directly on top of the bearing housings of the old mill, which dated from 1979. This meant Yara was able to utilise the existing mill's power transmission line, gearbox and foundations in the project. The original gearbox was, however, given a thorough overhaul during the shutdown.

Metso's contract with Yara also specified the design and manufacture of a new 350 tonne capacity installation cradle, to allow the mill and its contents to be lifted whenever necessary.

The mill, which weighs more than 150 tonnes, was transported to the mine on a 14-axle trailer in the week preceding the shutdown. On arrival, it was lifted into place with a massive lattice boom crane.

"We received a new custom-built mill at half the cost of what a standard mill [with] new power transmission, electrification and foundations would have cost us," said Antti Savolainen, the manager of Yara's Siilinjärvi phosphate concentration plant.

"The old equipment's replacement with a finished mill [was] carried out in 10 days during the annual shutdown. Given the strong demand for our concentrate, and a daily production volume of around 2,800 tonnes, this was well worth the investment," Savolainen added.

The new mill was fitted with 800 grinding rods following a successful pressure test. This allowed the grinding of phosphate ore to recommence on schedule when production resumed. The 500 t/h capacity mill now works 24/7, grinding the 25 mm ore feed using 1,250 kW of power.

"We want to rely on our partners and the know-how they provide. Metso has a good track record at Yara's Siilinjärvi mine. It supplied the linings of primary gyratory crushers and deliveries for the installation of an *MP800* cone crusher," said Savolainen.

He concluded: "It looks like this custom-built mill was also the right solution. Our target is for the new mill to grind phosphate ore at our mine with a 99.9 percent utilisation rate for the next 30 years." ■

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The importance of phosphate milling

A holistic understanding of the phosphate milling process is necessary, says **Ian Hancock** of Bradley Pulverizer. This ensures maximum plant uptime, the highest process efficiencies, and ultimately guarantees profitability.


PHOTO: BRADLEY PULVERIZER

Air-swept mill system.

Grinding and pulverising mills are the furthest upstream process in phosphate fertilizer manufacturing. The continuous crushing of phosphate rock to meet particle size specifications is essential for efficient downstream processing. Yet mills are more commonly seen as the 'noisy neighbour' to other process steps, rather than the essential engine that drives phosphates production. Regrettably, this lack of recognition for the importance of milling can cause inefficiencies upstream that are further compounded downstream.

Phosphate milling – the essentials

Phosphate rock is fed into the front-end of a production plant and manipulated many times during its long process journey and eventual transformation into valuable end-products. This continual production process is central to efficient phosphate fertilizer manufacturing, with each process stage requiring specialised equipment.

The production process starts with crushing and grinding phosphate in a mill. This then feeds downstream processes such as acidulation, mixing, and pelletising through to final packaging. Every item of process equipment is interdependent, with the whole plant functioning as an interconnected network. In many ways, it is the upstream milling of phosphate rock that ultimately drives plant profitability and the overall quality and yield of the end-product.

It therefore follows that a holistic approach to fertilizer production is critical. That is because the continuous nature of the plant production process means adjustments to one piece of machinery will almost always require adjustments to other equipment, both upstream and downstream.

Unfortunately, however, this holistic approach is not always followed. The result is lower quality products, lower yields, and higher maintenance costs. In our view, this often occurs because fertilizer processing incorporates very different process steps – each one being covered by a separate engi-

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neering discipline. The upstream crushing and grinding of phosphate rock, for example, requires a comprehensive understanding of mechanical engineering and material properties, while downstream phosphoric acid production requires chemical engineering expertise. Metallurgists also make a vital contribution to phosphate beneficiation.

Expecting plant operators to employ large numbers of engineering graduates able to cover every single process step is not always going to be economically feasible. Nevertheless, staffing imbalances, in which one engineering discipline is overrepresented, can inevitably lead to an overemphasis on one process while others are overlooked.

To ensure a holistic approach, we would therefore encourage fertilizer manufacturers to view their processing plant as a series of specialised yet equally important circuits that work together as one whole system. To be managed properly, each circuit within the overall system should be staffed appropriately in our view.

In this article, we focus on the importance of the upstream milling system in a phosphate fertilizer production plant – explaining how a proper understanding of its role can enhance overall processing efficiency, yield and plant profitability.

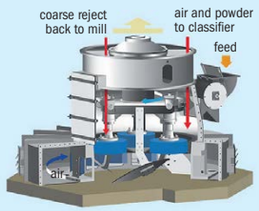
The role of the mill

Simply stated, the role of the mill in fertilizer processing is to crush/grind/pulverise the raw phosphate rock. Typically, the aim is to reduce quarter inch-size crushed rock into fine particles to meet the required specification for downstream processing or acidulation.

The degree of fineness and what particle size is acceptable varies significantly according to the production process and type of rock being used. This, in turn, influences mill selection. For an igneous phosphate rock, for example, single superphosphate (SSP) production require a feed with 90 percent passing 53 microns. This falls to 90 percent passing 75 microns when sedimentary phosphate is consumed. When it comes to phosphoric acid production, 90 percent passing 150 microns is acceptable for the widely-used dihydrate (DH) process; whereas much coarser feed is acceptable for the hemihydrate (HH) process, with 90 percent needing to pass two millimetres instead.

Mill selection is primarily based on an ability to continuously crush hard, friable phosphate rock to specification. This

Fig. 1: **Ring roller mill**



Source: Bradley Pulverizer

needs to be carried out as efficiently as possible, given that this will dictate downstream yield rates and, ultimately, profits. The three main mill options for phosphate ore are:

- **Ring-roller mills**: Vertical rollers rotate inside a fixed horizontal ring (Figure 1). Material fed between the rollers and the ring is ground to powder.
- **Ball mills**: A horizontal rotating cylinder contains a charge of steel balls. These balls tumble as the mill turns so that material caught between the balls is ground to powder.
- **Table-roller mills**: A horizontal table rotates with spring-loaded rollers mounted above. Material fed into the centre of the table passes underneath the rollers and is ground to powder.

Most phosphate processors choose air-swept milling systems due to their ability to remove fine particles from the grinding zone. Due to the cushioning effect from newly introduced feed, this allows the grinding action to be concentrated on the large oversize particles. This results in higher yields and, by minimising overgrinding, lowers energy consumption.

The air circuit is essentially the same for any air swept mill, being designed to maximise their inherent air sweeping effect. Inevitably, the high airflow needed to ensure all fines are swept from the grinding zone also carries over some oversize particles too. A classifier or separator is therefore needed to return these to the mill for further processing. Particles that meet the size specification, meanwhile, are removed from the conveying air by cyclones and bag filters.

Airflow is solely dependent on the milling rate. This means that similar capital and operating costs apply to every type of mill – making the selection of the correct type of mill a particularly critical factor.

While the mill remains a critical piece of fertilizer manufacturing equipment, it is fundamentally designed to be a reliable and largely unnoticed workhorse when functioning properly. Its role is to simply provide continuous pulverisation. Generally there is very little scrutiny beyond its ability to crush to specification while keeping noise levels and power usage within acceptable limits.

However, in fertilizer manufacturing, delivering the end-product downstream at the highest possible yield still requires precision-grinding of phosphate rock upstream. In practice, this means that mills need the help of classifiers to maximise their efficiency.

Classifiers: the brains of the operation

Fine grinding with air-swept mills involves the continuous return of oversize material to the grinding zone for further reduction to the desired size. The role of the classifier is to control both the amount of recirculation inside the mill and the particle-size distribution of the product.

Essentially, the classifier functions as the 'brain' of the grinding circuit. Critically, it automatically determines:

- What material should exit the mill as correctly sized product
- What should be returned for reprocessing.

Changing a classifier's settings can significantly alter the milling system's power consumption, capacity, vibration and product size distribution.

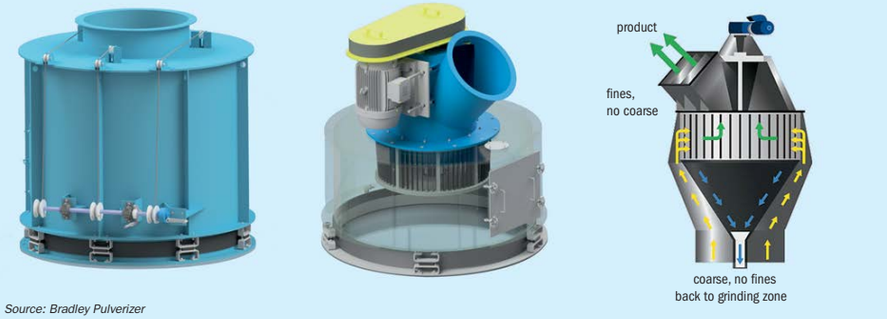
There are three main classifier types (Figure 2):

- **Static classifiers**. These are used for semi-fine grinding but have a very low efficiency and limited operational range.
- **Dynamic classifiers**. These incorporate a rotating rotor and, consequently, have a wider operational range.
- **High efficiency classifiers**. These combine useful elements both of the above technologies by using a static set of vanes to guide the airflow into a rotating rotor, alongside other optional features.

Upgrading an existing mill system with a new, correctly installed high efficiency classifier can deliver:

- Capacity increases of up to 25 percent
- Reductions in power consumption of up to eight percent
- Sharper classification curves.

Fig. 2: **Three main classifier types: static (left), dynamic (centre) and high efficiency classifiers (right)**

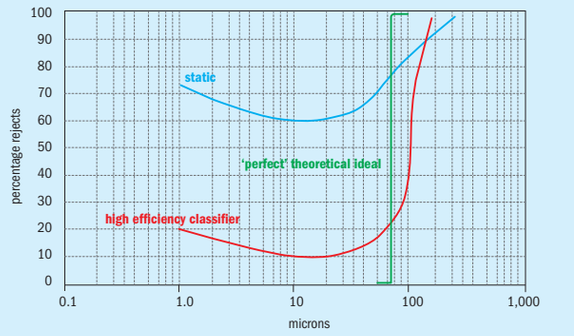


Source: Bradley Pulverizer

All classifiers have an efficiency rating, reflecting how well they separate material. Some are very efficient while others are less so. Inefficient classifiers are unable to achieve a good fine/coarse separation. This means the product stream will contain some coarse particles and the reject stream will contain fine material. This creates additional and unnecessary demand on the mill, resulting in higher recirculation rates which in turn requires more fan pressure and increases the power requirements of the fan drive.

A classifier's operational efficiency is determined from the 'Tromp Curve' (Figure 3) – a graph plotting percentage classifier rejects against particle size. Essentially, this curve shows how much on-size recovery there is in the reject stream. Curves which are as close as possible to a vertical straight line at the cut point are theoretically ideal. Less efficient static classifiers typically show gently sloping lines, whereas more vertical lines – closer to the maximum theoretical limit – are shown by high efficiency classifiers.

Fig. 3: **Tromp Curves: typical classifier efficiency plots for static and high efficiency classifier types**



Source: Bradley Pulverizer

In the fertilizer industry, dynamic vertical blade classifiers (VBC) are commonly specified for several reasons. VBCs are favoured because they offer high 'uptimes' with minimal maintenance and low percentages of reject particles. Another advantage is the ability for automating particle size control when coupled to an inverter (variable speed drive, VSD). The addition of a VSD is valuable as it makes on-demand adjustment of particle size possible. Lastly, the low pressure drop associated with VBCs helps propel particles through the classifier by maximising the air flow from the main mill fan.

It is the classifier that ultimately controls the mill's yield rate and hence the overall profitability of the plant. It is therefore imperative to evaluate both the mill and classifier together as a single system and not independent of one another.

The same ethos applies to post start-up problem solving. We recommend a structured or holistic approach when troubleshooting production issues, with scrutiny of the process itself to identify the true cause of the problem. After all, the problem that presents itself may well have an indirect cause. If the mill is apparently lacking power, for example, the right solution may not be installing a bigger motor or investing in a new more powerful mill. Instead, the problem could be solved – and often is – by making air flow adjustments at the mill and/or classifier.

Unfortunately, we do encounter mill systems where the classifier was not evaluated properly prior to installation and cannot achieve the yields required to achieve profitability. In such cases, it is still more cost effective to replace the classifier than the mill.

In our experience, most problems encountered in milling systems could ultimately have been avoided from the outset if:

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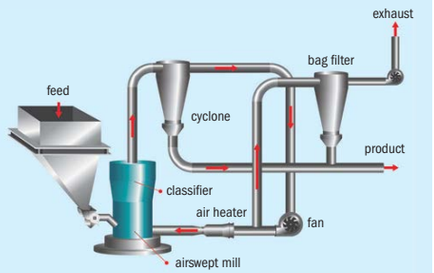
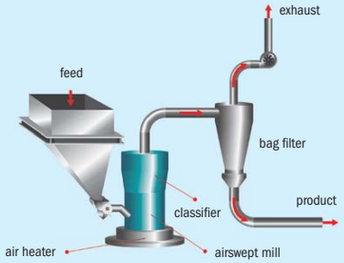
Fig. 4: **Recycled mill system**



Source: Bradley Pulverizer

Fig. 5: **Single pass mill system**



Source: Bradley Pulverizer

- A more thorough evaluation of classification requirements had been carried out pre-purchase, and/or
- If there was a better understanding of the process adjustments necessary to achieve maximum yields.

The complete mill system

After classification, the key to optimising system performance is the ability to effectively remove on-specification particles from the airstream and direct these as feed to the processing plant.

In addition to the air-swept mill and classifier, the other components of the mill circuit include:

- Fans and ducts for the pneumatic transport of crushed particles
- A bag filter that cleans dust-laden air in a single-pass mill system or maintains suction within recycled mill systems
- An integrated heater to reduce moisture and improve production.

Critically, these ancillary equipment items complete the circuit and minimise energy usage as well as ensuring continuous output.

Two main types of mill systems are available:

- Recycled mill systems (Figure 4) are optimal for the coarser grade materials encountered in phosphate processing
- Single pass mill systems (Figure 5), meanwhile, are ideal for fine to ultrafine grade materials and those materials with a high moisture content.

Recycled mill systems are most common in the fertilizer industry. This is due to their ability to maintain cyclone efficiency, when processing particles above 30 microns, as well as their lower maintenance costs.

Once again, properly specifying and maintaining all the ancillary equipment that completes the mill system is critical for optimum performance. This is yet another reason why we encourage both mill operators and project engineers to always evaluate the entire system whenever results are not as expected.

The mill itself tends to get the lion's share of attention because it occupies the heart of the system where the most aggressive action takes place. Paradoxically, though, attempting to overcome low yields by cranking up the mill's power usually ends up compounding the actual cause of the issue. In practice, an undersized exhaust fan or unmaintained bag filter, for example, can contribute to low yields and inefficiencies just as often, if not more so, than the mill itself. In fact, when performance issues with the mill are identified, they do tend to be of the obvious sort – such as significant wear on the rollers or wear ring where the grinding of phosphate rock is most intense.

Benefits of a holistic approach

The upstream mill system may seem simple, compared to other systems in a fertilizer manufacturing plant. Nevertheless, it should still demand equal attention due to the invaluable role it plays in the overall quality, yield and profitability of the end-product.

Any fertilizer product which contains P as a key ingredient will be partly derived from phosphate rock. It should always be remembered, therefore, that it is the mill which is responsible for crushing this hard, friable material to the specified particle size and supplying the feed to all downstream processes. The mill system often remains the forgotten workhorse in fertilizer processing plants and, consequently, often lacks the credit it deserves in helping transform phosphate ore into fertilizer.

The mill itself – to provide the uninterrupted tonnages required by fertilizer plants at high rates – must be rugged and function reliably in harsh operating environments. There are inevitable trade-offs and sacrifices, however. The primary requirement to supply a milled rock feed at high volumes will result in some inefficiency when it comes to meeting particle size specifications. Fortunately, this can be accounted for and corrected by incorporating equipment – such as an integrated classifier, baghouse, fan and heater – to create a complete mill system. Milling efficiency can be maximised, and downstream demands for both particle size and volume can be consistently met, by ensuring proper calibration, evaluation and maintenance of the entire mill system.

In our view, a holistic approach to the mill system is always imperative. This should be applied throughout the mill's operating lifetime, starting from when the initial scope of the mill system is first defined. Adopting a holistic approach helps operationally by providing a better understanding during the troubleshooting of ongoing problems. It also directly benefits the bottom line and delivers higher profits by lowering maintenance costs and energy consumption, while also raising production efficiencies and yields. ■

The agronomic advantages of *Polysulphate*

PHOTO: ICL

Available in its natural form, Polysulphate from ICL is a dependable, high-value product with a low environmental impact.

Polysulphate is an affordable, easy-to-use, multi-nutrient fertilizer with a low environmental impact. ICL's chief agronomist, **Patricia Imas**, highlights the crop benefits of this natural and high-value product.

A multi-nutrient, multi-tasking product

Polysulphate® is a new and unique multi-nutrient fertilizer exclusively mined in the UK by ICL. It is currently the world's only commercial polyhalite fertilizer.

Containing the natural mineral polyhalite, this valuable product is rich in four key plant nutrients in the following proportions:

- Sulphur (S): 48 percent SO_3
- Potassium (K): 14 percent K_2O
- Magnesium (Mg): 6 percent MgO
- Calcium (Ca): 17% CaO.

Importantly, K, Mg and Ca are all provided in sulphate (SO_4) form.

As a natural crystalline material, *Polysulphate* has a gentle way of breaking up and gradually releasing the four nutrients it contains as soon as it is applied to the soil. This prolonged-release characteristic is useful as a fresh supply of nutrients are continuously provided throughout the season to match the needs of the growing crop.

Polysulphate, due to its special solubility behaviour, also reduces the risk of leaching in sandy soils and during high rainfall conditions. Valuably, its prolonged released properties and lower susceptibility to leaching help prevent potentially damaging environmental losses.

Steadfast nutrient supply

Polysulphate supplies growing crops with all the sulphur, magnesium and calcium they need. Furthermore, it also replaces a significant proportion of the potassium that would otherwise be lost at harvest – thereby avoiding a potassium deficit for the following crop.

A product that provides four essential nutrients to crops in just one application – as *Polysulphate* does – is extremely convenient and cost-effective for growers. Supplying these four key nutrients in the right combination and quantity is an additional advantage. This helps deliver the enhanced quality that is so crucial when marketing fresh produce and trying to achieve the best possible financial returns.

Polysulphate is adaptable and makes an ideal natural fertilizer for all type of soils and crops. It is especially suitable for sulphur-hungry crops such as brassicas, cereals, pulses, field vegetables, clover-rich grassland leys and silage crops. The presence of sulphur, by improving nitrogen utilisation by the plant, also increases nitrogen use efficiency (NUE). Balancing sulphur with nitrogen supply is equally crucial for enhancing protein formation in plants.

Polysulphate, due to its low chloride (Cl) content, offers a new fertilization option for chloride-sensitive crops such as tea, tobacco, grapes and other fruits. Low chloride properties are also valued when higher dry-matter content is required in potatoes. *Polysulphate*, being pH neutral, does not adversely affect the acidity of the soil either. Additionally, its low salt index, in comparison to most equivalent starter fertilizers, makes it a safer product when applied to more sensitive crops.

Balanced and prolonged nutrition

Nutrients taken up by crops from the soil to grow leaves, fruits, roots, seeds or tubers eventually exit the farming ecosystem at harvest. Consequently, large amounts of K, S, Mg and Ca are removed from the soil every growing season. The higher the crop yield, the greater the nutrient uptake, and the larger the nutrient removal. A good potato crop, for example, can remove around 300 kg/ha of potassium (K_2O) and

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110 kg/ha of sulphur (SO_3) at harvest, together with about 20 kg/ha of both calcium (CaO) and magnesium (MgO).

The quality of produce in fruit and vegetable cultivation is more critical than with other crops. Indeed, it is quality that holds the key to securing the best economic returns for fruit and vegetable growers. An adequate supply of K, S, Mg and Ca nutrients provided by *Polysulphate* helps ensure quality over a wide range of parameters, including size, uniformity, colour, taste and shelf life.

Some nutritional disorders, for example, are caused by low calcium supply to fruits and tubers. These include:

- Bitter pit and internal brown spot in apples
- Internal tip burn in cabbage
- Blossom end rot (BER) in tomato and pepper
- Internal brown spot and hollow heart in potatoes.

Polysulphate avoids such disorders by providing calcium to plants in perfect amounts. The calcium sulphate present dissolves steadily in the soil solution, supplying calcium to crops throughout their growth period.

Approved for use in organic farming

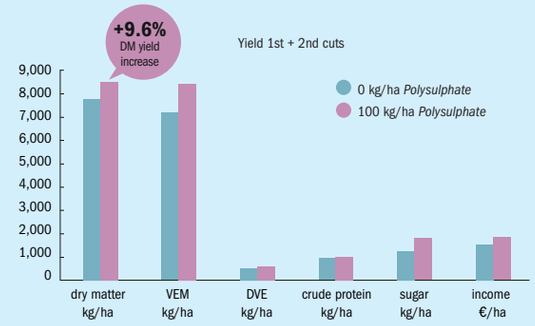
Unlike blended or compound fertilizers, *Polysulphate*, being a natural mineral fertilizer, easily meets the criteria for use in organic farming systems.

The mineral polyhalite is mined deep below ground in Cleveland, UK. Once brought to the surface, it is simply crushed, screened and bagged as *Polysulphate* – ready for onward transport and distribution to farms around the world. No chemical separation or complex industrial process are involved. The end result is a naturally pure and simple product for use with all crops.

Polysulphate is widely approved for use in organic agriculture internationally – holding organic certificates in the UK, France, Germany, Austria, Italy, the Netherlands, Hungary, Poland, Brazil and Israel. Additionally, standard and granular grades are OMRI-listed for organic use in the US and Canada. Furthermore, *Polysulphate* is included on the international list of organic farming inputs approved by regulations in the EU (EC 834/2007), the US (National Organic Program, NOP) and Japan (Japanese Agriculture Standard, JAS).

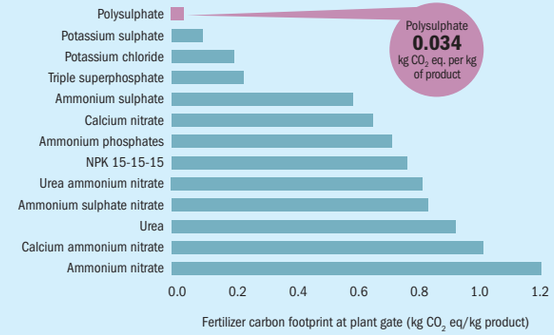
As well as being an excellent option for organic farmers, *Polysulphate* is also attractive for conventional farmers looking for a low-cost source of four key nutrients for their crops. In future, all farmers will need access to affordable, easy-to-use, multi-nutrient fertilizers with a low environmental impact. The low carbon footprint of *Polysulphate* is therefore another benefit that is attractive to organic and conventional growers alike.

Fig. 1: **The benefits of *Polysulphate* in organic farming: results of a 2016 mixed pasture trial in the Netherlands**



Source: ICL

Fig. 2: **The carbon footprint of *Polysulphate* in comparison to other commonly-used fertilizers**



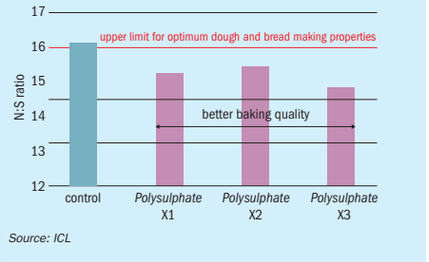
Source: ICL/Filkin & Co EHS Limited (November 2019).

The benefits of *Polysulphate* use in organic farming was demonstrated by a mixed pasture (grass and clover) trial on sandy soil in the Netherlands in 2016 (Figure 1). Its use increased dry matter production by 9.6 percent. Nutritional values of the forage, including feed unit milk (VEM), intestine digestible protein (DVE), and sugar content also improved. The application of *Polysulphate* generated an estimated additional income of €273/ha for the farmer, based on a price of €0.17/kg VEM and €0.65/kg DVE.

Lowering farming's carbon footprint

Polysulphate has the lowest carbon footprint (0.034 kg CO_2e per kg of product) when compared to common fertilizer alternatives, according to the results of a new study (Figure 2). Its production footprint is less than three percent of that of ammonium nitrate, for example. Its low carbon footprint is making *Polysulphate* the fertilizer of choice for those farmers wishing to manage their carbon usage and lower greenhouse gas emissions from their businesses.

Fig. 3: **N:S ratio of wheat grains at harvest**



Source: ICL

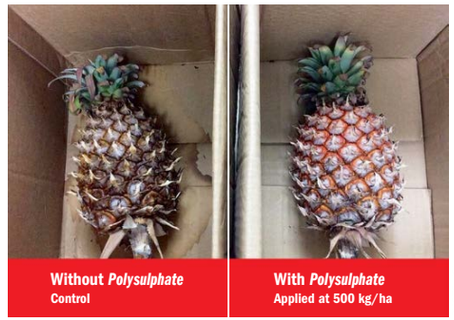


PHOTO: ICL

Fig. 4: Pineapples grown with Polysulphate as part of a trial in Malaysia had a longer shelf life compared to the control.

Improving nitrogen use efficiency (NUE)

Polysulphate is nitrogen-free fertilizer. By allowing farmers to separate S and K application from N application, this provides full flexibility with the choice of nitrogen source and application rate. *Polysulphate* can be applied before planting, for example, while nitrogen can be applied after germination – at the right time for the crop, in the right form, and in right weather conditions. This approach avoids the over-application of nitrogen and/or leaching. Higher nitrogen use efficiency can therefore be achieved without wastage and unnecessary cost to the farmer, or losses to the environment.

At the same time, *Polysulphate* can benefit wheat cultivation by delivering better grain protein quality and improving baking quality characteristics. In US wheat trials, the application of *Polysulphate* reduced the N:S ratio in harvested wheat grains. This helps improve baking quality by optimising dough and bread-making properties (Figure 3). Additionally, lowering this ratio avoids the unwanted asparagine and glutamine accumulations that can result from an S deficiency or an N surplus. Free asparagine is undesirable as it may promote the synthesis of acrylamide, a neurotoxin and potential carcinogen, during the baking process. *Polysulphate* therefore not only increases wheat yield but can also improve the nutritional qualities of processed products.

Polysulphate, having a high S content while lacking N but with the additional benefit of three other essential nutrients (K, Mg and Ca), is a useful fertilizer for legumes. In a *Polysulphate* treatment trial in Scotland, the crude protein content of alfalfa (lucerne) increased by about 10 percent. At the same time, the N:S ratio increased to the 12:1 target value required for optimal digestibility.

Making a world of difference to many crops

Potato and other vegetables have shown very good yield and quality responses to *Polysulphate* in global trials. Consequently, farmers now regularly include *Polysulphate* in the fertilization schedules for these crops.

A *Polysulphate* application rate of 400-700 kg/ha is generally suitable for potato and vegetables – and can be applied flexibly in several different ways. It can be incorporated straight into the seedbed before planting, for example, or applied as a constituent of a fertilizer blend at sowing or planting. For trees and perennial crops, *Polysulphate* can also be applied at the base of the tree or bush before the next flush of growth.

Polysulphate trials on potato in China showed that applications boosted yields by 7.4 percent and increased the proportion of large sized potatoes. Similarly, trials in Germany increased potato yield by 11 percent and starch content by four percent, while also reducing the bruising index after storage. In Swedish trials, *Polysulphate* increased the yields of three cooking potato varieties by 6-11 percent, in comparison to an equal dosage of potassium supplied by sulphate of potash (SOP).

Polysulphate has also been proven to give excellent results with a range of different fruits. In China, its application to five-year-old honey pomelo trees delivered higher fruit yield and better quality – especially the whole fruit size and flesh weight – while lowering fertilizer expenditure. In a pineapple trial in Malaysia, yields of 'grade A' fruit increased by 11 percent when using *Polysulphate*. Pineapple plants also exhibited fewer symptoms of potassium deficiency and were stronger with bigger leaves and larger size fruit. The fruit obtained with the control treatment, in contrast, had a shorter shelf life and lower Brix levels (soluble solids) compared to the *Polysulphate* treatment (Figure 4).

Good for crops and the environment

Taking all these positive, unique characteristics together, it is not surprising that increasing numbers of farmers across the globe are choosing to use *Polysulphate* on their crops. It is both a crop-friendly and environmentally-friendly fertilizer suitable for growers of grains, fruits, shoots, roots and tubers. In our experience, this natural and easy-to-apply organic-certified product is fast becoming a key crop nutrition tool for sustainable agriculture all over the world. ■

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Potassium nitrate: the more productive option

Chilean potassium nitrate producer SQM's Coya Sur plant.

PHOTO: SQM

Potassium nitrate is an efficient speciality fertilizer, being able to produce more for less. Whether applied to soils, via fertigation or through foliar application, it improves water use efficiency while boosting the uptake of potassium and other nutrients. **Katja Hora** and **Harmen Tjalling Holwerda** of SQM International highlight the main advantages of supplying potassium nitrate to crops.

To meet the needs of future generations, we need to produce more food with less inputs. This will require higher yields of staple food crops. These can be secured in two main ways:

- Firstly, by prevention of plant nutrient deficiencies, particularly in the critical stages of crop growth.
- Secondly, by preventing excess application of nutrients which are not needed by the crop and can cause soil salinity.

Additionally, the logistical disruption caused by the Covid-19 pandemic has illustrated the advantages of more local food production.

The application of fertilizers can also contribute more to human health. Fresh foods such as fruits and vegetables need to supply sufficient mineral nutrients – essential components of our daily diet – as do grains biofortified with micronutrients.

Proven crop benefits

Rice and potatoes are two examples of staple food crops that benefit from the use of potassium nitrate[1]. It is easy for farmers to make timely fertilizer applications with prilled potassium nitrate (*Qrop® KS*). Applications are especially valuable during crop stages when the availability of potassium and/or nitrogen in nitrate form is critical to achieving the highest yields – such as during the booting of rice or tuber-bulking in potatoes, for example.

For rice, on-farm field trials in Ecuador, Mexico and China have demonstrated how the use of *Qrop® KS* – as a replacement for potassium chloride (MOP) and urea – can increase production when applied at exactly the right moment in the crop cycle.

The need for potassium in potato crops is highest during the tuber-bulking stage. Potassium nitrate can be applied as *Qrop® KS* prills to soil or as water-soluble *Ultrasol® K Plus* via pivot irrigation. This supplies potassium and nitrate nitrogen at those moments in the growing cycle when the crop benefits the most from their direct uptake.

Scientific trials in the US and Belgium, and on-farm field trials in Brazil, have all shown that the use of potassium nitrate improves early potato crop development and increases marketable tuber yield, in comparison with a schedule based on potassium sulphate (SOP) or MOP.

Late season application of potassium nitrate, besides providing readily-available potassium, also improves the storage quality of potato tubers. This is linked to the uptake of exchangeable calcium and magnesium (Ca^{2+} and Mg^{2+}) from soils which is boosted in the presence of the nitrate anion (NO_3^-)[2].

Water use efficiency

Horticultural growers who supply crop nutrients via irrigation systems (fertigation) will select potassium nitrate as the preferred source of potassium and nitrogen, usually because it is 100 percent composed of the two nutrients that crops need most. Application of potassium nitrate ensures that potassium and nitrate nitrogen are directly available to the plant from the nutrient solution surrounding the roots.

In areas where good quality irrigation water is becoming scarce or expensive, saving water for crop production has become an important issue – both for the environment and for the commercial viability of agriculture. Water use efficiency shows how much of the agricultural water supplied is actually taken up by crops. This indicator can be improved by measures such as the recirculation of irrigation water, precision irrigation and avoiding excess irrigation to wash out soil salts.

The minimum water needs of crops are influenced by how much water is lost from the plant in the form of water vapour. This is known as water transpiration. Water needs are also directly related to the capacity of the plant to convert carbon dioxide to sugars, for a given amount of water loss by transpiration. This is usually referred to as intrinsic water use efficiency. Plants produce less sugar when transpiration is inhibited by water scarcity. Conversely, too much transpiration, without matching CO_2 conversion, may lead to loss of water without increasing yield.

Nutrients such as potassium and calcium are known to act as an important control on intrinsic water use efficiency. This is because they play a role in the opening and closing of stomata and – when deficient – may lower the intrinsic water use efficiency of the plant.

The type of nitrogen present in the root solution is also important, as a high ammonium concentration, with correspondingly low levels of nitrate, can lower water use efficiency. Recent plant physiology studies have demonstrated that a high NO_3:NH_4 ratio improves water use efficiency, confirming earlier empirical studies[3].

Boosting nutrient uptake

The improvement to water use efficiency that results when NO_3^- is supplied as the main nitrogen form to fertigated crops has several explanations. Overall, nitrate appears to improve plant growth and yield by boosting the uptake of cations (K^+, Ca^{2+}, Mg^{2+}) while using the same amount of water. The presence of NO_3^- has also been shown to drive up water uptake in the root zone[4]. In contrast, the lower uptake of cations in root solutions, observed when NH_4^+ is the main nitrogen source, has been found to be detrimental to plant growth[5].

> **Potassium nitrate can successfully supply potassium to crops via foliar application... preventing lodging and other deficiency symptoms.**

The foliar advantage

Reduced water availability has a direct impact on uptake of nutrients by the roots, and can be hampered by:

- Drought
- Saline soil conditions
- Reduced root system activity due to senescence linked to the ripening of seeds.

The absence of potassium is most likely to lead to yield loss if it is deficient during the generative stage of the growth cycle. This is when the crop starts flowering or filling its fruits, tubers or seeds. However, foliar applications to leaves during these critical crop stages is an effective tool for supplying plants with nutrients when they are unable to access these from the soil.

Potassium nitrate can successfully supply potassium to crops via foliar application. Several applications during the growing season improve potassium status and helps crops achieve their full yield potential. SQM's *Speedfol®* formulations – which are potassium nitrate based – have been shown to increase crop yields in many experimental and field trials. These have demonstrated its value in preventing lodging and other symptoms linked to potassium deficiency.

Potassium nitrate also acts in synergy with other plant nutrients by boosting the uptake of micronutrients such as zinc or iodine, for example. It can therefore be added to any foliar application as a routine booster to solve micronutrient deficiencies in crops.

In a study for the former Potassium Nitrate Association, the plant uptake and translocation of foliar-applied nutrients – in sulphate, nitrate-based and chelated forms – was promoted by the addition of potassium nitrate to the spray tank solution. As well as boosting nutrient uptake from the surface of leaves into the leaf tissue, potassium nitrate also aided nutrient translocation via the phloem to newly developing organs and seeds.

Iodine is an essential element for human health. The co-application of iodine with potassium nitrate was examined as part of a wheat biofortification study. This showed that their joint application markedly increased the uptake of iodine to new leaves and seeds[6].

Authors' note

Information cited in this article on potato and rice crop nutrition is sourced from an extensive library of free-to-access agronomic articles and advice available on SQM's website. Video resources are also freely available via the company's online Specialty Plant Nutrition (SPN) Academy.

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