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Cover: A field of potato plants.
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Food and fertilizer fears

Are we on the verge of a fertilizer production, trade and supply crisis? Some usually sober and authoritative voices seem to think so.

Events have certainly collided this autumn to create an increasingly toxic operating environment for the industry. The dizzying upwards spiral in fertilizer prices, crippling supply and logistical constraints, and the European energy crunch, to name just three.

This sense of a market unravelling has been heightened in recent weeks by the emergence of that measure of last resort – the export ban. By blocking trade, this policy could be the *coup de grâce* that turns an unfortunate sequence of events into a global fertilizer scarcity crisis.

Summing up the mood at the International Fertilizer Association's annual conference in Lisbon in September, Argus Media reported:

"Delegates spoke of a potential "disaster" and "catastrophe" ahead, based on concerns over high prices, tight supply and logistics. The key to the entire situation is a sharp increase in gas prices, which have led to significant rises in costs for nitrogen-based fertilizers and… production curtailments in Europe."

Speaking from the COP26 climate summit in Glasgow in early November, Yara's president and CEO Svein Tore Holsether could not have been more forthright. He warned of a dramatic shortfall in food production as rising energy prices cascade through global agriculture.

Holsether told *Fortune* magazine: "I want to say this loud and clear right now: we risk a very low crop in the next harvest. I'm afraid we're going to have a food crisis… not having food is not annoying, that's a matter of life or death."

In Europe, natural gas prices hit an all-time high in September. "To produce a tonne of ammonia [in Europe] last summer was $110 and now it's $1,000 – so it's just incredible," Holsether said.

Fertilizers Europe viewed these unprecedented gas prices – and the resulting ammonia production shutdowns (see our special report on page 8) – as an existential threat to the EU fertilizer industry. "There is a real risk this will lead to permanent closures or relocation of our sector outside Europe, if this situation is not addressed," the trade body said.

Fertilizer supply problems are unlikely to ease, even with an early return to normal European production, suggested Argus:

"As it stands, the most immediate concern is that there will simply not be enough nitrogen available to farmers come the key spring application season. A subsequent problem would be an extreme backlog and bottleneck of deliveries in early 2022."

Julia Meehan, the head of fertilisers at ICIS, highlighted a more widespread and serious global problem. She shone the spotlight on both high prices and the export bans now being put in place in Turkey, China and Russia.

"We are seeing record prices for every fertilizer type, which are all way above the previous highs in 2008 – it's very, very serious," Meehan said. With both crop and fertilizer prices at record highs, she warned of potential food shortages next year.

"Farmers are talking about switching their crops from cereals such as wheat and barley, which requires fertilizer containing high levels of nitrogen, to beans and pulses which need none," she said.

Recently introduced curbs on fertilizer exports by three major producing countries is the other emerging concern. These have been imposed to guarantee supplies to domestic farmers in China, Russia and Turkey.

Turkey introduced an export licensing requirement for fertilizers in early September. Chinese authorities then followed suit with extra customs inspections on fertilizer exports from mid-October.

China's move to curb fertilizer exports will be felt around the world, particularly by its biggest buyers, India, Pakistan and Southeast Asia. Even ready-to-ship cargoes are being held in China for extra checks and/or new export certificates.

Russia has also moved to limit fertilizer exports for six months from the start of December. Russian prime minister Mikhail Mishustin said his country will set export quotas of 5.9 million tonnes for nitrogen fertilizers and 5.35 million tonnes for other multi-nutrient fertilizers.

Europe is at the epicentre of fertilizer industry woes right now. Whether matters improve or worsen in the region will largely depend on the weather. An unexpectedly mild winter could ease market tightness by bringing gas storage levels back to normal.

Europe's fertilizer producers and farmers will certainly not be dreaming of a white Christmas. The spring application season and 2022 harvest could well depend on a winter without snow and ice.

Simon Inglethorpe, Editor

> **"Europe is at the epicentre of fertilizer industry woes right now. Whether matters improve or worsen in the region will largely depend on the weather.**

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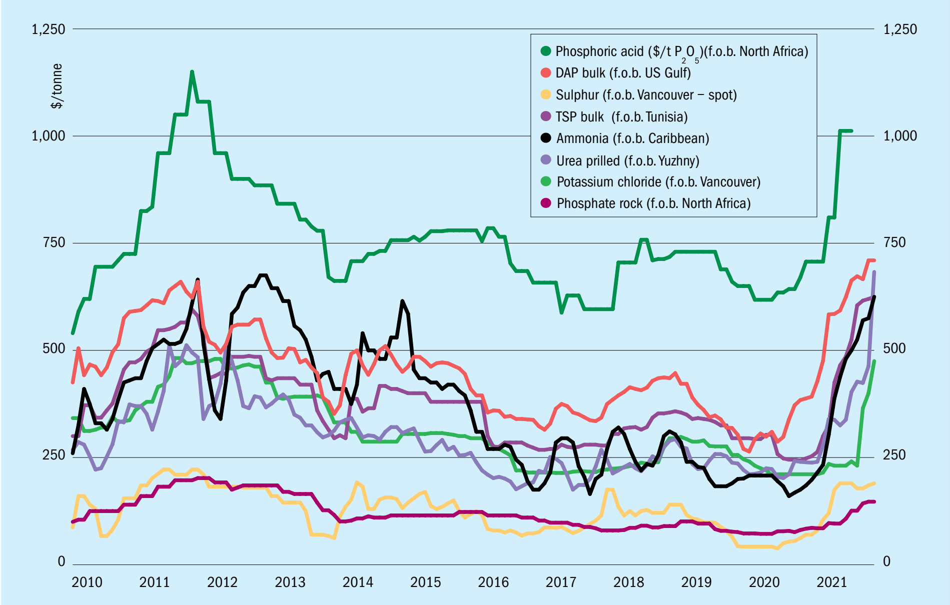
Market Insight

Historical price trends $/tonne



Source: BCInsight

Market price summary $/tonne – End October 2021

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	575-675	-	f.o.b. E. Europe 260-390	f.o.b. US Gulf	735-757	-	-
f.o.b. Yuzhny	603-710	685-765	-	f.o.b. N. Africa	661-760	600-650	1,120-1,200
f.o.b. Middle East	580-620	730-845**	-	cfr India	679-710	-	1,160*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	400-560	-	cfr US Gulf	200-260	f.o.b. Vancouver	180-205	-
f.o.b. Middle East	450-562	-	-	-	f.o.b. Arab Gulf	180-205	-
f.o.b. Western Europe	-	615-812	-	-	cfr N. Africa	195-230	-
f.o.b. Baltic	405-560	-	-	-	cfr India	225-260+	-

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.*

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: Several traders have struggled to export urea from China. This means the market is currently unable to count on Chinese exports to help meet the supply deficit. The fact that little urea will flow from Chinese ports, at least in the short-term, provided further price support to the broader urea market from mid-October onwards. While trading remained relatively thin, urea prices did notably rise in both Egypt ($845/t f.o.b) and Oman ($760/t f.o.b.).

Key market drivers: China export restrictions – with at least three export cargoes facing difficulties; demand destruction – no region is proving immune to the imbalance between fertilizer prices and grain prices; Europe natural gas prices – prices in Europe remain at elevated levels, although fertilizer prices have caught up enough to incentivise EU output in the short-term.

Ammonia: The latest round of import demand from Europe translated into steep price increases across several markets at the end of October. Supply remains reduced from the Black Sea, north Africa and Trinidad. A Middle East spot cargo sold into the European market at the end October lifted regional f.o.b. prices $65/t higher.

Most European production remains offline or operating at reduced rates. Feedstock costs did show signs of easing towards the end of October, with TTF month-ahead gas prices dropping to just below $25/mn Btu. This translates to an ammonia production cost of around $915/t, only $10/t above the last deal into the region.

In the east the steep rise in Middle East f.o.b. pricing is expected to push the market higher in the weeks ahead.

Key market drivers: Fertiglobe selling a 15,000 tonne spot cargo to Poland's Grupa Azoty at $905/t cfr for November delivery; Sabic selling a 14,000 tonne spot cargo to Yara at $715/t f.o.b. for November loading; the $160/t spike in the Tampa contract price when Yara settled with Mosaic at $825/t cfr for November shipment – this price being the second highest settlement on record.

Phosphates: Brazil was the main focus of activity towards the end of October. Importers purchased over 100,000 tonnes of Russian MAP at $800/t cfr and above. Argus assessed Brazilian MAP at $750-760/t cfr in mid-October, rising to $780-800/t cfr the week after.

Market liquidity was thin elsewhere. US barge prices slipped amid a lack of trade. There was no new business in India in late October either. Market participants there continue to wait for the final fourth-quarter phosphoric acid settlements with OCP. DAP offers for both India and neighbouring Pakistan were reported at $750/t cfr – although no trade was confirmed at these levels.

Key market drivers: Emerging Chinese phosphate export restrictions after authorities began customs inspections in late October – it is increasingly apparent that fresh shipments will be subject to delays of up to 20 days; Indian import deadline – importers there still need significant DAP imports for the current season, with the government urging importers to line up over 1.3 million tonnes for November to meet domestic shortfalls; Australian import ramp-up – several Chinese cargoes are scheduled to load following the reported purchase of a Moroccan MAP shipment.

Potash: Prices in major buying regions were steady at the end of October. Most demand was centred around south and southeast Asia. The drop in some freight rates has lifted netbacks for some producers. While supply for MOP is globally tight, high prices might be cooling demand in some regions.

Key market drivers: A yet-to-be-awarded Bangladesh private sector tender for up to 90,000 tonnes of MOP – suppliers have offered 15 lots totalling 325,000 tonnes of Russian, Belarusian and Canadian MOP in the $619-711/t cfr range; Canpotex being fully committed until 2022 – other MOP suppliers have also said they are unlikely to have much unallocated volume in the fourth-quarter.

NPKs: The closing date for Africa's largest NPK tender (1.2 million tonnes) from Ethiopia's EABC – which was already delayed by two months – was further extended to the 29th October. Africa's tender season is now at its peak with another two fertilizer tenders in Ghana and Mali closing at the end of October. Four other West African NPK tenders – covering over 360,000 tonnes of demand – have yet to be awarded. Many of these tenders are expected to conclude at reduced volumes due to the significantly higher price offers submitted.

Key market drivers: Increased demand for high-nitrogen NPKs due to the nitrogen price surge – with some European buyers seeking NPKs with high-nitrogen content as a cheaper alternative to buying straight nitrogen products; the absence of Chinese NPK exports from the market – no NP/NPK exports have been shipped out of China since restrictions came into effect on 15th October, with several already sold NPK cargoes stuck in Chinese ports.

Sulphur: Recent cfr sales have been concluded to India (upper $270s/t cfr), Indonesia and South Africa ($290/t cfr). The Middle East spot price, meanwhile, has been lifted to $223-230/t f.o.b. Spot sales at the high end of this range have recently been concluded to southeast Asia, India and Africa. Other markets such as China, North Africa and Brazil have lagged. China is weighing up the impact of the recent fertilizer export controls, while other markets with product booked under contract can afford to wait.

In the west, f.o.b. numbers have also stagnated, with the FSU having little spot product on offer. The Baltic is mostly committed under contract, while the Black Sea, because of competition from other bulk commodities, is experiencing significant delays due to a lack of barges and seagoing vessels.

Key market drivers: Indian prices firming on the back of one new spot sale and Middle East f.o.b. prices firming on the back of new sales there.

OUTLOOK

Urea: The price outlook is firm. High gas prices will squeeze marginal nitrogen supply in Europe and Ukraine leading to urea and nitrate production cuts. This will increase Europe's call on African urea supplies. India is also in a difficult position and will need to make further tenders. Its domestic urea production has lagged 2020 levels all year, despite the start-up of the new Ramagundam plant. On paper, the country needs five million tonnes of urea in the fourth-quarter of 2021 – yet only 740,000 tonnes was bought under the last RCF tender.

Ammonia: Firmer pricing is expected for November and December with a large proportion of European ammonia production expected to remain offline.

Phosphates: Current DAP price levels in India and Pakistan are unlikely to remain achievable and look set to jump on new business. MAP prices in Brazil are also likely to rise further, with Russian MAP trading higher at $815/t cfr for forward shipments up to January.

Potash: The price momentum seen in Asian markets will continue, with new tenders settled at higher prices. Markets are, however, reporting discomfort over the higher MOP prices. In Europe, some farmers are being forced to choose N at the expense of P and K fertilizers. While markets that are unable to afford higher prices will flatten off, crop prices in southeast Asia will support the region's upcoming MOP tender season.

NPKs: Demand is likely to outweigh supply in the near-term. More seasonal demand will emerge in Europe and southeast Asia, while enquiries from India and Brazil are expected to continue. Raw material price trends also remain firm.

Sulphur: While DAP pricing keeps firming, so will sulphur. Although there is uncertainty over the effects of Chinese fertilizer export restrictions on domestic sulphur consumption, demand from other markets is supporting pricing. Markets in the west are expected to catch up in the next round of business, as December demand emerges from less frequently seen spot market buyers.

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SPECIAL REPORT

European energy crunch triggers ammonia production chaos and collapse

Richard Ewing, Global Ammonia Market Editor, ICIS

Like the vital nitrogen fertilizer they handle, seasonal cheer will be in short supply for Europe's ammonia producers and buyers this festive season, after many difficult months in which upward price trajectories showed no sign of slowing.

The spike in European natural gas prices accelerated rapidly during the second half of the year – eventually triggering a series of capacity curtailments. Major plants across the continent then fell like dominoes, as producers struggled to cope with the painful price volatility of natural gas, their principal feedstock.

With European natural gas prices hitting record highs in early October, ammonia production costs became unsustainable for most players. One by one, units across the region stopped production and were idled indefinitely. The economics behind this were simple: with modern ammonia units requiring at least 33MMBtu (Metric Million British thermal unit) to produce one tonne of ammonia, gas prices of over $35/MMBtu made ammonia production prohibitive at nearly $1,200/tonne.

The ever-lengthening roll call of European producers who responded to the deteriorating situation by confirming plant shutdowns and/or capacity curtailments of indeterminate length included:

- Achema's Lithuania plant
- Several Yara plants in northwest Europe and Italy
- BASF's Antwerp, Belgium and Ludwigshafen, Germany plants
- CF Fertilisers UK's Billingham (later restarted) and Ince plants
- One of OCI's two Geleen plants, the Netherlands
- Grupa Azoty, Poland
- Odessa Port Plant (OPZ), Ukraine
- Fertiberia Palos de la Frontera and Puertellano plants in Spain.

At the same time, industry giants like Yara and BASF slashed their output substantially and switched, wherever possible, to imported volumes instead.

For larger players like Norway's Yara, this was a relatively stress-free process as they utilised their fleet of specialised tankers to lift ammonia from lower-cost countries like Trinidad – where they access output from two plants – and from Russia, where long-term contracts ensure a steady flow of ammonia from two Baltic ports. Russian gas costs in October were around a third of those in Western Europe and the energy-rich federation was criticised by some observers for aggravating the natural gas crisis by lowering gas flows to Europe, thus reducing storage volumes ahead of winter.

Despite the additional freight costs for the Caribbean cargoes, Yara's ammonia was still priced at an attractive discount when compared to European production costs. Government support was thin on the ground too, although the UK government agreed to help CF Fertilisers UK with the running costs of its Billingham unit. The important CO_2 by-product of ammonia production threatened to become scarce in Britain at one point. This triggered fears of UK nationwide shortages from sectors heavily reliant on CO_2 – notably the poultry, beverage and health segments.

The unprecedented gas price situation did, nevertheless, still create the odd headache for Oslo-headquartered Yara by necessitating the purchase of third-party spot volumes. These could only be secured at relatively high prices from suppliers in the Black Sea and Saudi Arabia on an f.o.b. (free on board) basis. Smaller players were even less fortunate. They had no option but to cast their nets far and wide, eventually paying hefty premiums to secure precious spot tonnages.

Austrian chemicals group Borealis dipped its toes into the cfr (cost and freight) spot market several times during the third and fourth quarters to acquire volumes for its Rouen operations in France. Poland's Grupa Azoty did likewise, buying cargoes for downstream operations at its Police site. Companies with their own plants in north Africa and the US fared better. This was especially true of Dutch major OCI which loaded Texan material for Rotterdam, and also lifted group product from Algeria (Sorfert) and Egypt (EBIC).

Such was the speed of Europe's natural gas nightmare, Yara introduced surcharges to industrial customers of up to 200/t on the sales prices of ammonia, urea and nitric acid from 1st October. It also moved to temporarily suspend all minimum take-or-pay and exclusive supply obligations due to runaway feedstock costs.

Key industry executives had plenty to say on the worrying situation. Svein Tore Holsether, Yara's president and CEO, expressed his concern and frustration at his company having to curtail around 40 percent of its European ammonia production.

"European nitrogen production is essential to global food security, and we are therefore concerned about the impact current European natural gas prices will have, especially for the world's poorest regions," Holsether said in late October. "The current situation clearly demonstrates the need for more resilient food supply chains, and I call on authorities, international organisations and food value chain players to work together to secure global food supply."

How did Europe reach this point? Well, the long 2020-2021 European winter certainly depleted gas supplies, so leaving the region in a precarious position, noted Tom Marzec-Manser, lead European gas analyst at ICIS. Europe's difficult situation was then compounded by strong competition for stocks on the open market, making inventory-replenishment more difficult.

"The previous winter was longer than usual, and we were still withdrawing storage gas in April and even into May this year, when normally that would finish by the end of March," Marzec-Manser said. "So, essentially, the market has been on the backfoot from the word go in terms of building up stocks for this winter."

He continued: "Demand for LNG globally at the moment has rebounded at an unprecedented rate since the worst of Covid-19 last year. Principally, demand for gas in Asia – mainly due to their economic bounce back – but also in places like South America for entirely different reasons. At the same time, there have been a number of LNG production problems, which is making the global LNG market very tight."

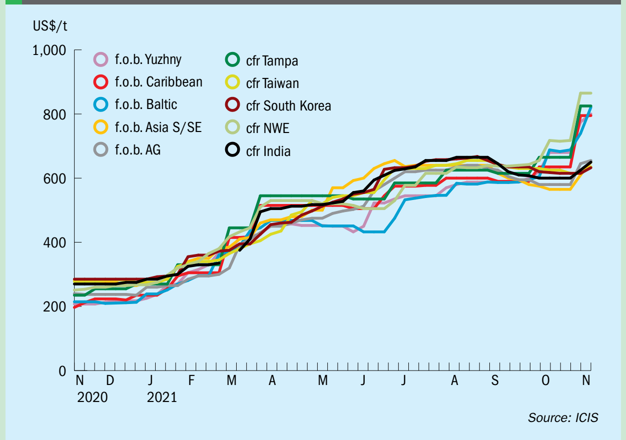
So, what about the next few months and the prospects for the European ammonia market going into 2022? From a feedstock perspective, a normalisation for European energy pricing will depend on a mild winter. There would be scope for national gas inventories to normalise going into the 2022 phase of this winter – but only if heating demand was below-average,

"It will depend on the weather," said Marzec-Manser. "The amount of gas that gets withdrawn from storage during Q4-Q1 of any given year can be quite a large range, and that is entirely driven by how cold it is. So, it is plausible that if it's a very mild Q4 the dependence on storage gas across the continent is relatively little. This would mean the amount of gas left in storage for Q1 is brought effectively back into line with seasonal norms. The market tightness could dissipate in this situation."

While record high natural gas costs in Europe capped a miserable year for ammonia buyers, 2021 turned into a highly profitable period for producers – thanks to robust demand from industrial customers and scheduled and unscheduled capacity cuts around the world. The price upswing started in the first-quarter of the year with upwards momentum then increasing as the months rolled on (Figure 1). Between January and November, benchmarks like the Tampa cfr and Yuzhny f.o.b. price rocketed from around $255/t and $220/t, respectively, to $825/t and almost $800/t on strong market fundamentals.

Supply restrictions were a key factor – especially the unplanned capacity cuts in early 2021 (Figure 2) which created fairly-low inventories at some producers – as was healthy downstream demand. The soaring prices of popular commodity fertilizers that require ammonia for their manufacture, such as urea and MAP/DAP, also kept margins decent for many producers. Favourable weather, good yields and bumper crop prices also meant farmers in many key demand markets could afford to spend more on fertilizers too.

Fig. 1: **Price trends for leading ammonia benchmarks, Nov 2020-Nov 2021**



Source: ICIS

Fig. 2: **Unscheduled ammonia plant shutdowns, Q1 2021**

Source: ICIS

Demand destruction was a term heard increasingly during 2021. But, to date, the threat of orders falling off a cliff has not really materialised. The seaborne ammonia market remains healthy as we head towards the new year, with surplus fundamental capacity of previous years having been absorbed in the main. That said, Ma'aden's new 1.1 million t/a ammonia plant in Saudi Arabia will churn out substantial export volumes from early 2022.

Exactly where all that ammonia will end up remains a mystery for now. But the Saudi major has more than doubled its fleet of tankers (from three to seven) and is expected to target long-term supply agreements both sides of the Suez, rather than rely on its well-established markets of India, China, Korea and Taiwan. Assuming European ammonia production costs remain uncompetitive until spring, it would not be a surprise to see suppliers take full advantage of attractive arbitrage opportunities and send spot volumes from the Kingdom or north Africa to buyers in Europe. ■

Additional reporting by Tom Brown, chief news correspondent at ICIS.

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RUSSIA

Casale helps KuibyshevAzot expand Togliatti complex

KuibyshevAzot has contracted Casale to build a new 1,575 t/d nitric acid plant and 2,000 t/d ammonium nitrate solutions plant at its Togliatti site. Casale had previously completed front-end engineering design (FEED) work for this project prior to the Covid-19 pandemic.

The new complex is scheduled for completion in the last quarter of 2024. It will incorporate Casale's *NA2000*™ dual pressure process for nitric acid and *AN2000*™ technology for AN solutions. These are designed to ensure low energy consumption and reduced emissions. Casale will be responsible for turnkey execution while its Czech subsidiary Casale Project will handle the construction phase.

Federico Zardi, Casale's CEO said: "We are particularly proud of this new win for our company which, in addition to strengthening the cooperation between Casale and KuibyshevAzot, comes in the wake of the successful completion of another nitric acid plant in Uzbekistan of very similar capacity. This confirms both our commitment in pursuing large EPC projects as well as the importance of the Russian and CIS markets for the development of our business.

"In addition, we strongly believe that the consistent use of highly qualified local resources in different phases of the construction – as planned for this project – besides bringing clear benefits in terms of speed and efficiency of execution – also generates positive effects on the local economy and employment. This creates the conditions for further collaborations as well ensuring a prosperous future for all stakeholders."

Stamicarbon to build second granulation plant for Acron

Maire Tecnimont subsidiary Stamicarbon has secured a contract for a 2,000 t/d urea granulation plant at Acron's Veliky Novgorod site. The company will supply the proprietary technology and equipment for the plant. This is second of two almost identical contracts awarded to Stamicarbon by Acron. A previous granulation plant with the same capacity was completed in 2020.

The new plant will be based on the same design as the first and will incorporate Stamicarbon's proprietary film spraying nozzles. Stamicarbon says these nozzles result in a better quality end-product by building up granules layer-by-layer. This process design, by reducing both dust formation and the formaldehyde content of the final product, also lowers operating expenditure, compared to other fluidised bed granulation processes. On average, the granulation plant will be able to operate continuously for three months without any interruptions for cleaning, according to Stamicarbon.

"Since the start of its operation in the summer 2020, the first granulation unit has demonstrated excellent performance, both in terms of process reliability and equipment," said Sergey Abramov, licensing manager at Stamicarbon. "Acron appreciated our technology and as a result chose Stamicarbon for the second unit of the same design and capacity."

CANADA

New Ontario fertilizer coating plant

Sollio Agriculture and Pursell Agri-Tech have formed a joint venture to build and operate a fertilizer coating plant in St Thomas, Ontario.

The new CAD 20 million ($11.9 million) plant will be dedicated to the production of controlled-release fertilizers (CRFs). Construction will commence this autumn with the plant expected to become operational in August next year.

Sollio Agriculture is the agribusiness arm of Canada's 100-year-old Sollio Cooperative Group, while US-based Pursell Agri-Tech is a leading coated fertilizer manufacturer and technology provider headquartered in Sylacauga, Alabama. The new coating plant will "open untapped markets for the many economic and environmental benefits offered by controlled-release fertilizers", Sollio said in a statement.

The new plant will produce CRFs using Pursell's innovative and proprietary coating materials and techniques. It will also make use of the company's patented technology. This allows micronutrients and temperature-sensitive additives – such as biologicals, growth enhancers and soil health promoters – to be incorporated within fertilizers.

CRFs offer a number of advantages. By improving the uptake of nutrients by plants, they have the potential to significantly improve crop yield and quality, while at the same time helping prevent ammonia volatilisation and nutrient leaching and runoff.

Historically, CRFs are used primarily in turf and ornamental markets and speciality agriculture in North America. In contrast, they have been applied much less frequently to commodity agricultural crops grown in the region, such as corn, wheat, canola and potatoes, due to cost and availability. However, the combination of Pursell's innovative coating technology and a local manufacturing capability should make the widespread adoption of CRFs in commodity agriculture more attractive and economically feasible.

"We are delighted to be joining forces with Pursell to make the numerous economic and environmental benefits of its CRF technology available to Canadian farmers," said Casper Kaastra, Sollio Agriculture's CEO. "Local manufacturing reduces logistics expense to customers, provides ability to offer previously unavailable CRF products to this market and supports nutrient stewardship initiatives associated with the use of fertilizer products."

"Partnering with members of Sollio Cooperative Group to build a plant in St Thomas is ideal," said Nick Adamchak, Pursell's CEO. "The plant gives growers in eastern Canada and the northeastern US access to controlled-release nitrogen, phosphate and potash fertilizers, as well as customized plant nutrition options."

He added: "This first license of the Pursell Technology outside of the US also enables us to move forward in further international licensing opportunities with our partners at Stamicarbon."

Pursell, which opened its flagship fertilizer coating plant in Sylacauga, Alabama in early 2018, also plans to open an additional plant in Savannah, Georgia.

Eirich Machines will supply equipment for the new 100,000 tonne capacity St Thomas coating plant. The company has been working closely with Pursell on the complete fertilizer production system. This includes material handling, liquid delivery, batch control, the use of Eirich intensive mixers and the overall process control system.

"We are extremely pleased to partner with industry leading companies such as Pursell and Sollio Agriculture, and we look forward to continuing our strong commitment and tradition of providing state of the art processing technology," said Matthias Erdmannsdoerfer, managing director of Eirich Machines. "This partnership shows our capabilities to provide the process knowledge and unparalleled support required to deliver complex processing plants in North America and around the globe."

Joe Brady, Pursell's CFO and sustainability lead, said: "Partnerships with leading innovators like Eirich Machines allow us to implement unique process advantages in our fertilizer plants. These include faster curing and batch times than traditional controlled-release technology and lower operating temperatures that allow temperature-sensitive additives to survive.

"We look forward to continuing our partnership with Eirich as we begin work with Stamicarbon in licensing our technology globally."

UNITED STATES

Green ammonia plant for Iowa

Maire Tecnimont has secured a contract to develop the first dedicated green ammonia plant in the US Midwest for Greenfield Nitrogen LLC. This will be delivered by three Tecnimont subsidiary companies, NextChem, MET Development and Stamicarbon.

The pioneering 83,000 t/a capacity ammonia plant will combine the best available technologies for green hydrogen production with Stami Green Ammonia technology. The latter was launched by Stamicarbon over the summer and is being used to build a renewable power-to-fertilizer plant in Kenya (*Fertilizer International* 503, p8; *Fertilizer International* 504, p20).

Under the agreement, NextChem will initially embark on a feasibility study for a 240 t/d green ammonia plant able to consume hydrogen generated by renewable energy. MET Development will assist Greenfield Nitrogen in the overall development of the project.

The green ammonia plant and associated storage unit will be located near Garner, Iowa, and will therefore be well placed to supply ammonia to a large local agricultural market. It will be powered from local renewable sources and will strengthen the development of the region's low carbon industry, according to the project partners.

The new plant – compared to the conventional 'grey' ammonia production route – is expected to save more than 166,000 tonnes of CO_2 emissions annually. Its output should also reduce the region's dependency on ammonia imports. The Garner, Iowa project is the first of a series of green ammonia plants that Greenfield Nitrogen wishes to develop across the US Corn Belt.

Pierroberto Folgiero, Maire Tecnimont's CEO, said: "We are very pleased that Greenfield Nitrogen has chosen Maire Tecnimont as their partner of choice for this exciting project. The combination of co-developer, technology provider and EPC contractor makes Maire Tecnimont a unique player in the green ammonia market, an area that will be vital to industrialize the on-going energy transition through green hydrogen."

New St Louis production plant

Ostara Nutrient Recovery Technologies is investing $25 million in a new *Crystal Green*® fertilizer production plant in St Louis City. The plant was officially approved by the St Louis Port Authority in August.

Ostara is renovating an existing St Louis plant located on the north Mississippi riverfront. This has been purchased from the trading, distribution and transportation company Bruce Oakley, who will also act as Ostara's long-term partner. The land for the new plant is being leased via a long-term agreement with Bruce Oakley and the Terminal Railroad Association of St Louis.

Vancouver-headquartered Ostara produces struvite-based fertilizers using technologies that recover phosphorous and nitrogen from wastewater streams. The company currently operates a fertilizer

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plant in Florida – but has been actively looking for an additional Midwestern production location for some time.

"We're excited to welcome another agtech company to Missouri, where agriculture remains our number one economic driver," Missouri governor Mike Parson said. "Ostara's investment in St Louis will create more career opportunities for Missourians, build on its mission to help farmers improve crop yields across North America, and protect water and soil quality around the globe."

"St Louis was a natural choice for Ostara to construct its newest and largest manufacturing facility that will produce our environmentally friendly *Crystal Green*® fertilizer," said Dan Parmar, the CEO of Ostara Nutrient Recovery Technologies. "As we gear up production over the next year, we're partnering with the St. Louis community and Missouri businesses to continue our mission to produce a sustainable phosphorus soil health solution that will enhance crop yields while protecting water sources across the globe."

Ostara's *Crystal Green*® and *Crystal Green*® *Pearl* fertilizers are granular slow-release phosphorus fertilizers able to release nutrients in response to plant demand. These products contain *Root-Activated*™ granules designed to increase yield, enhance soil health and significantly reduce phosphorus tie-up and runoff.

"Fertilizer produced at our St Louis facility will impact acres across the US by substantially improving crop yields and by keeping nutrients in the soil instead of leaching into our precious water bodies," said Parmar.

OMAN

Green ammonia projects gather pace

Another green ammonia project has been announced, this time in Oman. A consortium comprising Omani state oil and gas company OQ, Japan's Marubeni, Linde and UAE-based Dutco has initiated a feasibility study for a 330,000 t/a capacity green ammonia plant. This is just one of a raft of recent green and blue ammonia project announcements in Australia, Egypt, Malaysia, Norway and Saudi Arabia (*Nitrogen+Syngas* 374, p8).

If given the go ahead, the project, SalalaH2, would be sited in the Salalah Free Zone in the south of Oman. The partners are planning to produce green hydrogen from a 400 MW electrolyser. This will be powered from existing and new solar and wind parks with a total capacity of one gigawatt.

Yara acquires Finnish organic fertilizer producer Ecolan.

PHOTO: ECOLAN

The overall aim is to make Salalah a hub for the production and export of green hydrogen and ammonia by capitalising on the potential for solar and wind capacity in the region and the infrastructure at the Port of Salalah.

The consortium will study various offtake options for the project, including fertilizer plants in Europe, the global shipping industry and coal-fired power plants in Asia.

FINLAND

Yara acquires Ecolan

Norway's Yara International has expanded into organic fertilizers by buying Finland's Ecolan Oy.

The purchase, announced at the start of September, is Yara' first acquisition in the organic fertilizer segment. The move reflects the company's "commitment to play a bigger role in organic farming and in contributing to the circular economy", Yara said in a statement.

"By expanding our offerings into the growing organic farming segment in Europe, we can help improve nutrient use efficiency in this segment by capitalizing on our deep crop nutrition knowledge," said Mónica Andrés, executive vice president for Yara Europe.

"Our core competence lies in managing nutrients in the most sustainable and efficient way, whether this is for organic farming or conventional farming. We want to be the leading partner for all farmers, regardless of which farming system they use," she added.

Ecolan produces high quality fertilizers for agriculture and forestry from industrial side streams. These products help reduce CO_2 emissions and function as natural carbon sinks. The company has 21 employees and operates two production plants in Finland.

Yara and Ecolan have an established history of collaboration. Following several years of research and development, Yara introduced a new organic fertilizer line with a high nitrogen content to the Finnish market in 2019. This was produced on its behalf by Ecolan.

"Ecolan is a Finnish front-runner in the circular economy. We have had good cooperation during the past years and now we are able to combine Yara's and Ecolan's knowledge and expertise to develop recycled fertilizers even further. With this acquisition, we will be able to offer organic fertilizers also to markets outside Finland," said Timo Räsänen, director for specialty products for the Nordic and Baltic countries at Yara.

Ecolan has invested heavily in product development and expanding its production capacity. This has resulted in significant revenue growth and a strong market position. The company has been able to grow thanks to investor support from the Korona Invest. This Finnish private equity firm acquired a majority stake in Ecolan in 2015.

"Starting from small-scale production, Ecolan has with the support of Korona Invest grown into one of Finland's leading circular economy industrial companies. Through Yara's ownership, Ecolan's know-how can be utilized also internationally," said Vesa Lehtomäki, the chairman of Korona Invest.

Yara says it is working to find the best way to recycle nutrients that would otherwise end up as waste and then process these to produce organic fertilizers. The company is pursuing this through strategic partnerships with waste management and food companies, such as Veolia. "The circular economy has an important role to play in improving nutrient use efficiency, which is one of Yara's core areas of expertise," Yara said.

People

CF Industries announced several interlinked board changes in mid-October. Current chair **Stephen Furbacher** is to retire at the company's annual stockholders meeting in May next year. In a coordinated move, the board elected **Stephen Hagge** – currently an independent director of CF Industries – as Mr Furbacher's successor with effect from the start of January 2022. The board also elected **John Eaves**, another independent director and the executive chairman of Arch Resources, as incoming chair of the company's compensation and management development committee. He is taking over this role from the committee's former chair Mr Hagge. This appointment also takes effect from the beginning of 2022.

"I am honored by the trust placed in me by my fellow directors to serve as chair of CF Industries' board of directors," said Stephen Hagge. "On behalf of the board, I want to thank Steve Furbacher for his 15 years of service to CF Industries. His leadership has been an integral part of making CF Industries and its board of directors what they are today. We look forward to building on the progress we have made under his guidance as we work together to create long-term value for stakeholders."

Mr Furbacher will continue to serve on the board until his current term of office expires next May. He has been an independent director of CF Industries since 2007 and served as chairman since 2014. His retirement is in keeping with general company policy that directors will stand down once they reach the age of 74. Mr Hagge has been an independent director of CF Industries since 2010, most recently serving as chair of the company's compensation and management development committee and as a member of the audit committee. Mr Eaves has been an independent director of CF since 2017.

Compass Minerals announced two changes to its senior management team at the end of October. **Lorin Crenshaw** was appointed chief financial officer, while **Jamie Standen** was appointed chief commercial officer.

Lorin Crenshaw is expected to join Compass at the start of December. He will be responsible for all aspects of the company's financial management. Lorin brings to the company more than 25 years of high-level financial experience, most recently serving as chief financial officer at Orion Engineered Carbons, a global supplier of specialty and high-performance carbon black. Previously, Mr Crenshaw occupied financial leadership roles at Albemarle Corporation from 2009 to 2019. This culminated in a stint as chief financial officer of Albemarle's global lithium business from 2016 to 2019. He holds a BSc in business administration from Florida A&M University and an MBA from Columbia University.

"Lorin's broad financial expertise and lithium-specific experience combine to create an ideal skillset to help optimize shareholder value by fully leveraging our advantaged asset portfolio," said Kevin Crutchfield, president and CEO. "I look forward to Lorin joining our team at this exciting time for Compass Minerals."

In a coordinated move, Jamie Standen, who has been the chief financial officer of Compass since 2017, will change roles to serve as chief commercial officer from the beginning of December. Jamie joined the company in 2006 as assistant treasurer. Mr Standen spent six years in various roles at Kansas City Southern prior to this. He holds a BSc in accounting from the University of Kansas.

"I would put Jamie's knowledge of our core business and markets up against anyone's," said Kevin Crutchfield. "He has created lasting value for the company at every position he's held to date, and I have every confidence he'll continue to do so in driving our commercial, innovation, logistics and customer service strategies as chief commercial officer."

Brad Griffith, the current chief commercial officer of Compass Minerals, has left the company with immediate effect to pursue other career opportunities.

Matt Conradie.

ICL Specialty Fertilizers appointed **Matt Conradie** as its UK area sales manager in September. In this role, he will help develop and grow agricultural sales of ICL's specialty fertilizer portfolio. Sander Selten, ICL's business lead for Western Europe, warmly welcomed Matt to the company's expanding sales team:

"The experience of Matt in specialty fertilizers is considerable. Matt worked in the past as regional manager for Omnia Fertilizers and we welcome his extensive product knowledge to the team. With Matt on board, we will be better positioned to promote the ICL technologies in controlled and water-soluble fertilizers to the UK growers and farmers."

Calendar 2021/22

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.

DECEMBER

1-2
ACI European Mineral Fertilizer Summit, LONDON, UK
Contact: Hayden De Menezes
Tel: +44 (0)203 141 0607
Email: h.demenezes@acieu.net

7-9
Argus Green Ammonia – virtual event
Contact: Argus Media Group
Tel: +44 20 7780 4340
Email: conferences@argusmedia.com

9-10
2021 IFS Agronomic Conference, CAMBRIDGE, UK
Contact: Steve Hallam
Tel: +44 (0)1206 851 819
Email: secretary@fertiliser-society.org

MARCH 2022

7-9
CRU Phosphates 2022, TAMPA, Florida, USA
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

21-23
Argus/CRU Fertilizer Latino Americano 2022, MIAMI, Florida, USA
Contact: Argus Media
Tel: +44 (0)20 7780 4340
Email: conferences@argusmedia.com

28-30
CRU Nitrogen + Syngas Conference 2022, BERLIN, Germany
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

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Better nitrogen use

Improvements to nutrient use efficiency (NUE), particularly for nitrogen, can deliver dual environmental and economic benefits. We report on recent developments in nitrogen management and global progress on NUE.

PHOTO: PIXABAY

Precision farming can help deliver improvements in nutrient use efficiency.

With hindsight, 2015 is arguably the year when sustainability went mainstream, as it marked the UN's adoption of sustainable development goals and the signing of the landmark Paris climate accord. The latter has now resulted in country-level plans being drawn up – the so-called nationally determined contributions (NDCs) – which in turn will depend on action by industry sectors and individual companies.

Fertilizer producers, being part of an energy-intensive industry, will be tasked with reducing their carbon emissions out to 2050. But the drive to improve nutrient management is equally, if not more, important. Fertilizers currently contribute 2.5 percent to global greenhouse gas (GHG) emissions. This total divides 60:40 between emissions generated by the application of fertilizers to land (1.5%) and those emitted during fertilizer production (1%).

The need for sustainable nitrogen management has certainly risen up the policy agenda, culminating with the United Nations Environmental Assembly's March 2019 resolution. This noted that:

"Global, economy-wide nitrogen use is extremely inefficient with over 80% of anthropogenic reactive nitrogen lost to the environment, which leads to water, soil and air pollution that threatens human health, wellbeing and ecosystem services and contributes to climate change, due to increases in greenhouse gas emissions, and stratospheric ozone depletion."

Nutrient losses

Achieving global food security, today and in the future, cannot be achieved without fertilizers. With the global population due to reach 10 billion people by 2050, world agriculture needs to increase its productivity by 60 percent, from a 2005 baseline, if it is to meet extra demand for food. And fertilizers provide a dramatic and immediate improvement in land productivity. Within a single growing season, assuming water supply is also sufficient, fertilizers can double or triple farm productivity: for every single kg of nutrients applied, farmers obtain 5-30 kg of additional produce.

Yet the statistics on average nutrient use efficiency – the proportion of nutrients actually used by crops in the first year after application – are stark. For fertilizers applied to major cereal crops, nitrogen efficiency is around 40-65 percent, potassium efficiency in the region of 30-50 percent and phosphorus efficiency just 15-25 percent[1].

The above figures are for plots managed by agronomic researchers. Values for nitrogen use efficiency on fields managed by farmers are even less encouraging. Up to 70-80 percent of applied N can be lost in rain-fed conditions and 60-70 percent lost in irrigated fields, when fertilizers are improperly managed (*Fertilizer International* 474, p32).

Nitrogen losses are especially problematic due to their scale. Globally, agricultural soils receive an average total of 73 kgN per hectare per year, according to a recently-published study[2]. Fertilizers and manures are responsible for 61 percent of this supply, the remainder coming from natural nitrogen fixation (29%) and atmospheric deposition (10%). Yet, on average, only half of the nitrogen applied to fields is taken up by crops.

Nutrient use efficiency also varies dramatically regionally, being much lower in Eastern China (33%), for example, than in either the United States (65%) or Western Europe (61%). Losses to the atmosphere from ammonia volatilisation are also a major issue for nitrogen fertilizers, ranging from 17 percent in Europe and the US to 22 percent in China[2].

Inevitably, there are a range of undesirable environmental impacts associated with the inappropriate and excessive application of fertilizers – particularly nitrogen fertilizers such as urea. These include the release of nitrates into water bodies and emissions of ammonia and nitrous oxides into the atmosphere. The latter contributes to agricultural GHG emissions, while the former, alongside phosphorus pollu-

ICL SPECIALTY FERTILIZERS

ICL Ronald Clemens, marketing & portfolio manager CRFs

Is sustainability becoming more important?

For ICL, sustainability is a core factor in our company's mission. As a leading global specialty minerals company, we are creating impactful solutions for humanity's sustainability challenges – in the global food, agriculture, and industrial markets. We adhere to the highest environmental standards and utilise the best available technologies in order to develop sustainable approaches.

Does the industry need to do more on nutrient use efficiency and stemming nutrient losses?

We consider improvement in nutrient use efficiency as very important. It is clear that higher fertilizer efficiency is crucial to reducing environmental pollution, but also to make sure that mined nutrients from our mother earth are used in the most efficient way. In our innovation programmes, sustainability and nutrient use efficiency are core values.

What role will new products, such as controlled release fertilizers (CRFs) and enhanced efficiency fertilizers (EEFs), play in delivering improvements in nutrient use efficiency?

We see CRFs and EEFs as important technologies for improving the efficiency of nutrients. This first of all relates to nitrogen, but also to phosphorus and potassium. It is a way to improve yields – and so reduce the land used to produce similar quantities of food – or, alternatively, reduce fertilizer use and maintain existing yields. Together with the right fertilizer application methods, there is still a lot to win in nutrient use efficiency.

Environmental protection is often thought to come with a price tag attached. Can the higher nutrient use efficiency delivered by CRFs and EEFs help combine environmental improvements with economic dividends for growers?

This is very important. Economic benefits for the farmer make the entrance of CRFs and EEFs easier. Improved nutrient use efficiency means also economic advantages for the farmer by better yields or lower inputs. The lower inputs can also result in less applications and reduced labour costs. In a lot of cases this is already proven. That is why our agronomy department puts a lot of effort into field trials to show the economic benefits for the farmer in many agricultural crops.

Understanding nutrient use efficiency

Nitrogen use efficiency measures the ratio between:

- **Nitrogen output:** the amount of N removed from the field with the harvested product; and
- **Nitrogen input:** the sum of the amounts of N applied to cropland from mineral fertilizers, livestock manure and via biological fixation (by rice, sugarcane and legumes such as soybean).

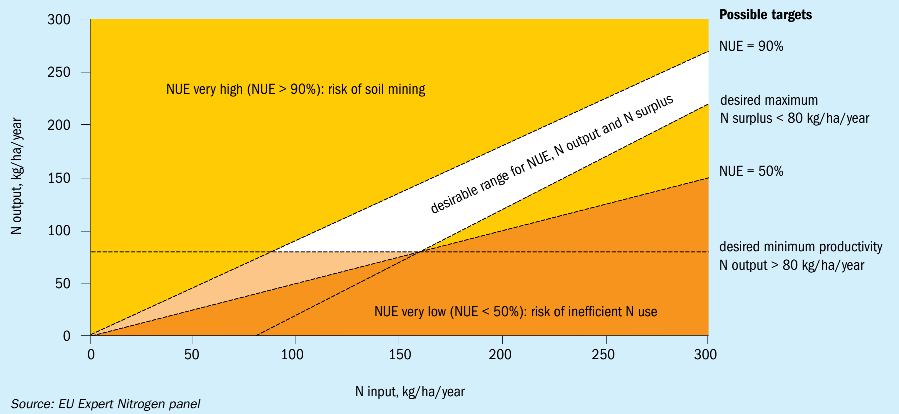
Low output/input ratios (below 50%) are associated with nutrient losses to the environment, while high ratios (above 100%) are indicative of soil nutrient mining, a process that eventually reduces soil fertility. Both these scenarios are clearly unsustainable. The optimum nitrogen output/input ratio is generally close to 60-90%, depending on the farming system and the crops cultivated, as values in this range promote high crop productivity[3] (Figure 1).

NUE trends vary widely between regions and countries due to difference in:

- Soils, crops and climate
- Fertilizer management practices
- The access of farmers to technology and knowledge
- Policy priorities.

Fruits and vegetables, for example, typically have a lower NUE due to their high nitrogen input requirements, whereas legumes such as leguminous soybean have a high NUE due to their ability to capture nitrogen and fix this biologically. Likewise, sandy soils have a lower NUE potential than loam soils as they are less able to retain nitrates[3].

Fig. 1: **Nitrogen input-output diagram with possible targets for NUE, N output and surplus**



Source: EU Expert Nitrogen panel

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STAMICARBON
Pejman Djavdan, CEO

Is sustainability becoming ever more important?
Stamicarbon, the innovation and licensing company of Maire Tecnimont Group, considers sustainability the key to the future of the fertilizer industry. Mineral fertilizers play a decisive role in feeding the world – but are faced by several challenges related to the fertilizer production process and application. Stamicarbon has accepted these challenges and is therefore focussing its innovation efforts on sustainable fertilizer technologies: specifically on production of fertilizers based on renewable energy, technologies for speciality fertilizers that are more efficient and effective, and digital transformation of current urea plants.

Does the industry need to do more on nutrient use efficiency and stemming nutrient losses?
Yes, there is a need for the fertilizer industry to respond to these environmental concerns and Stamicarbon, as part of its *Vision 2030* strategy, is pro-actively developing new and improved fertilizer production technologies – with the aim of decreasing emissions and energy consumption, and significantly increasing the nutrient use efficiency of fertilizers.

What role will new products, such as controlled release fertilizers (CRFs) and enhanced efficiency fertilizers (EEFs), play in delivering improvements in nutrient use efficiency?
Nutrient/nitrogen use efficiency can be significantly increased by offering a crop the right nutrients at the right time. Offering the right nutrients can be achieved by compounding different nutrients in the right ratio into one fertilizer granule. Releasing these nutrients over time can be achieved, either by inhibiting the biological transformations in the soil, or by controlling the release of the nutrients via our coating technology. Stamicarbon has several technologies available for adding micronutrients to urea and improving urea efficiency.

Environmental protection is often thought to come with a price tag attached. Can the higher nutrient use efficiency delivered by CRFs and EEFs help combine environmental improvements with economic dividends for growers?
Absolutely. It is possible to combine environmental improvements with economic advantages for growers – and it is important to make that economic case. But the actual economic advantages depend on the geographic location, crop type and local soil conditions. In regions with an overapplication of nitrogen but with an acceptable crop yield (e.g., China), savings on fertilizer usage may prevail. In regions with nutrient depletion and a low crop yield (e.g., Africa), an increase in the crop yield may take precedent, and in regions with an improved nutrient use efficiency and a high crop yield (e.g. USA or EU), the environmental improvements might be the decisive factor. ■

tion, depletes the oxygen content of rivers, lakes and the ocean. This ultimately results in the large-scale aquatic 'dead zones' that appear seasonally in the Gulf of Mexico and Baltic Sea due to run-off from major rivers.

Nutrient stewardship

In the early 2000s, the global fertilizer industry – notably the International Fertilizer Association (IFA), The Fertilizer Institute (TFI), Fertilizers Canada and the now defunct International Plant Nutrition Institute (IPNI) – developed the concept of '4Rs' nutrient stewardship. This specifically linked the management of plant nutrients to sustainability objectives through a simple yet universal message. This urged farmers to apply the right source of nutrients, at the right rate, at the right time, and in the right place – hence 4Rs.

By using the 4Rs to manage nutrients more efficiently, farmers can sequester more carbon in their soils and reduce:
- Agricultural land expansion
- Denitrification and the resulting nitrous oxide emissions
- The N and P flows from land that cause eutrophication
- Nitrate accumulation in groundwater.

In practical terms, nutrient stewardship can be delivered through fertilizer best management practices (BMPs). These allow fertilizers to fulfil their primary function – that is providing crops with a consistent and easily available supply of nutrients – and perform this efficiently by minimising the risks of losses and the negative effects of fertilizer overuse, underuse or misuse.

As well as promoting precision agriculture and associated technologies such as fertigation, fertilizer BMPs encompass the following approaches:
- **Balanced fertilization:** ensuring a proper and balanced supply of macronutrients and micronutrients to crops throughout the growing season.
- **Integrated plant nutrient management (IPNM):** supplementing the supply of available on-farm organic fertilizers to crops with mineral fertilizers.
- **Site- and crop-specific nutrient management:** the balanced use of crop nutrients taking account of soils, crops and climate. This allows growers to match nutrient supply with crop requirements, and improve soil fertility and optimise yields, while minimising losses to the environment.

In 2016, as part of their outreach work with farmers globally, IFA, the World Farmers' Organization (WFO) and the Global Alliance for Climate Smart Agriculture (GACSA) published the *Nutrient Management Handbook*. This accessible 35-page manual provides farmers with useful and straightforward practical information on how to improve nutrient use efficiency without detriment to crop yields, soil fertility and water productivity.

The Scientific Panel on Responsible Plant Nutrition

Following the outcome of its strategic review, IFA established a Scientific Panel on Responsible Plant Nutrition at the end of 2019. This was set up to strengthen and improve nutrient stewardship efforts internationally by answering a growing need for scientific research and expertise. The Panel is composed of eminent plant nutrition experts from leading research organisations around the world. Its mission is to advance sustainable plant nutrition and address the key challenges facing agricultural systems globally – especially how to improve agricultural productivity sustainably, while maintaining soil health and minimising nutrient losses to the environment.

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PURSELL AGRI-TECH

Nick Adamchak, CEO & president

Is sustainability becoming more important?
The progression to a more sustainable future in agriculture continues to gain momentum. Perhaps the best barometer of that is the amount of financial and scientific investment that is flowing into the crop nutrition space. Whether it is biological products, nitrogen fixation, controlled-release fertilizer or repurposing food waste, innovation in crop nutrition has never been higher. The fertilizer industry – The Fertilizer Institute specifically – is doing their part under the framework of the 4Rs programme.

Does the industry need to do more on nutrient use efficiency and stemming nutrient losses?
The short answer is yes. It is imperative that the industry address both greenhouse gas emissions as well as global water quality challenges. The recent EPA/USDA Challenge (*Fertilizer International* 503, p20) highlights the growing concern around extreme nutrient losses both in water and GHG emissions. Regulation could occur if the industry does not begin to show improvements in reducing nutrient losses, especially N and P. Improving nutrient use efficiency and reducing impacts to air and water quality are the focus of our ongoing efforts.

What role will new products, such as controlled release fertilizers (CRFs) and enhanced efficiency fertilizers (EEFs), play in delivering improvements in nutrient use efficiency?
In precisely calibrating nutrient release to the growth requirements of crops, controlled-release fertilizers are the most efficient nutrient delivery system available. CRFs deliver additional efficiencies by also eliminating nutrient leaching and volatilisation. Pursell's unique ability to also incorporate micronutrients, biologicals and humates inside the coating adds to a farmer's ability to improve plant health and maximize yields. As the relative cost and availability of CRFs/EEFs come down, adoption will be much higher.

Environmental protection is often thought to come with a price tag attached. Can the higher nutrient use efficiency delivered by CRFs and EEFs help combine environmental improvements with economic dividends for growers?
Farmers and Certified Crop Advisors (CCAs) must understand the financial and environmental benefits of using more efficient fertilizer technologies. Higher NUE results in higher yields which offer a financial payback. Additionally, more efficient fertilizers support soil health and regenerative agriculture which have further paybacks to farmers. ■

Progress on nutrient use efficiency

In May 2020, IFA reported on progress in improving nutrient use efficiency (NUE) worldwide[3] This painted a generally improving picture. At the global level, NUE has actually been steadily rising for three consecutive decades now, reversing the falling trend that preceded this up until the end of the 1980s. This rising trend has been driven by the continuous improvements in NUE achieved by developed countries, says IFA, as well as by China more recently. Global NUE was estimated at 59 percent in 2017.

A general trajectory in NUE is observed in many countries (Figure 2). NUE typically falls and then rises as it moves through four main stages:

1. **Nutrient mining**. Before countries adopt nitrogen fertilizers, their NUE is very high, often well over 100%, as they do not have enough N from manure or through biological nitrogen fixation to offset N removal through harvests.
2. **Early development**. As nitrogen fertilizers become available (and/or are subsidised to stimulate demand), fertilizer consumption generally increases much faster than removal by crops. As a result, NUE drops quickly.
3. **Turning point**. An inflection or turning point is eventually reached. This generally happens once medium to high crop yields are attained, and once farmers, policymakers, scientists and others begin to prioritise the improvement of NUE to limit nitrogen losses to the environment.
4. **Sustainable intensification**. Finally, after the turning point is reached, nitrogen surpluses stabilise or decrease owing to access to improved knowledge, inputs and technologies. Such improvements protect crop productivity while reducing nitrogen losses.

At a given moment in time, countries occupy different points on the U-shaped NUE curve shown in Figure 2. This reflects the maturity of their agricultural sector and their relative crop productivities. IFA suggests that, for those countries still at the start of the NUE trajectory (particularly in sub-Saharan Africa), there is potential to 'tunnel through' this U-shaped curve and avoid the unsustainably low NUE turning point described above. Building on the experiences of more mature agricultural economies, this could be achieved by taking environmental considerations into account from the outset – and consequently implementing policies that encourage both greater and more efficient use of nitrogen fertilizers.

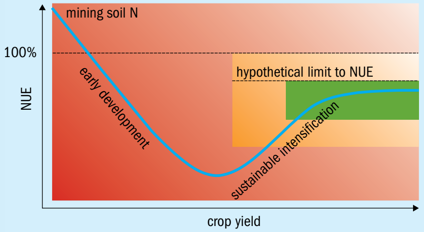
IFA examined how NUE has changed in six countries – Brazil, the US, Denmark, China, India and Nigeria – from the 1960s to the 2010s. Its report concluded that:

- Too high and too low nitrogen output/input levels are both equally unsustainable
- Countries with a large share of their area planted to legume crops have a higher NUE, while countries with a high proportion of less nitrogen efficient crops (e.g., fruits and vegetables) have a lower NUE
- Countries where farmers have adopted fertilizer BMPs, new technologies (e.g., precision farming, drip irrigation etc.) and improved crop varieties have a higher NUE
- Countries where fertilizers are heavily subsidised (e.g., India) have a lower NUE
- Countries with high livestock production density have a lower NUE, as manures make up a higher percentage of total nitrogen input
- The integrated use of mineral and organic fertilizers is most promising for sequestering soil carbon in agricultural soils.

The report sensibly recommends adopting fertilizer BMPs that are tailored to site- and crop-specific conditions. This should enhance NUE and reduce environmental nutrient losses while increasing yields.

IFA also concludes that combining the 4Rs message with new products and technologies can deliver further improvements in NUE. Precision agriculture, for example, by simultaneously increasing productivity and reducing

Fig. 2: Nutrient use efficiency curve showing the U-shaped trajectory followed by many countries



Source: IFA (2020)

GHG gas emissions, is capable of steering agriculture towards a more sustainable 'input-optimised' model. Examples include:

- Mobile/digital apps that allow farmers to send pictures of their crops and receive tailored fertilizer recommendations
- Hand-held sensors that can measure the nitrogen status of crops
- Sensors that can assess the water requirement of plants by measuring pressure on leaves.

Nevertheless, reaching out to the world's 500 million farmers – especially smallholders – to help them implement fertilizer BMPs remains the major challenge. By improving the access of farmers to knowledge and inputs, policymakers and fertilizer producers have a role to play too. Subsidy reforms that promote the efficient and balanced use of plant nutrients will also undoubtedly be necessary.

Economic *and* environmental rewards

The EU's recently-published *Farm to Fork* Strategy sets Europe the goal of reducing its nutrient losses by 50 percent by 2030. In its response to the Strategy, Norway's Yara International highlighted both the importance of nutrient use efficiency and the role of technology:

"Farmers can reduce nutrient losses by improving nutrient use efficiency, as these are two sides of the same coin. With our extensive agronomic knowledge and portfolio of solutions, Yara can help farmers increase nutrient use efficiency.

"Farmers can do this by using precision and digital farming tools and by adopting optimal nutrient management practices – applying the right fertilizer at the right time, in the right dose and at the right place."

Indeed, by adopting best practices and solutions that already exist today, Yara says that European farmers could:

- Improve nutrient use efficiency by 20 percent
- Increase yields and income by 5-7 percent
- Reduce the carbon footprint of mineral fertilizers by up to 20 percent.

This illustrates how improving NUE can be as good for the bottom line as it is for the environment. ■

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Fertilizer finishing: last but not least

New innovations and the latest equipment options from FEECO International, Casale, thyssenkrupp Fertilizer Technology and Eirich are helping to perfect the fertilizer finishing process.

FEECO INTERNATIONAL

Coating and finishing techniques for advanced fertilizers

Carrie Carlson, technical writer, and **Shane Le Capitaine**, process sales engineer

Fertilizer technology continues to advance to meet the ever-changing needs of modern agriculture. Market demand is shifting, as scientists continue to reveal the secrets behind optimal crop production, with growers seeking fertilizer products that offer enhanced performance and deliver precise nutrition.

In this article, we examine how fertilizer coating, particularly when carried out in a rotary drum, is being used to meet these new goals. Other finishing techniques used in the manufacture of advanced fertilizers are also explored.

Why coating?

Coating is a flexible and already-proven technology (Figure 1). The technique ensures that products satisfy the increasingly stringent quality criteria required in today's fertilizer market, and can also deliver crop nutrient products in new formulations.

Importantly, coating allows producers to add value and create premium products by minimising dust and caking and improving flowability and appearance. As a result, coating provides granular fertilizer producers with entry into higher-value end-markets.

PHOTO: FEECO

Fig. 1: Coated monoammonium phosphate (MAP) fertilizer.

Fig. 2: Uncoated (left) and coated (right) urea granules. Urea is commonly coated to prevent moisture absorption from the air and subsequent caking.

PHOTO: FEECO

Anti-caking properties

Any fertilizer producer or distributor can attest to the numerous problems caused by caking. These include spoiled products, clogged equipment, poor handling, dust formation and workplace hazards. For these reasons, mitigating the potential for caking is a key objective during fertilizer production, handling and transport – with coating offering a simple solution to these issues and more.

By coating fertilizers with anti-caking agents and moisture inhibitors, producers can maintain the integrity of granular products throughout their lifecycle, so avoiding the potential problems associated with caking (Figure 2). Common anti-caking agents include:

- Oils
- Waxes
- Polymers
- Clay
- Diatomaceous earth
- Talc
- Speciality chemicals.

Dust prevention

Similarly, the creation of dust causes problems for both fertilizer producers and growers alike. Excessive dust can, for example, cause product losses, be a respiratory hazard, increase caking, and result in inaccurate field application.

Coating minimises the potential for dust formation by creating a protective layer around each granule. This prevents attrition and reduces fines generation due to product breakdown. Common dust -reducing coatings include:

- Oils
- Waxes
- Polymers
- Speciality chemicals.

Controlled-release and enhanced efficiency fertilizers

Another way in which coating technology is helping to meet the demand for advanced products is through the creation of enhanced efficiency and controlled-release fertilizers. Coating techniques can be used to either control the rate of nutrient release or deliver active ingredients. This enables fertilizer producers to tailor their products to meet the specific requirements of growers and the end application.

Valuably, coatings provide a way of improving nutrient use efficiency, by incorporating beneficial additives or by creating a physical barrier between the granule and the surrounding environment (Figure 3). Coating technology therefore provides a major tool for reducing nutrient runoff and, correspondingly, increasing plant nutrient uptake – two key objectives in modern crop production. Although the coatings used to control nutrient release or improve use efficiency are often product-specific, they include:

- Speciality chemicals
- Polymers
- Clays
- Waxes.

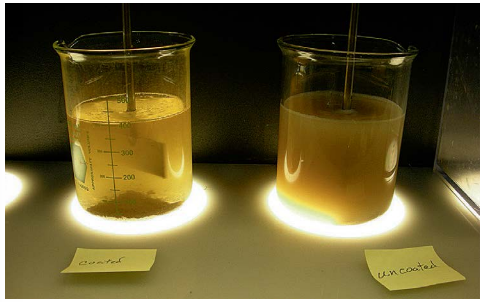

Fig. 3: A solubility test on coated (left) and uncoated (right) products carried out at FEECO's Innovation Center

PHOTO: FEECO

New nutrient formulations

Coating is also becoming a popular technique for improving the nutrient composition of fertilizer products and hence their value. Fertilizer producers can create an entirely new formulation simply by coating a fertilizer product with a micronutrient or other beneficial additive. Such customised nutrient formulations can be designed to match regional soil requirements or satisfy crop-specific needs – a rising trend in crop nutrient management. Coatings allow the incorporation of a wide range of additional secondary nutrients and micronutrients such as:

- Sulphur
- Boron
- Copper
- Magnesium
- Iron
- Manganese
- Zinc
- Molybdenum.

Glazing: a finishing technique for potash

Besides coating, glazing has now emerged as a favoured technique for improving potash products obtained via roll compaction. Roll compactors typically generate irregular-shaped potash granules. The resulting sharp edges increase attrition and generate fines as they rub together and break down.

Potash producers can, however, use glazing to combat this problem. In this

BENEFITS OF THE COATING DRUM

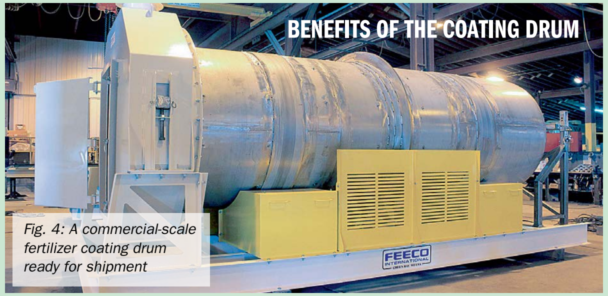

Fig. 4: A commercial-scale fertilizer coating drum ready for shipment

The coating drum is recognised within the industry as a high-capacity device able to provide superior results, compared to several other fertilizer coating options available on the market. Coating drums, being a well-established and proven technology, offer a number of advantages for creating uniformly coated products. These are summarised below.

Greater uniformity

Perhaps the most critical advantage of the coating drum – and the reason why it is often favoured – is its ability to provide highly uniform results. Because, when it comes to coating, uniformity is key.

Unfortunately, the benefits that advanced fertilizer formulations should provide are often lost due to inadequate and poorly applied coatings. Coating performance depends on a thorough and uniform surface coverage; even a small discrepancy in coating can create an entry point for moisture, negating the benefits of the coating altogether.

The tumbling motion that occurs within the coating drum, when combined with an expertly designed spray system, promotes a highly uniform distribution of the coating throughout the material bed via granule-to-granule transfer.

Higher production, lower maintenance, less coating

What makes coating drums an ideal fit for the fertilizer industry is their significantly higher throughput compared to other devices. Furthermore, a well-designed coating drum avoids the over-spraying that is characteristic of other devices. This results in increased production as less time is devoted to cleaning and maintenance requirements. Because over-spraying is avoided and wastage is reduced, coating drums also require less coating to achieve the desired results.

Gentle handling

Coating drums are able to provide the gentle handling required by many fertilizer products. This is a valued characteristic as it prevents premature product breakdown and the unnecessary generation of dust and fines.

Many of the advantages of coating drums, as described above, apply equally to glazing and tumbling/polishing drums as well. (Figure 4)

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technique, potash coming off the roll compactor is fed to a rotary drum where it is sprayed with a small amount of water and tumbled. This tumbling action smooths the edges and faces of the granules. The addition of water enhances this effect by causing a thin layer on the surface of granules to dissolve and recrystallize – resulting in the formation of smooth, polished granules during tumbling. This glazing technique – sometimes referred to as polishing or conditioning – may also be carried out in a pug mill or, when applicable, at the discharge end of a rotary dryer.

Tumbling/polishing for finishing granules

Similarly, other fertilizer producers also incorporate a tumbling or polishing drum into their processes to round and polish granules with hard edges and rough surfaces. This again creates a more rounded and smoother product less susceptible to dust and fines generation.

Developing advanced fertilizers with a rotary drum

One of the advantages of the rotary drum, whether used for coating, glazing, or polishing, is that it is a familiar technology that is easily incorporated at the end of a fertilizer production line. However, to achieve the best results – and ensure the desired product goals and objectives are delivered – the design of the rotary drum needs to be tailored to the intended application and the specific material characteristics.

In practice, the design of the coating drum often has a dual focus, being centred on both the bed action and spray system configuration (Figure 5). When optimising bed action, the following critical variables need to be considered:

- Bed depth
- Drum speed
- Flighting
- Drum size
- Retention time
- Granule shape and surface characteristics.

When properly configuring the spray system, the critical variables include:

- Spray rate
- Spray locations
- Nozzle type
- Coating and material temperature.

The most optimal design is typically identified through testing procedures – such as those provided at the FEECO Innovation Center. Here, experts work to gather process data, evaluate material behaviour, and design the most efficient and effective coating drum as possible for the application at hand.

Fig. 5: Testing in a coating drum at the FEECO Innovation Center

Concluding remarks

To meet the changing demands of modern agriculture, coating, glazing and tumbling/polishing will play an increasingly important role as fertilizers become more advanced. These finishing techniques offer a wealth of opportunity to reduce nutrient runoff, improve nutrient use efficiency, and generally provide a better, more user-friendly product. This is particularly true of fertilizers processed in a rotary drum.

The incorporation of already-proven technology, such as a coating or glazing line, into an existing process is advantageous as it is relatively seamless compared to the incorporation of new technologies. Nevertheless, thorough testing remains essential when it comes to developing a coating drum that can efficiently and effectively produce the desired end results. ■

CASALE

Vibrating skin bucket technology improves urea product quality

Gabriele Marcon, solid fertilizer technology leader

Introduction

Nowadays, the ability to combine process efficiency with product quality is the main goal of urea producers. This is especially true for any company wishing to remain a market leader while, at the same time, also meeting increasingly stringent sustainability criteria. Indeed, quality and efficiency have now become mandatory and key requirements when adopting new technologies, as these need to encompass competitiveness, design for the environment and care of the customer.

With this in mind, Casale has recently developed an innovative technology for improving the product quality in the prilling finishing section. This is the last stage of urea production before the product is dispatched to end-users. Casale has made developing innovative technologies for urea plant finishing sections a specific priority. These efforts have culminated in the successful development of an advanced vibrating prilling bucket – the so-called 'vibrating skin bucket'. This is now available on the market following the completion of an R&D project. This successful research was carried out with the valuable support of Donald Snyder, the founder of Tuttle Prilling Systems.

Casale's vibrating skin bucket (VSB) superimposes a continuous axial vibration on the bucket's conventional rotational movement. This new design, in comparison with a traditional rotating bucket, offers increased plant production combined with improved urea prill uniformity (size and shape). Furthermore, the VSB achieves a reduction in both the fine particle content of the product and dust emissions from the top of the prilling tower.

Casale's new vibrating skin bucket (VSB)

The VSB is the most advanced type of urea prilling bucket technology currently available on the market. It offers the following key features:

- Suitable for prilling tower with diameters up to 28 metres
- Uniform prill size distribution
- Low dust emissions
- Low prill temperature

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Fig. 1: First industrial VSB installation

- Performs well over a wide range of plant operating conditions.

As stated above, the technology was developed in collaboration with Donald Snyder, founder of Tuttle Prilling Systems. This programme of cooperation initially led to the unique prilling bucket design. This was followed by the execution of pilot-scale tests to validate the theoretical calculations.

Following very promising pilot test results, Casale was able to prove VSB technology at industrial scale. Subsequently, Casale also successfully completed the first industrial VSB installation (Figure 1). This technology is now available on the market for both small- and large-capacity urea plants.

Description of the technology

The VSB rotates on a vertical axis like a conventional prilling bucket. Thanks to its innovative, patented design ('Vibropriller', Figure 2), the external conical wall of the bucket also vibrates in a vertical direction, while the liquid contained inside the bucket is kept in an almost vibration free state. This vibration is induced by an electronic actuator installed above the prilling bucket.

The operating mechanism of the VSB, based on Rayleigh's principle of controlled breakup of liquid jets, guarantees the generation of liquid droplets with predictable diameters. The bucket's vibrating skin, thanks to its unusual ridged shape and optimised hole size distribution, is specifically designed to enhance both the uniformity of the droplets generated and occupancy over the cross-sectional area of the prilling tower.

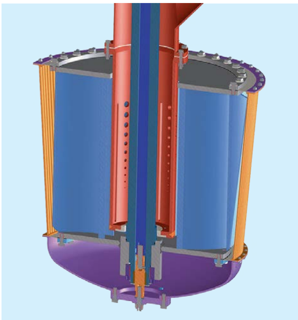

Fig. 2: Schematic of Casale's Vibropriller showing rotating plus vibrating components (orange and purple) and static liquid melt distributor (red).

Compared to a conventional rotating bucket, the configuration of the VSB enables higher plant production while delivering improvements in prill uniformity (size and shape). In addition, the VSB achieves a reduction in both the fine particle content of the prilled product and the amount of dust emitted from the top of the prilling tower. Table 1 shows the product size distribution achieved with the first industrial installation of the VSB versus that obtained with a standard rotating bucket.

The VSB differs from other 'viproprillers' technologies currently available on the market, as the vibration is only transferred to the external wall of the bucket and not to the liquid inside. Its innovative assembly (Figure 2) therefore allows better control of liquid droplet generation to be achieved. The main components of the VSB (Figure 3) are as follows:

Vibrating bucket: The complete bucket (excluding the urea melt distributor) rotates on its axis, driven by the electric motor. An electronic actuator, installed above the prilling bucket, transmits the vibration to the bottom cover and consequently to the conical perforated wall of the bucket. The bucket is fed with urea melt through a pipe distributor.

Shaft: The hollow-tube design of the driver shaft enables the electronic actuator to be installed inside it.

Electronic actuator: An electronic actuator located inside the rotating shaft transmits the vibratory motion to the external skin of the bucket. The actuator uses a sinusoidal current of controlled frequency and voltage for this purpose. The frequency of the supplied current determines the frequency of the vibration generated by the actuator, while the amplitude of the vibration is proportional to the applied voltage.

Table 1: **Particle size distribution of prilled urea: standard rotating bucket vs the VSB**

	Standard rotating bucket	Casale's VSB		
Load	**100%**	**50-75%**	**75-100%**	**100-120%**
<1.25 mm	3.0	1.8	1.5	1.6
1.24÷2 mm	13.0	6.4	4.0	3.9
1.5÷2 mm	54.0	73.5	73.2	74.0
2÷4.5 mm	30.3	18.3	21.3	20.5

Source: Casale

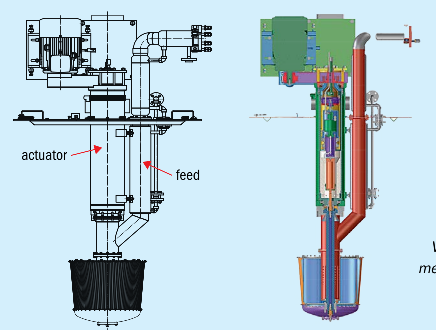

Fig. 3: VSB general assembly: mechanical drawing (left) and 3D model (right).

Source: Casale

Fig. 4: Casale's proprietary control system for remote operation of the VSB.

VSB control system

Casale has developed a patented control system for the VSB (Figure 4). This can be easily integrated within the plant's existing distributed control system (DCS).

The rotational speed of the bucket is controlled by an inverter installed on the electric motor. The vibration, meanwhile, is controlled by means of a signal generator (powered at 220 Vac). This regulates the frequency and the voltage of the signal supplied to the electronic actuator. This signal generator can be operated manually from a local panel or via the DCS.

The patented VSB control system allows the vibration (frequency and amplitude) to be controlled remotely and automatically. By measuring the urea melt flow rate fed to the bucket, the DCS (using a simple function) automatically adjusts both the frequency and the amplitude according to the plant load, so avoiding the need for any manual input. Similarly, the rotational speed of the bucket can also be adjusted automatically from the DCS in accordance with the feed flowrate of the urea melt.

Performance improvements

The VSB offers the following performance improvements:

- Tighter product size distribution with 20 percent higher uniformity index.
- The design can be specifically tailored to meet the desired average prill diameter.
- Dust emissions reduced by 25 percent.
- Delivers a steam saving due to the lower urea solution recycle from scrubbing.
- Reduction in prill temperature.
- Able to maintain excellent product quality when operating at between 50-120 percent of urea plant load.

Conclusions

Casale's vibrating skin bucket (VSB) design has been successfully tested and operated at industrial scale. This installed unit has delivered outstanding results in terms of uniform prill size distribution, low dust emissions and low prill temperature. The VSB has also been shown to function well over a wide range of operating conditions. In our view, these characteristics make the VSB the most advanced type of urea prilling bucket technology available on the market currently.

THYSSENKRUPP FERTILIZER TECHNOLOGY & GPIC

Advanced urea spray nozzles

Thomas Johner, Tobias Bluhm-Drenhaus and Christian Schröder of thyssenkrupp Fertilizer Technology and GPIC's **Abdulmonem Al-Najjar**

Bahrain-based Gulf Petrochemical Industries Company (GPIC) was established in 1979 as a joint venture between the governments of Bahrain, Saudi Arabia and Kuwait. GPIC's 1,700 t/d urea plant was initially commissioned in 1998. The plant produces granular urea using *UFT*® fluid bed urea granulation technology. Subsequent improvements to the plant have increased its daily output to 2,100 tonnes of urea in winter and 1,950 tonnes during the summer.

However, the high rate of dust formation from the urea solution spray nozzles remained an operational issue for GPIC, as is common with any plant running constantly above its nameplate capacity. Despite this, no loss of production occurred as any urea dust generated from the wet scrubbers was internally recycled back to the evaporation section.

Nevertheless, when operating the plant in this way, the overall process is limited by the capacity of the evaporation unit due to the high flowrate of recycled urea solution. It therefore became necessary to reduce the concentration of the feed urea solution to maintain reasonable parameters within the granulator. This in turn raised the moisture content, increased dust formation and created other operational issues.

All of these issues were addressed by thyssenkrupp Fertilizer Technology (tkFT) as part of continuous efforts to improve the *UFT*® fluid bed granulation process to meet customer needs. Specifically, tkFT investigated how to improve the two-fluid spray nozzle design – working together with one of the most renowned spray nozzle producers in this field.

Following phase doppler anemometry (PDA) lab tests, selected spray nozzles types were benchmarked against the standard *UFT*® spray nozzle at tkFT's batch-operated pilot plant. The new spray nozzles were tested under identical conditions, in terms of urea concentration, formaldehyde content, fluidisation air, load per sprayer, etc.

The goal of these pilot plant tests was to improve the spray pattern of the urea solution droplets. The main aims being to reduce the amount of dust generated, as well as the build-up rate of scaling on the granulator walls, while maintaining excellent product quality and increasing stable operating time. Operationally, the objective was to significantly extend the duration between granulator washings (the running cycle intrinsic to all fluid bed granulation processes) and therefore reduce the flushing work carried out by the operator.

Based on the successful pilot-scale test results, a spray nozzle prototype was installed at GPIC's commercial urea granulation plant in Bahrain. This was operated at very high production rates (more than 20 percent above nameplate capacity) under very harsh conditions, especially during the summer.

The results of the pilot- and industrial-scale demonstration tests proved that advanced spray nozzles can deliver a significant reduction in dust generation of 30 percent or more. This improvement is achieved while keeping the process parameters within an acceptable range. This makes a retrofit of an existing urea granulation plant feasible – without major mechanical modifications to any of the related equipment.

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The advanced spray nozzles significantly reduce the dust load on the exhaust gas scrubbers. As a consequence, by reducing the amount of recycled urea in the evaporation unit, it is possible to increase plant output and improve the running cycle while maintaining final product quality.

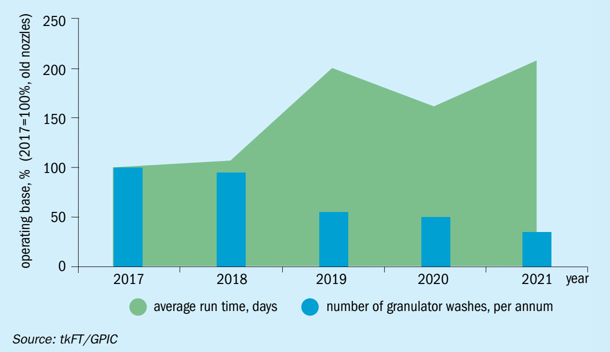
The gains in operational performance of the GPIC granulation plant from reducing the amount of dust generation are clearly shown by process data. These were collected over a three-year period following the installation of the new spray nozzles in late 2018. The number of annual granulator washings was reduced by more than half, compared to the period before the newly developed *UFT*® spray nozzles were installed. Correspondingly, the average granulator run time between these washings was also doubled. The plant's uptime and overall performance also benefitted from the shorter time required to wash the granulator.

This improved performance (Figure 1) was also due to the excellent learning curve resulting from the cooperation between the plant's operator GPIC and the process licensor tkFT.

"Even three years after the installation of the new *UFT*® spray nozzles, I am amazed about the performance our plant can achieve," said Abdulmunem Alnajjar, the urea superintendent at GPIC's plants operation department. "The investment paid out in no time, especially since the implementation can be done in only a few hours and no big and expensive revamp is required."

Subsequently, these new types of *UFT*® spray nozzles have been installed at two new large-scale urea plants (3,500 t/d and 1,750 t/d capacity) constructed in central Asia in 2018 and 2020. These have achieved outstanding results in terms of product quality, production flexibility and operational reliability. Based on these results, we are confident that many more urea granulation plants can be refurbished and adapted to benefit from advanced *UFT*® spray nozzles.

Fig. 1: **Positive effects of the new *UFT*® urea spray nozzles on granulation run time at GPIC's Bahrain urea plant**



Source: tkFT/GPIC

EIRICH

Granulating fertilizers for a cleaner environment

Thomas Lansdorf, sales manager, fertilizer process technology

Thanks to the availability of fertilizers, we are able to produce enough food to feed the world's ever-growing population. But, as with all natural resources, supplies of fertilizers such as potash and phosphate are inevitably limited. Fortunately, the ability to deliver fertilizers in granular form can play an important role in ensuring that valuable and finite plant nutrient resources are manufactured and used efficiently. Furthermore, Eirich's innovative *SmartMixer* makes the production of fertilizer granules particularly simple and cost-effective.

Rising demand and energy costs push up prices

Thankfully, the world economy has recovered significantly since the start of the global Covid-19 pandemic. But, as demand has recovered, energy costs and raw material prices have also reached record highs – making fertilizer production much more expensive. The costs of nitrogen and phosphate fertilizer production in particular rose substantially in the second-quarter of 2021, as shown by the World Bank's Global Fertilizer Price Index.

Even if prices begin to stabilise in the short term, analysts still expect further rises over the next few years. This will make it more important than ever to manufacture and use fertilizers as efficiently as possible.

Granulation – keeping fertilizers in fine shape

Arguably, even the best fertilizers have little worth if nutrients cannot be applied to crops in the correct proportions at the right rate. This simple fact is what continues to keep the demand for granulated fertilizers high. Especially as stable, round and free-flowing granules are needed when applying fertilizers with a centrifugal broadcaster. Granules with these characteristics can be applied optimally across the field to deliver an even distribution of nutrients over the soil.

In commercially-available fertilizers, a range of different nutrients need to be combined together within each and every granule. This helps to ensure that individual plants are supplied with all the nutrients they require (Figure 1).

In addition, it is also best if a continuous supply of nutrients is available to crops during the growing season. Excess nitrogen in the soil, for example, can be harmful to the environment. In controlled-release fertilizers (CRFs), granules are coated to slow down the release of nutrients and ensure a more uniform supply to plants. The use of CRFs also avoids the need to frequently re-apply fertilizers. This significantly reduces the workload for farmers, saves resources and protects the environment.

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Fig. 1: Ideal fertilizer granules: each granule contains all the nutrients in the same concentration; controlled-release fertilizers (CRFs) which benefit from an additional coating can also regulate the release of the nutrients.

Eirich *SmartMixer* – an ideal granulator

The Eirich *SmartMixer* is capable of mixing, granulating and coating raw materials within one single item of equipment. It operates rapidly and can granulate powdered materials in a matter of minutes (Figure 2). Chemical reactions can also be carried out within the mixer quickly and completely. In many applications, the *SmartMixer* combines individual processes together – enabling, for example, a homogeneous mixture to be produced from filter cake, dusts and slurries etc.

Within the mixer, water is firstly added to uniformly moisten the powder mixture. Forces of adhesion then act between the particles leading to the formation of granules. It is also possible to add binding agents or other additives to the granulating fluid – typically water – as required. The addition of a binding agent increases the strength of granules to ensure that these will not disintegrate under mechanical stress. When required, larger pellets (5-10 mm size) can also be produced using a disk pelletizer unit.

The *SmartMixer* combines fully-automated mixing and granulation processes in a single system. By combining individual processes in this way, Eirich can create a complete fertilizer production plant – one that is capable of continuously manufacturing fertilizers to consistently high quality standards around the clock (Figure 3).

Many straight fertilizers are used as important constituents of compound fertilizer mixes. They can also be granulated individually to improve field distribution and reduce dust formation. Examples of popular straight fertilizers include:

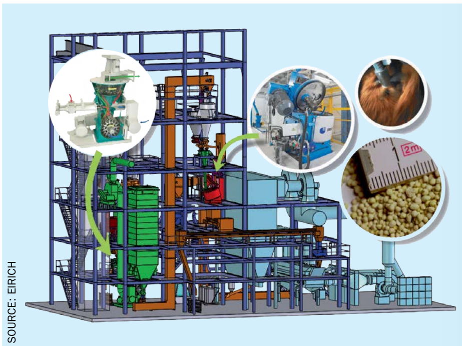
- Potassium sulphate (sulphate of potash, SOP, K_2SO_4)
- Potassium chloride (muriate of potash, MOP, KCl)
- Ammonium sulphate (AS, $(NH_4)_2SO_4$)
- Diammonium phosphate (DAP, $(NH_4)_2HPO_4$)
- Polyhalite ($K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$) etc.

The goal of granulation is to produce uniform and round granules with a target size of 2-4 mm. High throughput rates of several tonnes per hour are required for the main straight fertilizers listed above. High capacity *R28* and *R33* type Eirich mixers are therefore used for this purpose (Figure 4). Eirich can offer a range of customised granulation processes capable of manufacturing large amounts of granular fertilizers.

Dissolving minerals with acids

Phosphate rock can be dissolved in sulphuric acid at industrial scale to manufacture superphosphate. This process can be carried out particularly quickly and efficiently in an Eirich mixer. Dissolution in acid transforms the insoluble apatite (calcium phosphate) present into a soluble and plant-available form of phosphorus. Similarly, the valuable nutrients present in other insoluble minerals can also be made more available to plants by treatment with sulphuric acid or phosphoric acid. Serpentinite, which contains magnesium silicate, is one example.

Eirich has installed a modern production plant in Paraguay which uses serpentinite to manufacture fertilizer. This plant combines a *RV19* Eirich mixer with a *TR36* disk pelletizer. The serpentinite rock is crushed, ground and then dissolved with sulphuric acid in the mixer. This generates a moist reaction product which readily forms granules in the disk pelletizer. The soluble end-product obtained via this process is applied as fertilizer to soils to improve the growth and yield of maize and grain crops.



Left: Fig. 2: The Eirich SmartMixer. Right: Fig. 3: EIRICH SmartMixer within a fully automated mixing and granulation plant.

Wood ash – a valuable resource

It has long been known that wood ash can be used to fertilize crops, as it contains many nutrients that were stored by the trees during growth. The phosphate content of the ash is particularly valuable, as is the potassium, magnesium, and calcium it contains. The presence of these elements as carbonates also helps to neutralise the pH of acid soils. However, highly alkaline ashes do need to be applied evenly. This fact has made the granulation of wood ash a very popular and successful option. Wood is consumed as a fuel on a particularly large scale in Sweden. Eirich mixers and disk pelletizers are employed to granulate the resulting ash which is then used as a fertilizer to replenish forest soils.

Fig. 4: Industrial granulation of fertilizers at Eirich's headquarters in Hardheim, Germany, using two R33-72 (7 m³ capacity) mixers. Each mixer can achieve around 50 t/h throughput.

Recovering valuable resources

Because they are finite, it is becoming ever more important to use all natural resources both sparingly and sustainably. For example, phosphorus – which is in high demand as a fertilizer – is contained in large quantities in sewage sludge ash. This can be concentrated and recovered by the precipitation of struvite (magnesium ammonium phosphate). This can then be dried and granulated using an Eirich mixer which is capable of handling all the required process steps in a single unit.

The recovery and reuse of secondary raw materials is requiring new types of preparation processes and technologies. This is being done, for example, in Duisburg, Germany with an Eirich *RV24* mixer and *TR36* disk pelletizer. These produce nutrient-rich microgranules for agriculture from gypsum filter cake and other compounds such as kieserite and iron salts.

Conclusions

Energy prices and the costs of raw materials look set to rise in the future. This means that the sustainable use of finite resources will become increasingly important. Cost-effective fertilizer finishing techniques such as granulation – by ensuring that fertilizers are used efficiently – can contribute to more eco-friendly agriculture. Granulation helps ensure that plants receive the nutrients they require in the correct amounts during the growing season. At the same time, granulation also prevents fertilizer losses due to disintegration and wash-out from soils. ■

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Evaluating the performance of granulation aids

The consistency and integrity of fertilizer granules are key when producing a high-quality product for crop nutrition. Granulation aids help achieve this by increasing crush strength, improving size distribution and reducing recycling volumes during manufacturing. **Christina Konecki** of Arkema-ArrMaz outlines how their performance can be properly evaluated.

Granulation aids – also known as granulation binders – are valued for their ability to help build granule mass and improve size distribution. Yet they can also make granules more prone to crumbling due to moisture absorption. Assessing moisture impact, crush strength and size distribution is therefore critical when evaluating granulation aids.

What are granulation aids?

Granulation is a proven process for manufacturing high-quality fertilizer products with tight size distribution and good handling properties. Fertilizer granules are generally produced from a slurry of fine crystalline particles through a process of agglomeration. The function of granulation aids is to improve the interactions between the crystals that hold fertilizer substrates together[1, 2]. Granulation may occur via two agglomeration mechanisms – layering or coalescence – this being dependent on the chemistry of the fertilizer matrix and the binder used.

While granulation aids may exhibit similar agglomeration mechanisms, it is generally their bonding strength – derived from chemical characteristics – that contributes to final granule hardness. This point was illustrated by a study on biochar granulation[3]. This found that granule size was dependent on the type of agglomeration mechanism. Large granules, for example, were formed via coalescence with a polymer binder. The strongest granules, however, were formed using a sugar-based binder that agglomerated through layering. This study therefore showed that the bonds formed between sugar and biochar were stronger than those created with the polymer binder[3]. Another granulation study, for ammonium chloride, found that the best binder had a very strong ionic charge which promoted better agglomeration[4].

In the last decade, scientific research has shown that fertilizer binders can provide added value that goes beyond improved granulation. The surprising secondary benefits include:

- The controlled release of fertilizer nutrients
- Better soil aeration
- Improved fertilizer consumption
- Heavy metal chelation
- The ability to add nutrients.

Key factors to consider

The fertilizer industry typically uses clay, starches, sugars, lignosulfonates and polymers as granulation binding agents. When selecting a granulation aid, it is important to consider:

- Fertilizer type
- Regulatory requirements
- Added nutrient factors
- Application method
- Binder viscosity
- Loading rate.

The chemical structure of both the fertilizer and binder plays an important role in granulation, but it can also impact the release profile of the fertilizer.

In a study of the effect of binders on the release profile of urea, a more hydrophobic granulation aid (corn starch) had a longer release profile than a hydrophilic polymer (hydroxypropylmethylcellulose), for example[5]. Similarly, the use of a chitosan binding agent extended the release profile of urea-kaolinite granules. Approximately 60 percent of the urea was released after 30 days, compared to 99 percent for urea on its own[6].

Inevitably, there are trade-offs between the cost of adding a binder and the resulting improvements in granule properties. The cost-benefit ratio is therefore an important consideration for granulation binders. Polymer additives, for example, usually continue to increase granule strength as their concentration is raised, but they are a more expensive option. Sugars and starch binders, meanwhile, may be cheaper, but they do not impart the same level of granule hardness.

When evaluating granulation aids or binding agents, in order to optimise the granulation process, it is always good practice to consider several chemical types and different dosages. Dosage rate can alter the viscosity of the fertilizer solution – which also contributes to granulation. The method of binder addition must also be considered, with particular attention paid to temperature, pH, moisture and the physical state of the binder.

Evaluation methodology

To demonstrate how granulation aids should be evaluated, Arkema-ArrMaz measured the performance of a selection

Fig. 1: **Examples of incompatible binder-fertilizer interactions after drying**

PHOTO: ARKEMA-ARRMAZ

Fig. 2: **Measuring fertilizer granule hardness in the Arkema-ArrMaz coatings lab**

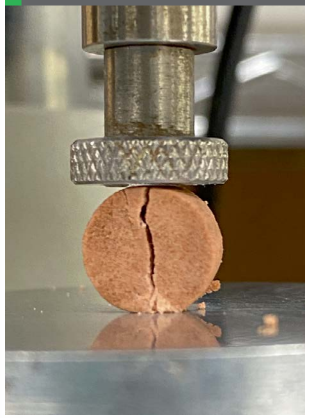


PHOTO: ARKEMA-ARRMAZ

of binders from its granulation aid product line. Various properties can be tested for and analysed, depending on the fertilizer producer's individual needs. These range from granular hardness to the impact of moisture absorption and nutrient release. In this case, Arkema-ArrMaz evaluated the ability of binders to improve granulation performance by measuring their impact on the granule crush strength of the fertilizer manufacturer's product – both before and after exposure to humidity. Granule crush strength measures the kilograms of force (fkg) required to break the fertilizer material.

The evaluation methodology proceeded in three stages.

Simulating the granulation process: Firstly, to successfully measure granulation performance on a small-scale, dry fertilizer powders were collected and the binders formulated. The binders were next mixed into the fertilizer at the desired loading level, either as a liquid solution or as dry powder. Then, to simulate the granulation process, these fertilizer-binder mixtures were extruded as pellets.

Identify fertilizer-binder incompatibilities: Once the pellets have been made, and before hardness is evaluated, signs of incompatibility with the fertilizer salt should be identified. Figure 1 shows examples of incompatible binder-fertilizer interactions after drying. Example A shows crumbling where granules are unable to form, while example B demonstrates that the binder-fertilizer is not firm enough to produce individual granules. Performance testing can begin once dry and intact granules are produced.

Measure initial and post-aging granule hardness/moisture absorption: Granule hardness is the most common laboratory metric used by producers to measure how a binder will perform in the field (Figure 2). However, depending on the fertilizer type, moisture absorption is another factor that can also be considered. Changes in moisture absorption can be evaluated by monitoring mass gain over time in humid environments and/or by measuring post-moisture granule hardness. If, after the addition of binder, the granule can withstand exposure to humidity while maintaining granule hardness, then it is likely that the binder will not cause harmful effects under real-life storage, handling and transportation conditions.

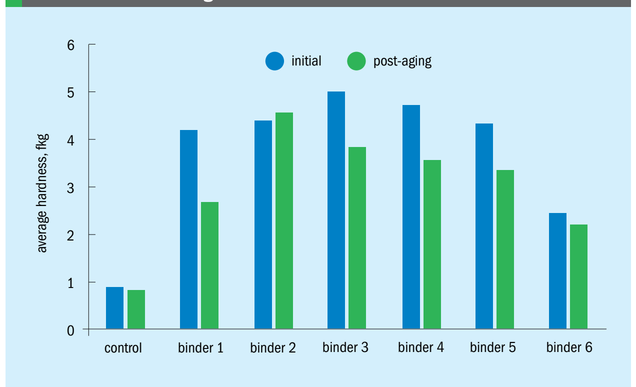
Granulation aid performance across different fertilizer substrates

The three fertilizer substrates examined here were potash (KCl), gypsum (calcium sulphate) and an NPK mixture. Depending on the substrate, specific binders from Arkema-ArrMaz's granulation aids product line were selected for testing at different additive rates. Each fertilizer type was, however, compared to the same water-only control sample.

Substrates were evaluated for binder selection by measuring initial and 'post-aging' granule hardness. Pellets were produced by combining the fertilizer powder with water and the binder agent, and then extruding these into 4 mm thick pellets. The initial hardness value was measured once these pellets were dry. The post-aging samples were exposed to 65 percent relative humidity (RH) for 24 hours at 30°C and then allowed to dry before hardness was again measured.

Potash was granulated with six different binders at 0.5 weight percent (Figure 3). Both initial and post-aging granule hardness improved for all of the binders evaluated, versus the control. This improvement was greater than 150 percent in all cases. Binders 2 and 6, however, showed the most consistent improvement in initial and post-aging hardness. This level of performance would be beneficial for fertilizer granules being exposed to varied temperature and humidity cycles during storage, handling and transportation.

Fig. 3: **Average hardness of potassium chloride granules with six different binders at 0.5 wt% loading**



Source: Arkema-ArrMaz

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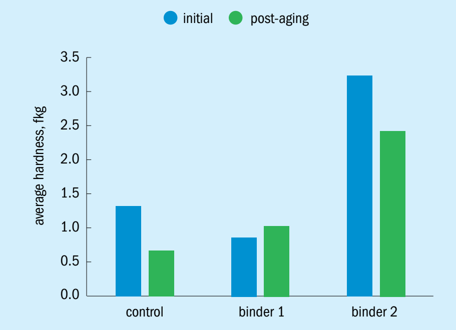
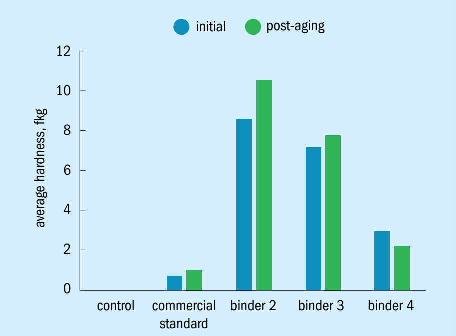
Fig. 4: **Average hardness of NPK granules with two different binders at 0.5 wt% loading**



Source: Arkema-ArrMaz

Fig. 5: **Average hardness of calcium sulphate granules with four different binders at 6 wt% loading**



Source: Arkema-ArrMaz

Similarly, the NPK substrate was granulated with two binders at 0.5 wt% load (Figure 4). Binder 2 showed improvements in both initial and post-aging granule hardness of more than 80 percent, compared to the control. Binder 1, meanwhile, performed slightly less well than the control. This confirmed that binder 1 and the fertilizer were chemically incompatible for granulation.

The calcium sulphate samples were tested at a high binder loading of six wt% (Figure 5). However, it was not possible to form an intact, solid pellet for the control samples as these crumbled. Consequently, it was not possible to measure and obtain an initial or post-aging hardness value for the control. This itself indicates that calcium sulphate would benefit greatly from a granulation aid. For calcium sulphate, the efficacy of three Arkema-ArrMaz granulation aids was instead tested in comparison to a standard off-the-shelf commercial binder.

All four binders improved calcium sulphate granule hardness. But the improvement obtained with the commercial binder was less significant than that delivered by the Arkema-ArrMaz binders, particularly binders 2 and 3. Both these binding agents are likely to provide high strength granules in the field at a much lower loading level. The higher than normal binder loading used with calcium sulphate (6 wt% versus 0.5 wt%) suggests there is further scope for fine-tuning binder concentration to deliver the desired improvement in granule hardness.

Summary

Fertilizer producers wishing to produce granulated products of consistent high-quality may find that standard commercial granulation aids are unsuccessful – and that custom-formulations, such as those available from Arkema-ArrMaz, are necessary instead. Indeed, binder selection is unique to the individual fertilizer, the type of process, and the exact needs of the end-user.

> **This evaluation approach demonstrates the effectiveness of custom-formulated granulation aids for improving product quality.**

Choosing the right granulation aid will produce fertilizer granules with improved strength and consistency. Valuably, it may also provide a range of secondary benefits that make the fertilizer product more marketable. These include more sustainable, natural or organic compositional characteristics, controlled-release properties, or the ability to improve nutrient uptake.

In this article, we show how granulation aid performance can be successfully evaluated by simulating the granulation process on a small scale in the lab. The hardness and moisture absorption of pelletised samples are measured before and after (post-aged) exposure to specific relative humidity and temperature. As the above data show, this evaluation approach demonstrates the effectiveness of custom-formulated granulation aids for improving product quality and optimising the fertilizer production process. We recommend that producers request this type of data from their supplier. This will ensure that the best granulation aid or binder is selected for your unique fertilizer product and process. ■

Author

Christina Konecki is the North America manager of coating technologies at Arkema-ArrMaz. Baziela Cabrera, Arkema-ArrMaz lab technician, is thanked for providing the data.

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Enhanced efficiency fertilizers for sustainable agriculture

Morocco: agricultural greenhouse gas emissions in Africa are on an upward trend.

PHOTO: BCINSIGHT

Conventional fertilizers can be transformed into enhanced efficiency fertilizers (EEFs) using coating agents and inhibitors. Greater use of EEFs, by preventing nutrient losses and avoiding excess nutrient supply, can help global agriculture become more sustainable, as **Urvi Mathur** of Neelam Aqua explains.

Rising agricultural emissions and excessive fertilizer use

In 2018, global emissions from agriculture rose to 9.3 billion tonnes of CO_2 equivalent, a 14 percent increase this century. Crop production and livestock are the main emission sources contributing 5.3 billion tonnes (57%) of CO_2 to this total. Three major economies – India, China and Brazil – are the top three agricultural emitters globally, a sign of agricultural intensification and the rising use of fertilizers and agrochemicals in recent decades. Emissions from African agriculture are also on an upward trend currently.

Agricultural land – which accounts for nearly 40 percent of global land area – notably generates large volumes of nitrous oxide, largely due to livestock manures and the soil application of nitrogen fertilizers. This is concerning as nitrous oxide makes up around one-third of global agricultural emissions (CO_2 equivalent) and has 300 times more global warming potential than carbon dioxide. It is also a major ozone-depleting chemical.

The increased use of nitrogen fertilizers, especially urea, stems from the need to raise yields and guarantee food security (a vital requirement in most developing countries) at a time when the population is rising yet the available arable land area is falling. While balanced fertilization is a necessity for delivering good crop yields, excessive fertilizer use has the potential to severely damage the environment.

The excessive application of mineral fertilizers, beyond crop requirements, is completely counterproductive too, as this has little to no effect on yields. Indeed, on average, around 50 percent of the nitrogen fertilizers applied to soils are never consumed by the crops. Instead, they are lost to the environment – as a result of volatilisation, nitrification and denitrification processes (see box).

Nitrogen losses: a threefold problem

Nitrogen is lost to the environment via three main processes: volatilisation, nitrification and denitrification.

Volatilisation

During volatilisation, urea is converted into ammonia via the hydrolysis reaction with the urease enzyme. Nitrogen is then lost to the atmosphere as gaseous ammonia if the fertilizer is not incorporated into the soil. As well as being climate-sensitive, ammonia emissions can also increase air pollution, be an air quality hazard for humans, and ultimately cause soil acidification if redeposited. The amount of nitrogen lost to volatilisation varies from region-to-region depending on soil properties (pH, moisture and texture), the climate and weather.

Nitrification

This is vital step in the nitrogen cycle as it is a mechanism used by microorganisms to obtain energy. Nitrification proceeds in two conversion steps: microorganisms firstly convert ammonium (NH_4) into nitrite (NO_2), this is then subsequently converted into nitrate (NO_3). Nitrates provide nitrogen to crops in an optimal and highly available form. But their highly mobile nature also makes nitrates susceptible to leaching and groundwater pollution.

Denitrification

This is natural soil microbial process that converts nitrate into three gaseous forms of nitrogen – nitric oxide (NO), nitrous oxide (N_2O) and nitrogen (N_2) – which can then be lost to the atmosphere. The process is generally promoted in water-logged soils where oxygen supply is limited and bacteria therefore consume the oxygen present in nitrate for respiration instead.

Although the above three processes are all natural and an integral part of the nitrogen cycle, nitrogen losses need to be drastically reduced to a level that does not inflict harm on ecosystems, the environment and the planet.

Enhanced efficiency fertilizers (EEFs)

The development of urease and nitrification inhibitors as fertilizer additives has been a major advance in agricultural technology. These nitrogen inhibitors, by protecting against ammonia volatilisation and nitrification respectively (see box), significantly reduce nitrogen losses associated with urea application while helping to maximise crop yields. Crop nutrient products that incorporate nitrogen inhibitors are generally termed **enhanced efficiency fertilizers (EEFs)** or **stabilised fertilizers (SFs)**.

The use of EEFs, by optimising nutrient use efficiency, has proven to be extremely helpful in intensive farming systems. Improving use efficiency, especially that of nitrogen, significantly reduces the adverse environmental effects of fertilizer use by increasing crop nutrient uptake.

The rate of nutrient release from fertilizers generally depends on factors such as rainfall, humidity, climate/weather and soil properties (pH, moisture, texture, microbes etc.). However, EEFs include two other groups of products that can act to slow or control the release of nutrients, these being known as **slow-release fertilizers (SRFs)** and **controlled-release fertilizers (CRFs)**, respectively.

SRFs and CRFs are designed to slow-down or regulate nutrient release throughout the growing season so it is more in sync with the needs of crops. This helps to overcome the problem of rapid and excessive nutrient release associated with conventional commodity fertilizers. The use of SRFs and CRFs also avoids the necessity for repeated split applications of fertilizers later in the season which are generally required to maintain nutrient supply.

The use and popularity of enhanced efficiency fertilizers is growing with sales of stabilised, slow-release and controlled-release types generally increasing. Although only applied on farmlands in a few parts of the world currently, EEFs are helping global agriculture become more sustainable and therefore benefiting the environment and the planet.

Conventional fertilizers can be turned into enhanced efficiency fertilizer using additives and coatings supplied by companies such as Neelam Aqua (see box). As well as improving nutrient use efficiency, these agents can also provide valuable anticaking and dust suppressant properties.

Neelam Aqua & Speciality Chem Ltd

Established in India in 1980, **Neelam Aqua & Speciality Chem Ltd** is a market leader in fertilizer additives. The company has expanded over the last four decades, with 11 factories and manufacturing units across the world now providing easier access to its products.

Neelam Aqua has constantly developed and championed technologies able to overcome the low nutrient efficiency exhibited by so many fertilizers. The company has also promoted the smooth transition to sustainable agriculture in both India and the Middle East by launching a plethora of sustainability initiatives – most notably the 'per drop per crop' campaign to address the high level of water usage in agriculture. This has emerged as a pressing problem in water-scarce countries.

Neelam Aqua manufactures a wide range of fertilizer coatings and additives designed to improve product quality. These include anticaking, colouring and dust suppressant agents. The company's *Neelcoat 1N 1000* product is an effective controlled-release additive for nitrogen fertilizer that also provides anticaking and dust suppressant properties. Neelam Aqua also offers three *Urecoat* anti-caking formulations for urea: *Urecoat 2000* is specifically designed for prills, *Urecoat 2002* contains a urease inhibitor, and *Urecoat 2002N* incorporates neem oil.

These speciality products are generally derived from plant extracts and are fully biodegradable. By creating enhanced efficiency fertilizers, they also have a role to play in the global mission to make agriculture more sustainable.

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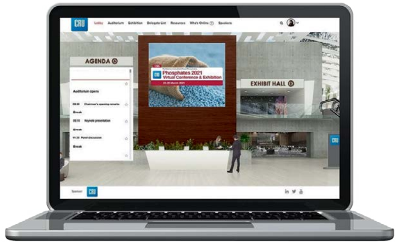
CRU Sustainable Fertilizer Production Technology Forum

More than 230 delegates from 45 countries participated in CRU's Sustainable Fertilizer Production Technology Forum, 20-23 September 2021. To highlight this successful virtual event, we report on keynote and selected technical presentations.



The time for change is now

Chris Lawson, CRU's head of fertilizers, welcomed delegates and set the scene for this year's event:

"This forum comes at a critical juncture within the fertilizer industry. On a daily basis, we're seeing new policies, new projects, new initiatives all surrounding decarbonisation and sustainability.

That's particularly important right now with the November COP26 meeting fast approaching. That very important meeting is something the fertilizer market is going to have to react to.

And right now the market is in a state of hyperactivity. We haven't seen anything like this before.

High natural gas prices in Europe, the aftermath of Hurricane Ida in the US, volatile policy decisions in India, soft export barriers in China, sanctions on potash from Belarus, booming agricultural commodity prices. All of this is resulting in very volatile and fast price rises within the fertilizer market.

These pressures have also been exacerbated by the lingering effects of the Covid-19 pandemic. While fertilizer supply chains have been resilient throughout the pandemic, they are really being tested by a lot of externalities right now.

And we truly do think that these external factors are only going to become greater going forward. Carbon emissions, carbon pricing, ESG investor pressure, increased regulatory scrutiny are all going to grow in weight and importance for fertilizer producers and the industry's market participants.

This shows how important an orderly transition into a new way of producing, distributing and consuming fertilizer is going to be. With that comes the increasing importance of new technologies.

These technologies need to be efficient, they need to be low cost and they need to be low emitting. The industry can't stick its head in the sand when it comes to emissions, sustainability and ESG issues.

The time for change is now. Scientists from around the world agree that climate change is real and that we're already seeing its impacts in full force.

We can curb and adapt to these impacts. That's why we need to change the industry now – and quickly." ■

Green ammonia project finance

CRU's **Willis Thomas** gave the CRU view on the financing of green ammonia projects. He identified three key factors governing the availability of project finance: market feasibility, project competitiveness and economic feasibility. These, in turn, raised the following critical question for investors:

- Will the project be able to place its planned sales volumes in target markets?
- How certain is it that customers (off-takers) will take sales volumes long term?
- How well positioned is the project relative to existing and future producers?
- Will this project be cost competitive enough to place its product?
- What returns will be made investing in the project and can it withstand cyclical lows?
- Finally, what market developments could make or break this project?

Opportunities for green ammonia will certainly abound, suggested Thomas, if the major ammonia import markets globally were to go low-carbon. These include 4.7 million tonnes of import demand in Europe, 3.0 million tonnes in East Asia (Korea mostly) and 4.2 million tonnes in North America. The demand for alternative shipping fuels from the maritime sector also provides another attractive market opportunity – although this is unlikely to become fully commercialised until after 2030.

"There are certainly opportunities for sales of carbon-free ammonia in traditional and new markets, but there are also a number of important limitations which must be understood for each project," Thomas said. "Developers need to carefully assess their ability to place products in the market – where, when and to what extent."

Cost is also a barrier currently. "The wide range of green ammonia costs are not competitive… yet," said Thomas. Green ammonia production costs are in the range \$500-800/t at present versus the <\$250/t levels typical of 'grey' ammonia producers on the cost curve. Reducing the capital cost of electrolysers will be key in closing this cost gap, said Thomas.

The fact that there isn't a real market for green ammonia today also makes any price forecasts theoretical. This situation will change though, as the first green ammonia cargoes are likely to be sold within the next 18 months. Green ammonia is likely to be sold within the \$600-800/t range out to 2023, suggests CRU, but could reach parity with green ammonia by the 2040s.

Future cost reductions for green ammonia are predicated on factors such as lower renewable prices, upscaling of the technology, access to financing and willingness to pay a 'green premium'. At the same, production costs for grey ammonia look set to escalate in future due to increasingly stringent environmental regulations, carbon pricing and cost inflation.

"The commercial feasibility of green ammonia projects will vary greatly depending on the time required to bring down opex and capex costs, the individual plant configurations, the business models and the locations of these projects," said Thomas. "Developers need to consider delivered cost too, and prices in different geographical and application markets, to fully understand their project."

Green ammonia projects will require strong business cases to win financing, Thomas concluded:

"The growing numbers of green ammonia projects globally will mean developers face increasing competition for financing. Thus, they must build and stress test their project business case both early and often."

Industry-wide action

Volker Andresen of the International Fertilizer Association (IFA) provided an overview of the latest development in fertilizer industry sustainability. "I will try to answer the question whether sustainable fertilizers are a challenge or an opportunity for our industry," he said.

Two landmark developments in 2015 – the UN's adoption of 17 sustainable development goals (SDGs) and the signing of the Paris climate accord – have helped mainstream sustainably, in Andresen's view. Importantly, the UN Environment Programme (UNEP) later went on to specifically link 11 of the 17 SDGs to the fertilizer industry.

External pressures on the sector have just kept on rising too, noted Andresen, including the:

- UNEA resolution on the health and environment impacts of pesticides and fertilizers
- UNEA resolution on the sustainable management of nitrogen
- FAO code of conduct for the sustainable management and use of fertilizers.

Andresen outlined what the IFA is doing to accelerate sustainability in response to these and other pressures. The launch of IFA's new sustainability committee this year has certainly provided the necessary added impetus.

"One of the first things that we did is reach out to IFA members and asked them to select their top priorities," said Volker. "They selected eight top must-win battles for us."

In order, these are as follows:

- Ammonia technology roadmap
- CO_2 reduction commitment
- Nutrient stewardship roadmap
- Nutrient stewardship benchmark
- Sustainability committee vision
- IFA sustainability principles
- Sustainability metrics
- Sustainable fertilizer academy.

The ammonia technology roadmap has been IFA's priority number one. The roadmap – a collaboration between the International Energy Agency (IEA), the European Bank for Reconstruction and Development (EBRD) and IFA – was published in October, in advance of November's COP26 climate conference in Glasgow. It sets out a plan to decarbonise ammonia production globally by 85-95 percent by 2050, with milestones at both 2030 and 2040.

In tandem, IFA has also been working on an industry-wide CO_2 reduction strategy – its second most important sustainability priority – and is set to make a firm public commitment on this next year.

Looking ahead, Andresen said: "We will publish a roadmap on nutrient stewardship, similar to what we've done for ammonia production. We are also working on nutrient stewardship benchmarking which we hope to launch next year.

"That is just the tip of the iceberg – there are many other things the IFA is doing."

The carbon emissions challenge

In his presentation, CRU's **Alex Derricott** highlighted a noticeable shift by policymakers towards prioritising emissions reduction.

"Are we entering a new normal for fertilizers when it comes to carbon emissions? Well, governments previously had to balance food security and emissions. We're now seeing a swing towards climate and emissions policy taking priority," he said.

Fertilizer production can occur with low emissions, pointed out Derricott – contrasting the emissions from producing potash (0.16 t CO_2/t KCl) with more energy intensive ammonia production (2.48 t CO_2/t NH_3). The emissions per tonne for ammonia production are, in fact, similar to steel, but lower than that of either copper or aluminium. On a total CO_2 emissions basis, the ammonia industry is also placed third behind steel and aluminium.

"Overall, fertilizers are not the most polluting products – but nitrogen production, and ammonia in particular, are the most exposed. Within the ammonia industry, everyone has a part to play, both gas and coal producers. However, Chinese coal is a particular challenge and the pathway to reduce emissions in China isn't necessarily all that straightforward and clear," commented Derricott.

Carbon taxes look like they're here to stay, suggested Derricott, with more carbon pricing schemes emerging internationally to incentivise emissions cuts. These include:

- The long-standing EU emissions trading scheme (ETS) – the world's most advanced cap-and-trade system – and its forthcoming extension via a carbon border adjustment mechanism (CBAM).
- The launch of the Chinese ETS scheme in July this year. This currently covers the power generation market but will be rolled out to encompass nitrogen production in future.
- The Canadian carbon tax which affects the country's potash and nitrogen producers. This could add around \$10/t to ammonia production costs in 2021.

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"However, with the rise of carbon taxes being introduced around the globe, ammonia producers are probably going to be the most exposed, particularly in the immediate term, and could face some significant increases in costs," concluded Derricott.

Green ammonia on a mega scale

Trevor Brown of the Ammonia Energy Association spoke about how low-carbon ammonia is enabling the energy transition.

By 2050, around 70 million tonnes of existing fossil fuel-based ammonia capacity will be shut down or converted to renewable inputs, according to some estimates, while 500 million tonnes of additional green ammonia capacity is set to be developed using renewable inputs (electricity, biomass). The established fertilizer market supplemented by substantial emerging markets for maritime fuel, hydrogen carriers and fuels for electric power generation are all expected to ratchet up demand for 'clean' ammonia.

In the fertilizer industry, announced projects include the following (pilot-scale/full-scale electrolyser capacity shown):

- **Yara** and partner Engie, Pilbara, Australia: 10/500 MW
- **Fertiberia** and partner Iberdrola, Spain: 20 MW/800 MW
- **Yara** and partner Orsted, Sluiskil, the Netherlands: 100 MW/2 GW
- **Yara** and partner HEGRA, Porsgrunn, Norway: 25 MW /500 MW
- **CF Industries** and partner thyssenkrupp, Donaldsonville Louisiana: 20 MW/Not known.

These are dwarfed by newly-announced non-fertilizer projects for green ammonia. These include the following mega projects (maximum ammonia and electrolyser capacity shown):

- **Asian RE Hub**, Australia: 9.9 million tonnes, 16 GW
- **Svevind**, Kazakhstan: 15 million tonnes, 45 GW
- **Aman**, Mauritania: <20 million tonnes, 30 GW
- **Al Wusta**, Oman: <10 million tonnes, 15 GW
- **Western Green Energy Hub**, Australia: 20 million tonnes, 50 GW
- **Grand Inga Dam**, DRC: >20 million tonnes, 40 GW hydroelectric.

Projects on this scale are going to be needed if industries are going to be fully decarbonised over the next two to three decades, Brown suggested. Even five percent decarbonisation of the shipping industry by 2030 – via the adoption of zero-carbon maritime fuels – would require 60 GW of electrolyser capacity making 30 million tonnes of green ammonia. Furthermore, the 93 percent decarbonisation of shipping by 2046 would necessitate one terawatt of capacity generating 300 million tonnes.

"In various stages of development, we've got about 100 million tonnes of green ammonia underway from roughly 200 gigawatts of renewable electricity, with some more committed than others," commented Trevor Brown. "When you're scaling up to this size, it's a lot easier to see how the economies of scale are going to come in, and how financing – on oil & gas scale – is going to enable a molecule like ammonia to actually support decarbonisation in industries like the maritime fuel sector."

Selected technical presentations

Clariant's **Stefan Gebert** explained how the company innovative catalysts are reducing carbon intensity and paving the way for blue and green ammonia.

In blue ammonia production, the company's proven range of catalysts offer significant energy savings and CO_2 reductions in process routes used prior to carbon capture and storage (CCS). These include the:

- Steam methane reforming (SMR) route: *EARTH* reformer
- Autothermal reforming (ATR) route: *ReforMax*
- Partial oxidation (POX) and water gas shift (WGS) routes: *ShiftMax*.

> "It's a lot easier to see how economies of scale and financing are going to enable a molecule like ammonia to support decarbonisation

Clariant is also offering *AmoMax 10 Plus* as a solution for green and blue ammonia. This superior wustite-based catalyst enables sustainable and cost-efficient ammonia production. Global annual ammonia production generates more than 450 million tonnes of CO_2 emissions. Yet Clariant calculates that *AmoMax 10* series catalysts – if widely adopted – could potentially deliver a global emissions savings of more than two million tonnes CO_2 annually.

Bernd Mielke of thyssenkrupp Uhde examined what the new blue ammonia plants of the future might look like. He suggested that only large plants – in excess of 3,500 t/d, for example – would be able to satisfy increasing demand for blue ammonia from markets such as low-carbon marine fuels. Blue ammonia production via the autothermal reforming (ATR) route also offers distinct advantages, in his view. These include:

- Lower capex for large-scale ammonia plants (both blue and grey)
- Potential for simpler CO_2 capture when a high degree of removal is required – as CO_2 is removed from one point only
- High degree of modularisation and prefabrication that reduces on-site construction cost.

thyssenkrupp Uhde has a strong offering for blue ammonia that includes its own proven and effective ATR technology and access to technology from partner GasConTec.

Joey Dobree revealed how Stamicarbon is developing the world's first commercial-scale, renewable-powered nitrate fertilizer plant in Kenya. This will have the capacity to produce 550 t/d of calcium ammonium nitrate (CAN) or NPK fertilizers. This innovative 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 (*Fertilizer International* 503, p9).

The renewable power-to-fertilizer plant incorporates new Stami Green Ammonia technology (*Fertilizer International* 504, p20) and the company's existing nitric acid technology. Front end engineering design (FEED) is scheduled to start later this year with construction due to follow in 2023.

At the heart of Stamicarbon's novel green ammonia technology is an efficient, high-pressure ammonia synthesis loop and a reliable electric compressor for condensing ammonia. These features 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 plant in Kenya.

The Lake Naivasha 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 energy 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 for nitrogen fertilizers by around 25 percent, as well as improving domestic fertilizer affordability and availability.

Ricardo Sepulveda of PegasusTSI outlined the potential for green methanol and green ammonia production via carbon capture and hydrogen generation at existing phosphate fertilizer production sites.

A typical one million tonne capacity phosphoric acid plant, for example, will generate 150,000 t/a of CO_2. Flue gas from these plants contain 4-10 percent CO_2, while fertilizer granulation plant flue gas also contains 0.3 percent CO_2. Carbon dioxide can be captured from these gases by CO_2 absorption in amine solution using proprietary systems such as *CANSOLV*.

Waste heat from on-site sulphuric acid production, meanwhile, can also be captured and converted to medium pressure steam with a heat recovery system (HRS) – and then used to generate electricity. This, in turn, can generate hydrogen from water using an alkali electrolysis unit.

Together, CO_2 capture and heat recovery can provide the feedstocks for two different production routes. Firstly, captured carbon dioxide and electrically-generated hydrogen can be combined to manufacture green methanol. Alternatively, hydrogen can be combined with nitrogen in ammonia synthesis to manufacture green ammonia. Pegasus TSI has calculated the investment costs and the revenue potential for both routes.

Efficient phosphoric acid production technologies, such as Technip Energies' *Diplo* process, could significantly boost phosphogypsum recycling and reuse, according to **Marieke Maenhaut**. Valuably, the two-step *Diplo* process combines higher P_2O_5 recovery with the advantages of the dihydrate (DH) production route, such as the flexibility to accept different phosphate rock types.

The *Diplo* process can also be combined easily with a simple phosphogypsum purification process, avoiding the need to consume costly high-quality phosphate rock. Other benefits include process simplicity, ease of operation, low maintenance cost, high plant availability and low capex (*Fertilizer International* 502, p58).

Dirk Köster of thyssenkrupp Uhde introduced a new process that allows phosphogypsum to be reused and turned into new products as part of the circular economy. In future, the new process should allow full-scale phosphogypsum treatment units to be integrated within phosphoric acid plants (*Fertilizer International* 501, p48). Upgraded phosphogypsum from the new process can be reused in two different ways: firstly, for sulphuric acid and clinker production and, secondly, as gypsum (plaster, stucco) for the building industry.

thyssenkrupp has successfully tested its innovative two-step phosphogypsum treatment and purification process at laboratory-scale. It has also devised a conceptual model and cost estimate for a full-scale commercial treatment unit. A pilot plant is currently in planning and will be used as a springboard for developing the full-scale plant. Full commercialisation of this treatment technology will, however, require close cooperation between phosphogypsum producers and cement producers or off-takers.

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Field application of potassium – an important crop nutrient under drought conditions.

PHOTO: K+S

Optimising potato crop nutrient management during droughts

Dr **Heike Thiel** and Dr **Wilm Fecke** of K+S Minerals and Agriculture GmbH outline how better nutrient management can reduce potato yield losses during lengthy dry spells – and make better use of the available water.

A number of prolonged and unexpected droughts have hit global agriculture in recent years. Such droughts, with their combination of extreme heat and intense solar radiation, have presented all growers with special challenges.

A drop in crop yields during long-lasting droughts is arguably inevitable. But could better nutrient management reduce crop losses during lengthy dry spells – and make better use of whatever water is available? In this article, we attempt to answer this question by examining the effects of potassium and magnesium on the water use efficiency of potato plants under drought conditions.

Applying nutrients in sulphate form

Potatoes belong to a group of chloride-sensitive, leafy crops that require a lot of potassium and magnesium. Farmers need to pay particular attention to chloride sensitivity when selecting fertilizers for potato growing. The movement of assimilates formed in the leaves is inhibited in potato plants exposed to excessive amounts of chloride. In addition, the presence of chloride in soils also impairs the development of fine roots, while in the case of foliar fertilization it also causes leaf stress.

The salt index is a helpful indicator for selecting the right choice of fertilizer (Table 1). This index shows that chloride-based *Kali 60* will, for example, causes more stress to potato plants than the sulphate-based *Patentkali* (30% K_2O, 10% MgO, 42.5% SO_3). The latter product causes practically no stress when it is applied to the crop.

EPSO Microtop (15% MgO, 31% SO_3, 0.9% B, 1% Mn) should also be suitable for potatoes based on its salt index. This is also reflected in its EC values. In fact, with its magnesium, sulphur, boron and manganese content, *EPSO Microtop* is a standard foliar fertilizer in potato cultivation. Additionally, its low chloride content means it is compatible with organic fertilizers, such as slurry, digestate, compost and manure, which may contain significant amounts of chloride, depending on their origin.

Table 1: **Salt index of different fertilizers**

Product	Nutrient content	Salt index	Chloride- or sulphate- based
Kali 60 gran.	60% K_2O	116	chloride
Korn-Kali	40% K_2O, 6% MgO, 12.5% SO_3, 4% Na_2O	82	chloride
KaliSOP gran.	50% K_2O, 44% SO_3	46	sulphate
Patentkali	30% K_2O, 10% MgO, 42.5% SO_3	41	sulphate
ESTA Kieserit	25% MgO, 50% SO_3	35	sulphate
EPSO Microtop	15% MgO, 31% SO_3, 0.9% B, 1% Mn	21	sulphate

Source: K+S

On better soils, attempts are often made to apply *Kali 60* or *Korn-Kali* (40% K_2O, 6% MgO, 12.5% SO_3, 4% Na_2O) to potato crops early before planting. This is not always successful. That is because chloride ions, for example, may eventually reach the plant roots due to the capillary movement of water during dry periods. In many cases, the optimum fertilization time in winter is also missed, causing problems with too much chloride subsequently. Finally, potato tubers will normally suffer after chloride fertilization. Their starch content is generally negatively affected, this leading to less flavour and losses in starch during processing.

Patentkali is especially well suited and therefore recommended for potato cultivation. This is due to its ideally balanced ratio of potassium to magnesium as well as its low salt index. The magnesium deficiency that is often observed in potato crops is usually caused by the over application of potassium resulting in a non-ideal K:Mg ratio.

Monovalent potassium (K^+) competes with the divalent magnesium (Mg^{2+}) for uptake by the plant. Due to this antagonism, magnesium can be quickly displaced if the soil supply of potassium is high. Combined potassium and magnesium fertilization at the correct ratio is therefore recommended.

Optimising water use efficiency under drought conditions

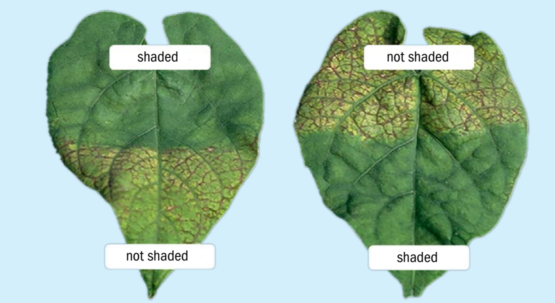
The water use efficiency (WUE) of crops measures the volume of water needed to produce a given amount of biomass (e.g., litres per kg of dry matter). Conversely, it is can also be expressed in terms of the amount of biomass produced for a given volume of water (e.g. kg of dry matter per litre of water).

Strictly speaking, WUE is a measure of how efficient the plant is at productively using water for growth. During crop cultivation, the goal is to achieve a high WUE as this will increase the yield (and profits) obtained per litre of used water.

Due to the positive impact of WUE on yield, it is very important for plants to be able to properly regulate their physiological processes, especially under drought conditions. This is a major prerequisite for both good growth and high yields in stress situations.

Although drought occurs primarily due to low rainfall, it is exacerbated by the high rates of evaporation and transpiration at elevated temperatures. Under these conditions, where the availability of water is the limiting factor for crop production, a high WUE is required for plant systems to reach acceptable yields. WUE is also influenced by both the choice of crop variety and the availability of nutrients. Potassium, in particular, plays a key role in the regulation of WUE and the water balance of plants, as explained below.

Fig. 1: **Influence of low magnesium supply on plant leaves exposed to solar radiation stress**



Sunburn: Plants suffering from Mg-defiency react much more sensitively to high solar radiation and temperatures than plants well supplied with magnesium. When magnesium is lacking, the energy “unused” for the production of sugars during photosynthesis persists and forms reactive oxygen species which have an acytocidal effect. Therefore, light damage is greater as solar radiation becomes more intensive if the magnesium content of the leaves drops.

Source: K+S

The importance of potassium under drought conditions

Potassium has numerous metabolic functions in plants. Due to osmotic effects, this nutrient is also crucial for regulating the plant's water balance. This starts with the entry of water through the roots until water exits the plant through the stomata of leaves.

Plants self-regulate their stomata function over time, including during stress conditions such as nutrient deficiency or water scarcity. If water becomes scarce during the growing season, it is important to maintain transpiration – and thus the opening of stomata – as long as possible.

The osmotic pressure in cells will remain stable if potassium is present in adequate quantities. Its presence gives plants the opportunity to continuously take up water, via transpiration, from the roots to the leaves. This process continues to happen and is maintained, even during initial drought. This is important as water channelled into the stomata helps maintain photosynthesis. At the same time, open stomata also ensure the continued uptake of carbon dioxide (CO_2) – which is then synthesised into sugars with the help of solar energy.

Plants will use even small amounts of water for biomass and yield formation. Importantly, transpiration and yield are always higher when potassium supply is sufficient than when it is deficient. This is because deficiency, by lowering transpiration, reduces plant growth. Potassium is also believed to slow down the synthesis of abscisic acid, a plant hormone which can trigger the emergency ripening of entire stands.

The wilting of potato leaves, an undesirable symptom often observed during hot weather, is more pronounced when potassium is deficient. Wilting signals that the water balance is disturbed and that potassium is insufficient for effective transpiration. Wilting is undesirable in potato plants because it can lead to ripening of the potatoes and stop their growth. This also affects the quality of the potatoes as the new tubers formed may remain unripe and contain lower starch levels.

Magnesium helps the potato to reach water

In addition to potassium, magnesium is also a valued nutrient in potato cultivation. By controlling the transport of assimilates within the plant, it ensures enough sugars

POTATO CROP NUTRITION

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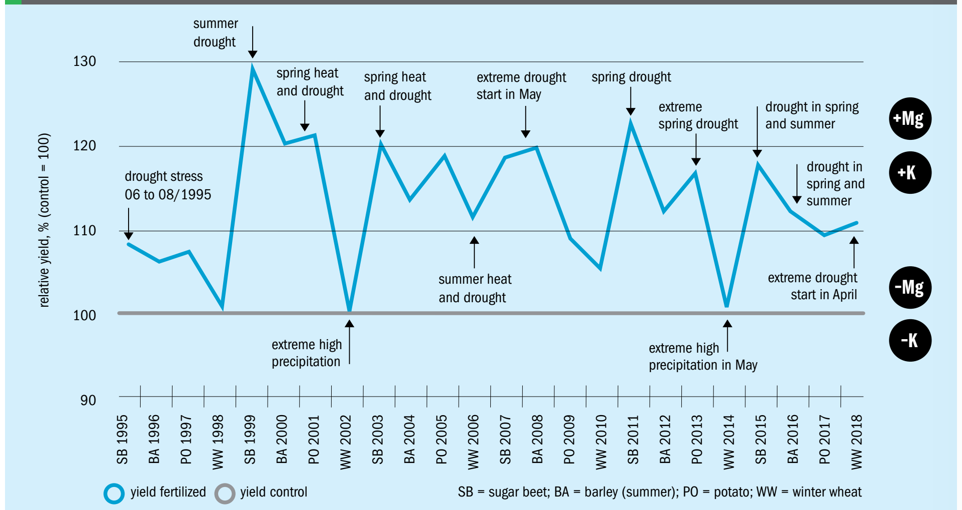
Fig. 2: **Influence of potassium and magnesium supply on the relative yields of different crops under drought conditions**



Source: K+S

and other carbohydrates are provided for plant development. Magnesium also plays an important role in the conversion of light energy during photosynthesis. It also helps limit the 'sunburn' caused by reactive oxygen species. The resulting sun damage, although chlorotic initially, later becomes necrotic (Figure 1).

Additionally, magnesium is needed for enzymatic processes. This provide the pathway for carbohydrates to be distributed and reach target organs such as tubers and young leaves, etc. This mechanism also underpins magnesium's role in root growth, which is similarly dependent on a good supply of carbohydrates.

A well-developed root system is important for water uptake from the soil, especially under drought conditions where water is still present in lower soil layers. A deep and complex root system also aids nutrient uptake. Root development is influenced by various parameters. As well as magnesium supply, soil moisture and oxygen availability at the time of planting are particularly important.

If a sufficient supply of water is readily available, only short roots will be developed when, for example, it is very wet during or after sowing. Such water saturated conditions can have negative consequences when they are followed by drought, as the short roots formed will be unable to reach and absorb the water (and the nutrients these contain) in deeper soil layers.

> **"The basic prerequisite for high crop yields and top quality is an optimum supply of potassium.**

Drought stress in the field

Fertilization plays a crucial role especially during heat and drought events. A long-term crop rotation trial in Germany provides good evidence for this (Figure 2). Spring and/or summer droughts led to yield losses in many years. However, the trial results show that potassium and magnesium fertilization boosted yields, versus the unfertilized control, especially in dry years.

This long-term German trial provides a clear example showing how potassium and magnesium fertilization with *Patentkali* can secure higher potato yields, especially in times when water supply is insufficient. It demonstrates that regular fertilization with these two nutrients can reduce the risk of yield losses associated with unfavourable weather conditions.

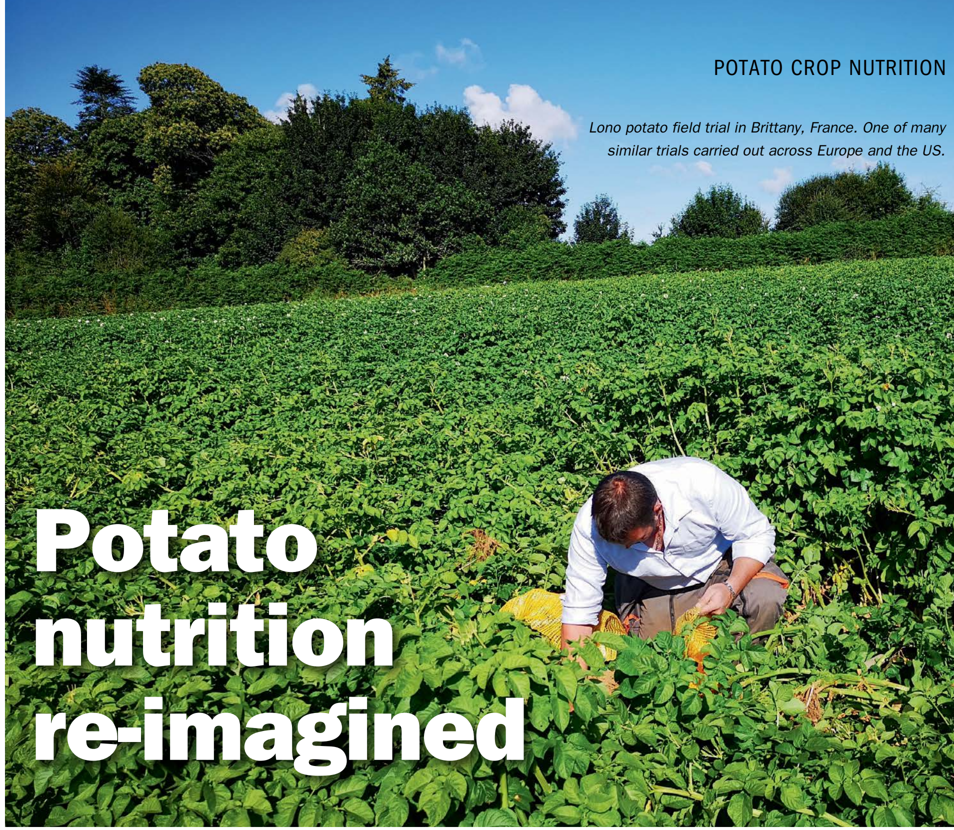
Conclusion

Fertilization with mineral nutrients plays a prominent role in yield and quality – the two main factors crucial to the economics of potato cultivation. Potassium, in particular, is prized as the nutrient most needed by potato plants.

Together with magnesium, which positively influences the carbohydrate supply to roots and tubers, potassium is an important guarantor of high yields and good quality, even during non-ideal weather conditions.

Patentkali, by combining potassium and magnesium in the best ratio, is a highly effective potato fertilizer. Its sulphate-based and chloride-free composition ensures balanced potato cultivation with less plant stress, especially in years with lower rainfall or drought. Valuably, using sulphate-based fertilizers prevents additional chloride from accumulating in the root zone when rainfall is low. This avoids exposing the potato plant to undesirable stress factors.

In summary, the evidence shows that balanced and sulphate based fertilization with potassium and magnesium is able to minimise the risk of yield losses during sustainable potato cultivation, especially in years with almost no rainfall. ■



Lono potato field trial in Brittany, France. One of many similar trials carried out across Europe and the US.

PHOTO: LEVITY CROP SCIENCE

Potato nutrition re-imagined

Yield, quality and profitability are the primary focus for the modern potato grower. But these objectives need to be balanced against the need to reduce the environmental impacts that result from cultivating the world's fourth-biggest food crop. *Fertilizer International* talks to **David Marks** of Levity Crop Science about how its unique approach to product development is helping farmers adopt more sustainable agricultural practices.

Delivering more from less

"Everything we do at Levity has one singular objective: identifying ways in which crop production can be made more sustainable. Of course, that demands better and more efficient use of resources, as well as a reduced environmental impact.

"But it also means maximising yield and production – we have to get more from less."

That's Dr David Marks, founder of UK-based Levity Crop Science. This innovative, R&D-led business develops and markets so-called 'smart' or 'functional' fertilizers. Levity's crop nutrient products are, in fact, difficult to categorise, as they combine the attributes of both biostimulants and conventional fertilizers.

Their benefits are, however, more easily understood. Compositionally, the company's products are designed to boost farm production and profitability, while reducing wasted resources – often the root cause of subsequent environmental problems. These are also the problems for which farming, and farmers, generally take the blame.

"Take nitrogen, for example," says Dr Marks. "Every potato grower knows how vital nitrogen management is for the growing potato crop. They'll tweak their N regimes to reflect different end uses, and time their applications to optimise yield and quality.

"Yet many growers would probably be surprised to find out that the crop in their fields is making use of only 25-35 percent of the applied nitrogen fertilizer. Leaching, microbial action and mineralisation can see up to three-quarters of that nitrogen become inaccessible to the crop."

Dr Marks says the most commonly used forms of nitrogen in agriculture are often determined by availability: "They're also based on what's been easiest to secure in large quantities, not necessarily what's best for the plant."

It was this kind of supply-driven approach that led Dr Marks to consider how to make better use of nitrogen in the field. By understanding how plants absorb and use different types of nitrogen, Levity has successfully brought to market products that offer much greater nitrogen use efficiency (NUE).

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Nitrogen – available in three different forms

Nitrogen is commonly supplied to crops in ammonium form (e.g. urea) or as nitrates (e.g. potassium nitrate, NOP) or as combination of these two forms (e.g. ammonium nitrate, AN). Nitrates can deliver superior yields and quality in arable, fruit and vegetable crops (*Fertilizer International* 506, p28) – including potatoes (*Fertilizer International* 506, p56). They generally have a much lower environmental impact relative to urea-based fertilizers as well, due to their ability to avoid volatilisation losses. Their production can also have a lower environmental impact. Nitrates are, however, prone to leaching and have a lower nitrogen content than urea.

There is, however, a third form of plant-available nitrogen – amine urea. This, in stabilised form, is the nitrogen fertilization option favoured by Levity Crop Science.

"Plants can absorb three different types of nitrogen," explains Dr Marks. "Nitrate, ammonium and amine all result in different responses, and the plant expends different amounts of energy to absorb, transport and utilise each one of them.

"Soil-applied ammonium is quickly converted to nitrate by soil microbes. Yes, the plant can turn it back into ammonium – but it's an energy-intensive process."

Plants process nitrates within leaf cell structures called chloroplasts. Transporting it to the chloroplasts uses energy though, as does the generation of the enzymes needed to convert nitrates into amino acids, the building blocks of proteins. In fact, says Dr Marks, it can take 12 times more energy (carbon) to turn nitrate into plant protein than for the same unit of nitrogen absorbed as an amine.

"For protein synthesis, the plant can use both amine and ammonium forms immediately," notes Dr Marks. "That allows the plant to use its captured and converted solar energy for growth instead, immediately, without any kind of a processing lag. Carbon instead becomes biomass – i.e. yield."

Because amine and ammonium are both processed in the roots, there's no energy expended in transport or enzyme generation. The added attraction is that amine in the roots has a positive effect on the production of cytokinin, a plant hormone that triggers reproductive growth: another plus for tuber production.

> **Yet many growers would probably be surprised to find out that the crop in their fields is making use of only 25-35 per cent of the applied nitrogen.**

Stabilised amine urea (SAN) technology

Levity has focused its efforts on finding a means of delivering amine directly to the plant. It settled on a stabilised form of amine urea. Rather than using polymer coatings, or the urease and bacterial inhibitors preferred by other manufacturers, the company instead developed its own unique approach.

"The problem with inhibitors is that they can affect the mineralisation process. Sometimes that's favourable, but not always.

"Our stabilised amine urea (SAN) technology – *LimiN* – relies on forming a cross-linkage between the NH_2 amine and a monovalent or divalent cation. This has the effect of making the NH_2 form of nitrogen invisible to soil bacteria.

"And by supplying nitrogen as SAN, we give the plant access to a more efficient form of nitrogen. Not only can we apply less nitrogen and achieve the same amount of plant growth, but the nitrogen usage itself is more energy-efficient within the plant.

"Crucially, the amine form also encourages more reproductive growth – the tubers – because it has an effect on the plant's hormone balance."

Yield improvements and more

Early field trials of the technology showed that SAN not only increases yield, but, in creating shorter plants with more roots, the crop also demonstrated greater resilience to drought-induced stress and lodging. Greenhouse trials revealed that leaf chlorophyll content increased in the presence of SAN, thus improving the plant's photosynthetic activity.

Lono, a Levity product that incorporates *LimiN* technology, has demonstrated yield increases for potato growers around the world. "Exports account for more than 70 percent of Levity's sales," reports Dr Marks, "which means we get to prove our products in numerous soils, climates, varieties and marketplaces.

"*Lono* generally averages around five percent more yield over the control, but some varieties respond particularly well. For example, there's a chipping variety common in the United States, *FL1867*, where we've seen a 28 percent boost when *LimiN* technology was incorporated into the standard nutrition programme."

Of course, the increase in marketable yield is a clear benefit, as is the avoidance – admittedly more difficult to quantify – of losses associated with the field applications of nitrogen, such as leached nitrates and ammonia and nitrous oxide emissions.

Size matters

Further field trials with SAN also revealed another interesting property.

"By revising the fertilizer schedule while using SAN, we've shown that farmers can accurately manipulate tuber size distribution in the field, to meet the requirements of their end market: salad potatoes, chipping, crisping and so on.

"We discovered that early pre-tuberisation SAN applications increased the percentage of smaller 40-60mm tubers. Conversely, excluding that early application and concentrating on a bulking-stage timing increased the proportion of large tubers at the 60-80mm size."

Trials carried out in New Zealand in 2020 ably demonstrate this. *Lono* was applied to a crop being grown for seed potatoes – an extremely high-value end-use, where correctly sized tubers can be up to three times as valuable as those outside the optimum specification.

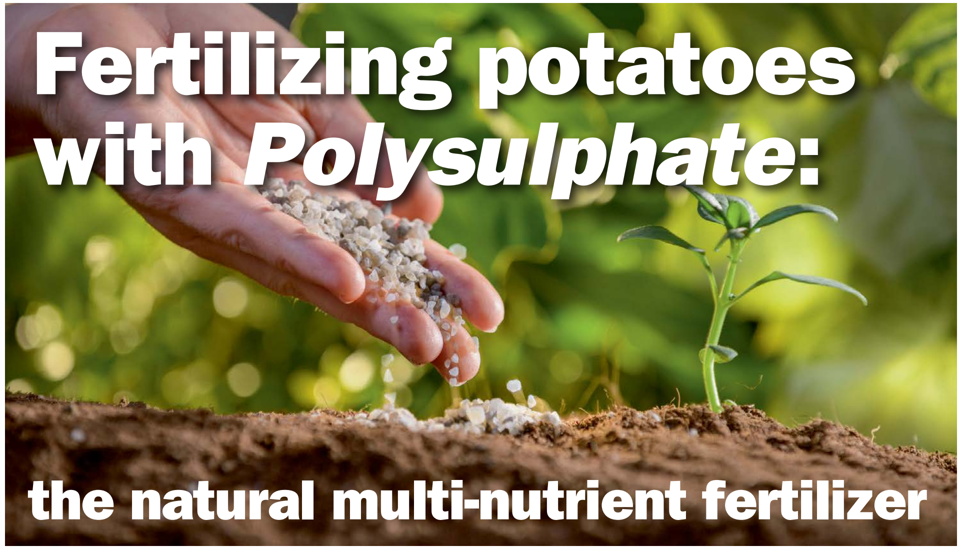
The trials with *Lono* delivered a per-hectare benefit of more than NZD4,000. "That's quite an extreme example, because of the relatively high value of seed potatoes," notes Dr Marks, "and a terrific demonstration of the manipulative effect of SAN.

"It's easy to see why it's becoming a routine treatment, especially in Europe, because of that dual effect of increased yield and consistent tuber size.

"But it's also a great vindication of Levity's approach to problem-solving," sums up David. "We all need to offer growers more responsible options for nutrition and crop protection, whether it's nitrogen in this case, or the other smart technologies we've pioneered, such as those for crucial trace elements like boron and molybdenum.

"Consumers increasingly expect their food to leave a smaller footprint. Delivering that challenge begins with us in the supply industry; farmers can't do it otherwise," he concludes. ■

Polysulphate delivers dependable high value at a low environmental impact.



Fertilizing potatoes with *Polysulphate*: the natural multi-nutrient fertilizer

PHOTO: ICL

Polysulphate is a new multi-nutrient fertilizer mined in the UK. Its unique characteristics and mix of nutrients make it especially suitable for potato crops, explains **Patricia Imas**, chief agronomist at ICL Innovative Ag Solutions (IAS).

Potato (*Solanum tuberosum*) is the world's third most important staple food crop. It is commonly grown on sandy, poorly fertile soils, and therefore usually requires regular irrigation and an adequate supply of plant nutrients to achieve high yields and good tuber quality. The demand from potato crops for key nutrients increases significantly 30-45 days after planting. This is when tubers begin to form and the canopy is at its peak growth.

At harvest, a good potato crop can remove around:

- 300 kg/ha of potassium (K_2O)
- 110 kg/ha of sulphur (SO_3)
- 20 kg/ha of both calcium (CaO) and magnesium (MgO).

Supplying four key nutrients

Polysulphate is a new multi-nutrient fertilizer mined in the UK by ICL. It is composed of a natural mineral (polyhalite), has a low carbon footprint (0.034 kg CO_2e per kg of product) and is approved for organic agriculture. Four essential plant nutrients are present: sulphur, magnesium, potassium and calcium. Sulphur is the leading constituent (48% SO_3) together with potassium (14% K_2O), magnesium (6% MgO) and calcium (17% CaO), all in sulphate (SO_4) form.

Polysulphate readily dissolves in soil, making all four nutrients available for plant uptake. Due to its unique natural crystalline composition and solubility behaviour, *Polysulphate* provides the crop with a continual and fresh source of these nutrients throughout the growing season. This nutrient release pattern, by matching the timing of nutrient uptake by the crop, minimises the risk of sulphate loss through leaching. *Polysulphate* is also notable for having a very low chloride content, very low salinity index, neutral pH and no liming effect.

Polysulphate for potato: a perfect match

The above characteristics make *Polysulphate* especially suitable for potato crops, as it provides an adequate and balanced supply of four essential nutrients (S, K, Mg and Ca) in one single application. As already indicated, these four nutrients are also released gradually, supplying a continuous fresh source of each to the growing potato crop.

In general, the application of *Polysulphate* to potato crops will result in:

- Higher yields
- Good skin finish
- Improved dry matter
- Increased starch content.

Many sulphur, potassium, magnesium and calcium fertilizers applied at planting or preplanting are ill-suited to the agronomic needs of potatoes. This is because the nutrients they provide can leach out of the root zone long before demand from the plant is at its peak. *Polysulphate*, in contrast, when incorporated preplant or at planting, delivers a natural and sustained release of all four nutrients which closely corresponds to the demand for these from potato plants.

Total potato crop uptake of potassium (tubers and haulm), for example, is around

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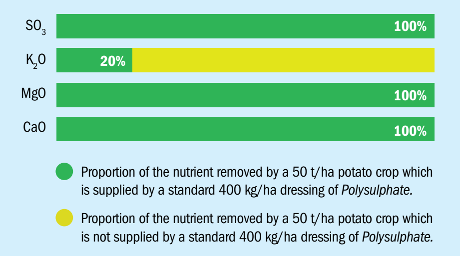
Fig. 1. **Proportions of nutrients supplied to potato crop by *Polysulphate* fertilizer: 400 kg/ha application and 50 t/ha yield**



Source: ICL IAS

Fig. 2: Demonstration plot for seed potato at the Potato Technology Centre, Shamgarh, Karnal, Haryana, India: plant response to farmer's fertilization practice (left) versus Polysulphate at a dose of 250 kg/ha (right).

400 kg/ha K_2O. Maximum uptake occurs 95-120 days after planting, even the daily uptake reaches 6.6 kg K/ha/day.

Quality in potato is more critical than with many other crops as it holds the key to securing the best economic returns. In particular, an adequate supply of K, S, Mg and Ca is needed to ensure quality is delivered – whether that is the desired size, uniformity, colour or shelf life of potatoes. Calcium is particularly crucial for skin quality. Nutritional disorders such as internal brown spot and hollow heart in potatoes, for example, are all caused by low Ca supply to the tubers.

Expected benefits of *Polysulphate*

Polysulphate is especially suitable for potato as it can supply all of the S, Mg and Ca needed by growing potato crops – and can also replace a significant proportion of the potassium removed at harvest (Figure 1).

Potatoes remove very large amounts of potassium at harvest. The proportion not supplied by *Polysulphate* can be applied as MOP (potassium chloride, KCl) which can be ploughed or worked into the soil a month or two before planting. This allows rainfall to move unwanted chloride down through the soil and away from the roots of the potato plant.

The solubility behaviour of *Polysulphate* means the Ca, K, Mg and S it contains are released gradually, providing the potato crop with a continual and fresh source of these nutrients throughout the growing season. This is critical for tuber formation in light, irrigated soils with low nutrient holding capacity. Importantly, fertilization with *Polysulphate* increases profits by improving quality as well as delivering high yields.

Making a world of difference

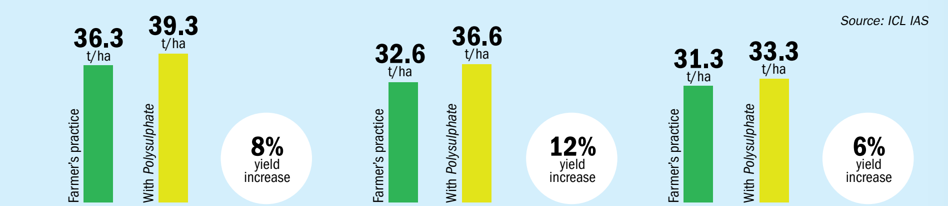
In our global trials, potato crops have shown a very good response to *Polysulphate* – in terms of yield and/or quality. As a consequence, farmers are now regularly including *Polysulphate* in their fertilization schedules. Crop experiments in Brazil, China, France, Germany, India (see Figure 2), Israel, the Netherlands, Peru, Sweden and the UK have all shown positive results.

For example, in a trial on dark volcanic soil (andisol) in Colombia, *Polysulphate* increased total potato yield by up to 27 percent compared to the control. The additional K, Ca, Mg and S supplied by *Polysulphate* in this trial also improved tuber size by up to 35 percent.

Similarly, in a trial in Peru, *Polysulphate* increased total yield by 7-12 percent, compared to the control, and improved tuber size by 5-13 percent.

Fig. 3: **Results of demonstration plots in Gujarat, India: *Polysulphate* delivered yield increases for all three potato varieties at different locations**

Source: ICL IAS



Variety:	Lady Rosetta (LR)	Variety:	Lady Rosetta (LR)	Variety:	Lokar
Farmer:	Dharmendra Kumar Kalidas Patel	Farmer:	Dhavlbhai Bhemjibhai Patel	Farmer:	Jasbhai Shankarbhai Patel
Village:	Navi Shinol	Village:	Poshina	Village:	Poshina
Tehsil:	Dhansura	Tehsil:	Idar	Tehsil:	Idar
District:	Aravalli	District:	Sabrkantha	District:	Sabrkantha
State:	Gujarat	State:	Gujarat	State:	Gujarat

The use of *Polysulphate* in a trial in Wisconsin in the United States achieved a 15 percent increase in marketable yield, versus the conventional grower practice of MOP plus gypsum.

Demonstration plots in Gujarat State, India, showed 6-12 percent yield increases with *Polysulphate*, as compared to the farmer's practice, depending on the potato crop variety and location (Figure 3).

Superior potato quality

Polysulphate has delivered consistent improvements in yield, specific gravity and dry matter while reducing hollow heart in potatoes, as shown by a US trial with the University of Minnesota (Figure 4).

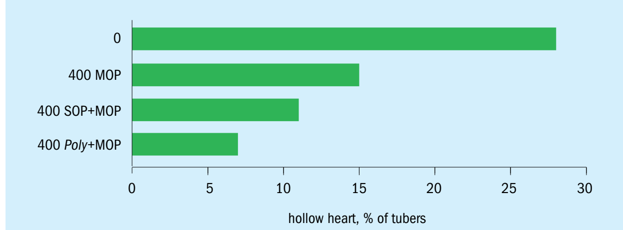
In addition to the above harvest improvements – which are clearly of direct benefit to growers – *Polysulphate* improves fry colour by reducing sucrose levels. A lighter fry colour is a desirable quality characteristic as it is directly linked to lower acrylamide formation during frying. Different potato varieties have all shown less sucrose and acrylamide levels when *Polysulphate* was applied to the crop, based on trials conducted by ICL in the UK. This results in lower penalties from potato processors and provides consumers with a healthier product.

Nutrient knowledge delivers crop benefits

A *Polysulphate* application rate of 400-700 kg/ha is generally suitable for potato and other vegetable crops. Straight *Polysulphate* can be incorporated into the seedbed before planting, or instead applied as a constituent of a fertilizer blend at planting.

This article illustrates how *Polysulphate*, as a fertilization option, is becoming key to high quality, sustainable potato farming around the world. In general, its application to potato crops will result in higher yields, good skin finish, improved dry matter and increased nitrogen use efficiency.

Fig. 4: **Hollow heart incidence in Russet Burbank potato tubers. Results obtained at the Sand Plain Research Farm in Becker, Minnesota, in 2018, as part an evaluation of *Polysulphate* as a K and S source for potatoes.**



Source: University of Minnesota (2018)

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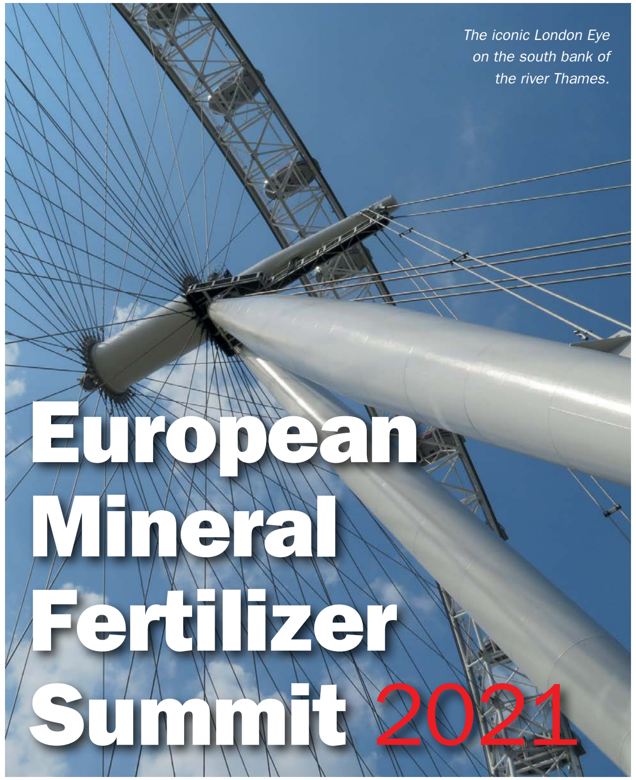

The iconic London Eye on the south bank of the river Thames.

PHOTO: BCINSIGHT

European Mineral Fertilizer Summit 2021

ACI will convene the 5th European Mineral Fertilizer Summit in London on 1-2 December 2021. *Fertilizer International* is proud to be a partner for this year's event.

ACI's 5th European Mineral Fertilizer Summit will take place in London on 1-2 December 2021. As in previous years, this two-day event will provide an invaluable forum for networking with a diverse range of attendees – including manufacturers, suppliers, distributors, academia, NGOs and regulators.

The Summit also features a packed programme of presentations (see below) designed to keep you up-to-date and well-informed about new developments. On both days, presentations by an impressive array of leading industry experts will provide you with all the latest insights and market intelligence. These will emphasise:

- The latest projects
- Innovative specialty products
- New production technologies and operational best practices.

The European Mineral Fertilizer Summit is an established, successful conference already in its fifth year. Past events, for example, have featured expert presentations from Yara International, ICL Fertilizers, K+S, European regulators and many others. This year's event promises to be no different.

The overall purpose of the 2021 Summit is to provide delegates with a sustainability roadmap for the mineral fertilizers industry. The conference, by featuring recent project success stories and showcasing new technologies, will be a ground-breaking, vanguard event.

Who will attend?

- Fertilizer end-users & major European farmers
- Key representatives from leading farming associations
- Agricultural distribution & logistics companies
- Commodity & specialty fertilizer producers
- Fertilizer feedstock & raw material suppliers
- Fertilizer trading companies
- Investors
- Policymakers
- Expert consultants

Opportunities to meet your target audience

The event provides an opportunity to showcase your technologies and demonstrate your latest products and services to the industry. Through branding and networking at the conference, companies can gain direct access to a senior level audience and enjoy an increased level of visibility and exposure. This will allow you to attract new business and forge lasting commercial relationships.

Conference programme – highlights

Eoin Lowry, Head of Agri, Bank of Ireland, will open the conference on the morning of Wednesday 1st December with a keynote address on the *Dynamics driving the future demand for fertilizers, and an overall market outlook.* **Dr Maarten Staal**, BASF's Team Leader for N-Management Technical Sales, will explain *How stabilizers reduce greenhouse gases (GHGs) in the field and improve crop yield* in his presentation after lunch on Wednesday. A presentation later that afternoon will look at *Other non-fertilizer uses for ammonia* – including the emerging zero-carbon maritime fuels market. Wednesday will then be rounded off with a lively panel discussion on *Ensuring the downstream market for fertilizers is sustainable.*

Twelve further presentations will also feature over the two-day event as part of the following six thematic sessions:

- Promising new technology in mineral fertilizers
- Moving towards a circular economy in the production of fertilizers
- Issues and opportunities in logistics and the transportation of fertilizer
- Opportunities driven by new regulation – and avoiding the negative impacts of political instability
- Targeting mineral fertilizer to improve its efficiency
- Growth opportunities in the market for non-NPK components of fertilizers. ■

November-December 2021

phosphates & potash **INSIGHT**

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Potash project listing 2021

Fertilizer International presents a global round-up of current potash projects.

Plant/project	Type	Company	EPC/EPCM contractor(s)	Equipment/technology	Location	Product	Capacity '000 t	Status	Start-up date
AUSTRALIA									
Beyondie	G, LBE	Kalium Lakes	DRA Global	Ebner/K-UTEC/Köppern	Western Australia	SOP	90	C	2021
Lake Way**	G, LBE	Salt Lakes Potash			Western Australia	SOP	245	P	N/A
Lake Wells	G, LBE	Australian Potash			Western Australia	SOP	170	FS	2023
Mardie	G, SW	BCI Minerals			Western Australia	SOP	140	FS	2025
BELARUS									
Petrikov	G, CM	Belaruskali			Gomel	MOP	1,500	UC	2021
Nezhinsky GOK	G, CM	Slavkaliy	China State Enginerring Corp./ Deilmann-Haniel	Herrenknecht Shaft Boring Roadheader (SBR) system	Lyuban	MOP	2,000	UC	2024
Soligorsk I+II+III	B, CM	Belaruskali			Soligorsk	MOP	1,000	UC	2021
BRAZIL									
Autazes		Brazil Potash	CITIC Construction		Amazonas	MOP	2,400	FS	N/A
Cerrado Verde	G*, CM	Verde AgriTech			Minas Gerais	SG	1,200	UC	2022
CANADA									
Bethune	G*, SM	K+S Canada			Saskatchewan	MOP	500	UC	2020/22
Bethune	G*, SM	K+S Canada			Saskatchewan	MOP	300	UC	2025
Esterhazy K3	B, CM	Mosaic	Hatch/AMC	DCM Group	Saskatchewan	MOP	1,800	UC	2024
Jansen	G, CM	BHP	DMC Mining	Herrenknecht Shaft Boring Roadheader (SBR) system	Saskatchewan	MOP	4,350	UC	2027
Milestone	G, SM	Western Potash	Artisan Consulting/AKITA Drilling		Saskatchewan	MOP	146	UC	N/A
Southey project	G, SM	Yancoal			Saskatchewan	MOP	2,800	P	N/A
Tugaske		Gensource/Helm			Saskatchewan	MOP	250	FS, P	2024
Wynyard	G, SM	Karnalyte Resources/GSFC	Amec FW (Wood)		Saskatchewan	MOP	625	FS, P	N/A
ERITREA									
Colluli	G, CM	Colluli Mining Share Co. (CMSC)	DRA Global		Danakil Depression	SOP	472	FS, P	2023
ETHIOPIA									
Danakil Potash	G	Circum Minerals			Danakil	MOP/SOP	2,000/750	FS, P	N/A
Yara Dallol	G	Yara/Liberty Metals & Mining/XLR Capital	SNC-Lavalin		Afar	SOP	600	FS, P	N/A
ISRAEL									
Dead Sea Works	B, LBE	ICL			Dead Sea	MOP	200	UC	2022
JORDAN									
Safi	B, LBE	Arab Potash Co.			Dead Sea	MOP	200	UC	2022
LAOS									
Ganmeng	G, CM	Lao Kaiyaun			Ganmeng	MOP	500	UC	2023
Ganmeng	G, CM	Sino-Agri			Ganmeng	MOP	800	UC	2021
MOROCCO									
Khemisset	G, CM	Emmerson			Khemisset	MOP	735	FS, P	N/A
PERU									
SalSud**	G, LBE	Salmuras Sudamericanas			Sechura desert	SOP	100	P	N/A
RUSSIA									
Solikamsk III	B, CM	Uralkali			Perm	MOP	500	UC	2021
Solikamsk II	B, CM	Uralkali			Perm	MOP	900	UC	2024
Talitsky	G, CM	Acron (Verkhnekamsk Potash Co.)			Perm	MOP	2,000	UC	2025
Volgakaliy I	G, CM	Eurochem			Volgograd	MOP	2,300	C	2020
Usolskiy II	G*, CM	Eurochem			Perm	MOP	1,400	UC	2024
Ust Yayvinsky	G, CM	Uralkali			Perm	MOP	2,000	UC	2022
SPAIN									
Muga	G, CM	Highfield Resources/Geoalcali			Navarra & Aragón	MOP	1,100	FS, P	N/A
UK									
Woodmsith Mine	G, CM	Anglo American	DMC Mining/STRABAG AG/ Jacobs	Herrenknecht Shaft Boring Roadheader (SBR) system	North Yorkshire	Polyhalite	10,000	UC	Under review
US									
Sevier Playa**	G, LBE	Cystal Peak Minerals			Utah	SOP	27.5	FS, P	N/A

NOTES:
* *Ramp-up/expansion* ** *Project on hold/under review*
- Greenfield projects (G): generally, these must have reached the detailed/bankable feasibility study (FS) stage for inclusion.
- Brownfield expansions (B): capacity indicates incremental additions, not total capacity.

PROJECT TYPE:
G Greenfield
B Brownfield expansion
CM Conventional mine
SM Solution mine
LBE Lake brine extraction
SW Seawater extraction

PRODUCT:
MOP Muriate of potash, KCl
SOP Sulphate of potash, K_2SO_4
SG Super Greensand, glauconite

STATUS:
N/A Not available or provided

PROJECT STAGE:
S Scoping
FS Feasibility study
P Permitted
UC Under construction
C Completed/commissioned

BHP

BHP greenlights Jansen potash mine

BHP has finally given the go ahead for stage one of its Jansen potash mine project in Saskatchewan, Canada. The delayed final investment decision, made on 17th August, commits the Australian mining giant to a further $5.7 billion investment to bring the project into production.

The Jansen project is located 140 kilometres east of Saskatoon, Saskatchewan, and is BHP's most advanced under-development project.

The 4.35 million t/a capacity Jansen mine is now expected to produce its first potash ore in 2027, following a six-year construction phase. The mine will then take a further two years to ramp-up to full capacity.

BHP expects stage one of the Jansen mine (Jansen S1) to generate an internal rate of return (IRR) of 12-14 percent – equivalent to a payback period of around seven years – and operate at a healthy earnings (EBITDA) margin of around 70 percent.

"Jansen is located in the world's best potash basin and is expected to operate for up to 100 years. Potash provides BHP with increased leverage to key global megatrends, including rising population, changing diets, decarbonisation and improving environmental stewardship," BHP said in a statement.

Mike Henry, BHP's CEO, said Jansen would help the company grow its portfolio of large, low cost and expandable world class assets.

"This is an important milestone for BHP and an investment in a new commodity that we believe will create value for shareholders for generations," Mr Henry said. "In addition to its merits as a standalone project, Jansen also brings with it a series of high returning growth options in an attractive investment jurisdiction."

He added: "Jansen is designed with a focus on sustainability, including being designed for low greenhouse gas emissions and low water consumption."

The extra $5.7 billion investment in Jansen S1 covers the design, engineering and construction of a complete underground potash mine and all of its associated surface infrastructure. This includes a processing plant, a product storage building, and a continuous automated rail loading system. Jansen's potash product will be shipped to export markets through Westshore in Delta, British Columbia, with the project's new funding also covering the necessary port infrastructure.


PHOTO: BHP

The Jansen project is located 140 kilometres east of Saskatoon, Saskatchewan, and is BHP's most advanced under-development project.

BHP said Jansen S1 is timed to arrive at an opportune moment for new potash supply: "We anticipate that demand growth will progressively absorb the excess capacity currently present in the industry, with opportunity for new supply expected by the late 2020s or early 2030s. That is broadly aligned with the expected timing of first production from Jansen."

> **"Jansen is located in the world's best potash basin and is expected to operate for up to 100 years.**

BHP predicts that Jansen will operate competitively, being positioned in the first quartile of the industry's cost curve, especially given that it expects long-term potash prices to be set by Canadian solution mines. These tend to have higher operating and sustaining capital costs than conventional mines like Jansen, as well as consuming more energy and water.

BHP has already invested $4.5 billion of capital in the Jansen project to date. This includes a $2.97 billion investment in shaft construction and associated infrastructure, plus the funding of engineering and procurement activities, and preparatory work on underground infrastructure.

BHP acknowledged that the full project would yield a much lower IRR if its investment to date was included. "This resulted in a significant initial outlay and… our approach would be different if considering the project again today," the company said.

The construction of Jansen's two shafts is 93 percent complete currently, with both shafts and associated infrastructure due to be finished sometime next year. BHP estimates that around half of all the engineering required for Jansen S1 has now been completed, significantly de-risking the project.

Following a fresh valuation of its potash asset base, and a new calculation of the value of its investments in Jansen to date, BHP included an impairment charge of $1.3 billion ($2.1 billion after tax) against its potash assets in its latest financial results.

The Jansen S1 mine will convert approximately 20 percent of BHP's 5.23 billion tonnes of measured and indicated resources into potash ore reserves. The mine's earnings potential is based on average potash price assumptions for the decade 2027-2037 supplied by CRU ($341/t) and Argus ($292/t). Sustaining capital for Jansen Stage 1 is expected to be approximately $15/t, plus or minus 20 percent for any given year.

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ACRON GROUP

Acron triples Talitsky potash project investment

Acron Group is ramping up investment and speeding up construction at its Talitsky potash mine project in Russia's Perm Krai region.

In a major step change, the company is more than tripling its capital investment in the project during 2021 and 2022, raising this from $60 million to $222 million. The company has also brought forward first production at the two million tonne capacity potash mine to 2025.

"Shafts are currently being reinforced and finished, construction of a motorway is near completion, and construction has started on the Ural 220/10/6 kV main step-down substation," Acron said in a statement on 16th August.

Acron also revealed that it is currently tendering for equipment suppliers and contractors to fit-out the Talitsky mine, its surface complex, and external infrastructure. The project has also secured a package of Russian government support due to its positive impact on the regional economy.

Alexander Popov, Acron's chairman, said: "In the current circumstances, we believe it is possible to accelerate construction to obtain the first batch of the product in 2025. Prior to the acute phase of the Covid-19 pandemic, we managed to dramatically improve the project's risk profile by finalising the sinking of the shafts. Now, we can conduct construction operations both underground and on the surface at the same time.

> "The project has also secured a package of Russian government support due to its positive impact on the regional economy.

"The project's budget has been clarified. Remaining investments are estimated at $1.3 billion. Of this amount, approximately $700 million will be spent before the first batch of potash is produced. All of the project's engineering and design solutions provide for further expansion of the mine's capacity from 2.0 million to 2.6 million tonnes per annum of potash."

Famako Anlagenexport GmbH, with Ebner as subcontractor, secured the major engineering contract for the project. This encompasses project design and the manufacturing, delivery and start-up of a large-scale crystallisation plant (*Fertilizer International* 501, p52). ■

OTHER PROJECTS

Kalium Lakes produces its first SOP batch

The Beyondie project produced its first batch of SOP in early October during commissioning, developer Kalium Lakes Limited (KLL) has announced. This makes Kalium Australia's first SOP producer, the company said in an Australian stock exchange (ASX) release.

The 90,000-tonne capacity SOP project is located in the remote Pilbara region of Western Australia, about 1,400 kilometres north of Perth. The project reached financial close at the end of 2019. This financing included AUD 102 million of senior debt funding from KfW IPEX-Bank, with approximately half of this amount supported by a guarantee from Euler Hermes, the German government's export credit agency. The company recently raised an additional AUD 50 million in capital to expand production output to 120,000 t/a.

Rudolph van Niekerk KLL's CEO, said: "We are exceptionally pleased with the outcome of the capital raising. This is a very exciting time for Kalium Lakes especially having regard to the production of first SOP and subsequent ramp-up to 90,000 t/a production expected to be achieved by March 2022. "

Project commissioning entered its final stages in November. The performance of the SOP purification plant is said to be steadily improving, with some stages already running at or above nameplate capacity. Construction of the compaction plant is also nearly complete with contractor DRA due to finish work on this before the end of November. Production expertise, equipment and technology for the project is being provided by Ebner, K-UTEC and Koeppern (*Fertilizer International* 501, p52).

Major equipment purchase for Muga potash project

Highfield Resources has signed a contract with Weir Minerals to supply processing plant equipment.

The Australian developer is purchasing the items for its flagship Muga potash project in Northern Spain. This under-development project has an annual production target of 540,000 tonnes of muriate of potash (MOP) under current plans, with the potential to double output over the longer-term. Highfield plans to access international markets by shipping potash through the Port of Pasajes, San Sebastian, 150 kilometres to the west of the proposed mine. Production costs of $91/t (cost to port) are anticipated.

Weir Minerals is supplying the Muga project with both primary and secondary concentrate screens. These will be used for size separation during crushing, grinding and desliming. Hydrocyclones supplied by Weir will also be used to remove fine particles from the froth flotation feed (desliming).

Highfield Resources CEO, Ignacio Salazar, said: "The signing of this supply contract with Weir Minerals is key to ensure that we are ready for construction. This is another important milestone for Highfield and continues to highlight the progress and commitment of the company to the efficient construction of Muga."

The purchase contracts for these long-lead equipment items, announced in late September, followed a successful AUD18.1 million ($13.5 million) capital raise by the company. Highfield said it expected to complete the purchase of all remaining items for the processing plant (cross-flow separators, dryers, thickeners and flotation columns) "in the next few weeks". Any remaining equipment, mainly needed for mining, will be acquired prior to the start of operations, according to the company.

Having been granted a mining concession in July, Highfield is currently focussed on moving Muga to the construction phase. The project received its 'DIA' (Declaración de Impacto Ambiental) environmental permit – another major milestone – from the Spanish government in June 2019. Highfield says it is working closely with advisors Endeavour Financial on raising finance for the project. It is also negotiating a construction agreement and project implementation plan with preferred contractor Acciona. ■

High-Purity SOP production using Veolia technology

Veolia's *HPD®* crystallisation technology is capable of manufacturing high-quality water-soluble potassium sulphate (SOP, sulphate of potash, K_2SO_4) using a range of different feedstocks. These can vary in quality and include sodium sulphate or other natural brines such as polyhalite, schoenite and even kainite.

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

World class R&D ensures project success

In the United States, Veolia's state-of-the-art evaporation and crystallisation R&D facility, outside Chicago, offers a wide array of evaporators, crystallisers and ancillary equipment. These unique capabilities can be used to design, test and validate process flowsheets for commercial-stage production. The facility is an excellent tool when it comes to the identifying the most cost-effective process options and potential performance enhancements.

SOP production case studies

Upgrading potassium chloride to SOP: Importing chloride-free fertilizer for crop production can be prohibitively costly. To make SOP more affordable and locally available in Turkey, Turkish-based Alkim Alkali Kimya A.S. (Alkim), one of the largest sodium sulphate producers in the world, decided to invest in its Koralkim facility to produce up to 50,000 t/a of soluble-grade SOP.

Alkim awarded Veolia a contract to supply *HPD®* crystallisation technology to produce SOP in crystalline, fully soluble form. The process involves a multi-stage chemical reaction between potassium chloride and brine saturated with sulphate salts from Alkim's existing operation. This takes place inside draft tube baffle crystallisers that promote the growth of highly pure SOP crystals.

Veolia's solution optimises capital investment by also including multiple-effect crystallisers that generate almost 35,000 t/a of food-grade sodium chloride as a by-product.

> "Veolia's SOP production process has enabled Compass Minerals to significantly reduce its water consumption.

Producing SOP from brine: North American crop nutrient and salt producer Compass Minerals needed to expand SOP production at its US operations. Veolia successfully integrated its *HPD® PIC™* crystalliser unit into the existing plant. This converts a brine feed containing schoenite into a high-purity SOP product, marketed by Compass as *Protassium+®*. Veolia simulated the process design and then validated this at its research facility. Veolia's installed process, thanks to more efficient recycling, has enabled Compass to significantly reduce water consumption, relative to the existing SOP plant.

Creating SOP from pulp & paper wastewater: Another production option is to manufacture SOP from the waste streams of pulp and paper mills. In this process, glaserite (a double salt of SOP and sodium sulphate) is initially recovered via a black liquor ash treatment system and then converted into high-quality SOP crystals for fertilizer use. For this and other feedstock options, the crystallisation process holds the key when it comes to controlling the purity and size of the final SOP crystals.

A pulping production plant in Brazil uses a washing process to increase the purity of the pulp. This generates an organic-rich liquor stream that is recovered for energy production. It is necessary, however, to remove chemicals from this liquor to avoid the undesirable build-up of chloride and potassium during the recovery cycle, as these can create corrosion and boiler fouling if left uncontrolled.

Veolia has successfully prevented this fouling and corrosion by treating 650 t/d of precipitator ash from the boiler using proprietary *HPD® ECRP™* (Enhanced Chloride Removal Process) crystallisation technology. The *ECRP™* technology is highly effective at removing undesirable impurities from the client's process. Valuably, it also takes a previously unwanted waste material and turns it into a useful fertilizer product for growing the next crop of trees for pulp production.

SOP for the future

As we move to a more 'circular' economy, companies will increasingly be looking to minimise their waste generation by investing in sustainable processes. This will shift the focus onto proven and successful production technologies that offer a triple win – for the bottom line, the environment and society.

As the above case studies show, forward-looking producers can now seize on higher-margin opportunities in the fast-growing agricultural market by producing specialty products. These can be manufactured from previously unexploited feed stocks, both profitably and sustainably, by incorporating innovative processes such as *HPD®* crystallisation technologies. ■

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Feed phosphates: overview and market update

PHOTO: ECOPHOS

The feed phosphates industry is caught between conflicting trends currently, according to **Alberto Persona** of the Fertecon fertilizer team at IHS Markit. While the long-term demand-side fundamentals look broadly stable, there is still likely to be a fight for market share due to competition from substitute products and the emergence of new projects.

The innovative EcoPhos-owned feed phosphate plant in Dunkirk, France, is scheduled to be decommissioned following the company's bankruptcy in 2020 (see main text).

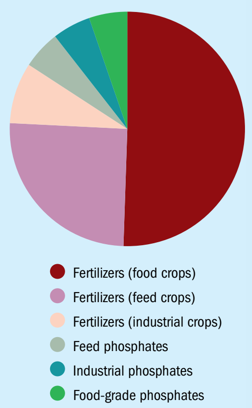
The role of phosphates in animal nutrition

While the world remains baffled by the sharp rise in fertilizer prices, it is easy to forget about some of the less well-known uses of phosphates. And also how interesting these are! Monopotassium phosphate and disodium phosphate, for example, are both ingredients in major Covid-19 vaccines – albeit in total measurable quantities of just a few tonnes, given the low concentration used.

Leaving aside this small industrial segment, a much larger non-fertilizer use – one of great significance to the overall P_2O_5 industry – is that of 'feed phosphates' (Figure 1). More properly known as feed-grade phosphate additives, if we're going to be precise.

Such a distinction, although it may sound pedantic, is actually an important one. All animals (including humans) receive phosphorus naturally in their diet via the consumption of food crops. After all, if plants take up phosphorus from phosphate fertilizer for growth, it is inevitable that both human and animals will end up ingesting some of this. Indeed, the majority of the phosphorus needs of livestock is supplied by plant-based sources.

Fig. 1: **Global P_2O_5 demand by sector**



Source: IHS Markit

The value of feed phosphates

The question then is: why the need for phosphate-based supplements in animal nutrition? The answer to that is not simply about phosphorus – it's about another important element, calcium, too.

Combined, these two elements, P and Ca, are the major constituents of bone structure. Therefore, what is important for proper animal development is both the total availability and the relative proportions of these two vital elements. In animal nutrition science, the latter is typically expressed as the Ca:P ratio.

As a consequence, more than 90 percent of global feed phosphate production focusses on three calcium phosphate products:

- Dicalcium phosphate (DCP)
- Monocalcium phosphate (MCP)
- Monodicalcium phosphate (MDCP).

Clearly, a traditional and fully plant-based diet would ensure sufficient P and Ca availability. Livestock has, after all, been farmed for centuries without the need for feed additives. However, the commercial pressures faced by modern, large-scale and intensive livestock farming are very different. The demands of this sector have ensured that feed additives do now have a place in the market. These include the need for rapid bone development and therefore faster weight gain. Thinking with a fertilizer mindset, this is the equivalent of supplying nutrients for higher crop yields.

Identifying the 'optimal' Ca:P ratio is, however, a far from easy task. This depends on:

- The species in question, even the specific breed
- Their stage of development
- Their productive purpose
- Even climate conditions.

Breeding animals (e.g., egg-laying chickens, sows and dairy cows) generally have higher calcium phosphate requirements. Younger livestock also benefit more from additives, versus older herd members, as this helps to optimise bone growth during their early development stage. In different climates (e.g., Northern Europe versus Southern Asia), even the same animal breed will biologically process additives at different speeds.

The demand picture is even more complicated. That's because we need to recognise that 'digestible' phosphorus – i.e., the amount of P absorbed during the digestion process – is what's required and valued by the feed market, not total phosphorus.

While plant-based phosphorus intake may still account for a significant proportion of gross phosphorus intake of livestock, much of this is excreted. The proportion lost in this way will vary, due to the parameters discussed above. But a reasonable ballpark estimate is that around 70 percent of phosphorus intake will be absorbed by livestock while 30 percent is excreted – hence the importance of manure as a fertilizer.

The value of mineral supplements such as feed-grade phosphates, in contrast, is that they are mostly digestible. This is particularly important when dividing demand by species and their different abilities to absorb phosphorus. Ruminants (e.g., cows, sheep, deer etc.) process food first by letting it ferment in the rumen, an additional stomach. This unlocks dietary phosphorus by converting it into a more digestible form. Monogastric animals (e.g., poultry and swine) do not have this ability – meaning the proportion of the phosphorus intake they absorb is correspondingly lower. (These difference in animal abilities to absorb phosphorus are reflected in the relative P-richness of manure flows – possibly a topic for a future article!)

What drives demand

In general, therefore, monogastric animals tend to benefit more from the addition of feed-grade phosphate additives in their diet, as this effectively supplements their less efficient digestive systems. This is, however, an oversimplification of what is in practice a very sophisticated and precise science. Nevertheless, it does provide a good overall understanding of what drives the demand-side for feed-grade phosphates (Figure 2).

Industry practices can also affect demand patterns. Intensive livestock farming permits better control of animal diets compared to free-range, low-load-rate grazing. This explains the higher adoption rates of phosphate supplements in areas such as North America and Western Europe compared to typically less intensive livestock regions such as Latin America.

Cultural differences and local preferences can also alter demand patterns. Anyone who has ever purchased eggs from a supermarket in China or Japan may have noticed that eggshells in both countries tend to be much thicker. This has arisen from a specific requirement in large-scale food distribution – given that harder eggs are less prone to breakage during long-distance transport – which in turn has resulted in a slight preference for higher-calcium feed additives, e.g. tricalcium phosphate (TCP).

In short, demand for feed-grade phosphates stems from the sophisticated science of animal nutrition. Despite this, there are some clear messages:

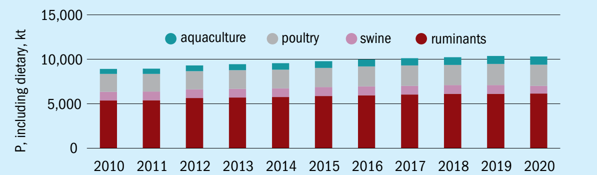
- Animals need feed-grade phosphate additives to balance the Ca:P ratio in their diets
- Commercial livestock farming favours greater adoption of phosphate additives.

Market size and demand distribution

Global demand for feed-grade phosphate additives is estimated at around seven million product tonnes– equivalent to about three million tonnes on a P_2O_5 basis. This represents about a five percent share of overall phosphorus demand.

However, to repeat an earlier point, we should not forget the large proportion of crops dedicated to feeding livestock. Importantly, around 30-35 percent of the

Fig. 2: **Overall demand for digestible phosphorus by animal class**



Source: IHS Markit

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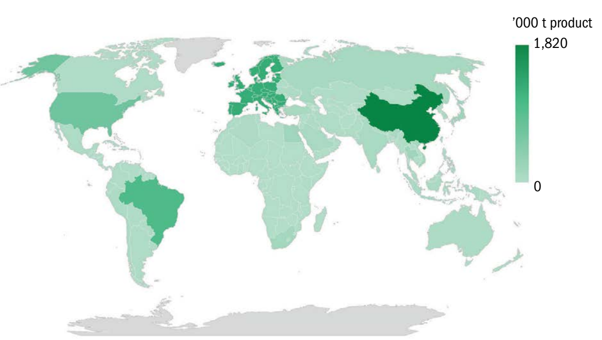
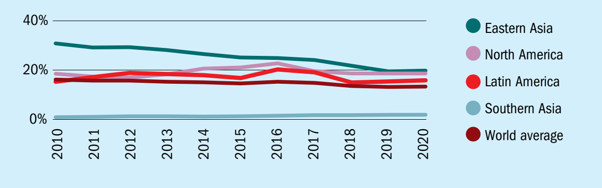
Fig. 3: **Geographic pattern of feed phosphate demand, 2020, '000 t product**



Source: IHS Markit. Microsoft screenshot reprinted with permission.

Fig. 4: **Trends in feed phosphate demand as a percentage of overall digestible P need, 2010-2020**



Source: IHS Markit

world's crop output is used as animal feed, according to recent IHS Markit estimates. We therefore need to factor in another 15 million tonnes P_2O_5 of phosphorus present in feed crops, based on total phosphate fertilizer demand globally of around 48 million tonnes P_2O_5. When combined with feed-grade phosphate additives, this brings the total phosphate industry exposure to the livestock sector to some 18 million tonnes P_2O_5 – a market share of just below 30 percent.

Perhaps unsurprisingly, the geography of feed phosphate demand typically tracks the size of animal stocks – albeit subject to local differences in feed additive requirement and usage – a pattern illustrated by Figure 3. (Please note that we have opted to show all European countries as a single bloc in Figure 3 – country-specific demand would be much lower.)

Another interesting take is to consider geographic differences in feed phosphate demand, but as a proportion of the total requirement for digestible phosphorus (Figure 4). This reveals significant regional differences. While the world average for feed phosphate demand hovers at around 15 percent of total requirement, some regions (e.g., Eastern Asia) feature much higher percentages, while others (e.g., Southern Asia) remain far below the global level.

An important cultural factor – the religious value attached to cows in India – explains the reason for Southern Asia's relatively low share (10-20%). Yes, the country's overall herd size is one of the largest globally, yet the vast majority of these animals are not fed according to industrial best-practice.

More of interest, perhaps, is the seemingly paradoxical declining feed phosphate trend in regions such as Eastern Asia, and Latin America to some extent, as these are both areas in which animal stocks have actually been growing. The reason for this decrease is the emergence of competing products – phytase in particular.

Competing products

Phytase is an enzyme which converts dietary phosphorus into digestible phosphates. This is the same enzyme that underpins the digestive process of ruminants – one which has been successfully isolated and commercialized as an additive to the diet of monogastric animals. Increasingly, the digestibility of plant-available phytic phosphates (the main form in cereals and oilseeds) has reduced the need for dietary supplements.

While phytase can indeed win market share against feed-grade phosphate additives (as shown by Figure 4), it is unlikely to displace them completely. This is because, as explained above, part of the importance of feed phosphates is that, as well as providing additional Ca and P, they valuably also skew the Ca:P ratio towards optimal levels. Something that is not achievable through dietary phosphorus alone.

Other competing products in the feed marketplace are fermented grains. These include:

- **DDGS (distiller's dried grains with solubles)**: a by-product of grain-based bioethanol production and therefore a notable factor in the US market.
- **Brewer's grains**: a somewhat less discussed by-product of alcoholic beverages manufacture that is significant in many areas of Europe.

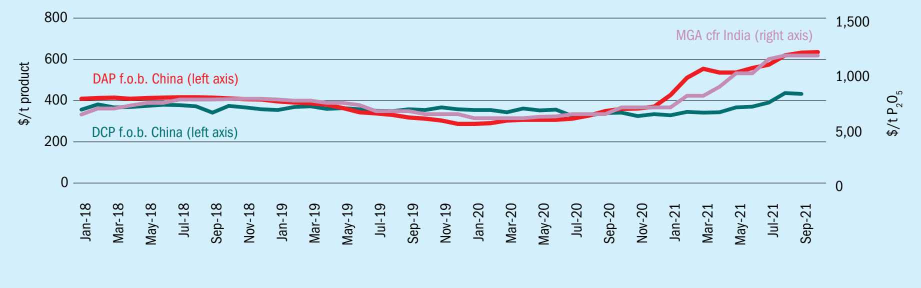
As their names suggest, these grains have been industrially fermented in a digestion stage that is necessary for both the above brewing processes. This has the effect of increasing the bioavailability of the phosphorus components in the process residues. Again, as with phytase, the adoption of fermented grains is subject to limits. Yet competition between alternative products options clearly can affect the overall choices made by feed producers across the full portfolio.

Demand prospects on the bright side

Another question arises when discussing the significance of competing products: will feed phosphate demand grow, flatline, or even decline?

Well, the latest estimates from the Fertecon team at IHS Markit suggest an overall positive demand outlook. Growth looks likely in those markets that are currently consuming feed phosphates at a sub-optimal level. This growth, in turn, should more than offset market pressures from substitute products.

Fig. 5: **Feed phosphate price rises have failed to match those of diammonium phosphate and merchant-grade phosphoric acid (MGA)**



Source: IHS Markit

This forecast is, however, subject to significant downside risks, as follows:

- A sharper than expected dietary shift away from meat consumption towards plant-based foods could reduce the overall size of the livestock industry. This could see P_2O_5 use globally move away from feed-grade additives, possibly towards fertilizers.
- Bioethanol production incentives could increase further the availability of DDGS, e.g. in China.
- The growth in organic-certified farming could also reduce demand for additive products classed as ineligible by organic regulations.

Nonetheless, we still expect overall demand growth in the feed phosphates market, spurred on by a rising population and a still-growing appetite for animal protein in the diets of people in emerging economies – even if the rate of growth is slightly less than proportional to the expected growth in animal stocks. On top of this, we also expect to see a good boost in demand for aquaculture-grade products from the growing adoption of fish farming and commercial algae production. Although a niche segment in the feed industry, this is of growing significance.

New product development and technologies will also have a role to play in future. Over the past few years, developments in feed-grade magnesium phosphate production (in Europe, for example) have been supported by the lack of magnesium identified in animal diets. Quality control will remain key too. In particular, ensuring consistent quality and control over impurities – most crucially fluorine – will become an increasingly important driver of success, especially in markets where further demand growth will be smaller and competition between suppliers intensifies.

The supply side – projects & costs

Our assessment of the feed industry would not be complete without a look at its supply side. In 2020, the European industry was hit by the bankruptcy of Belgium's EcoPhos – a significant producer and a company heavily involved in developing new production technologies based on hydrochloric acid chemistry. Its production site in Devnya (Bulgaria) has been acquired by local fertilizer company Agropolychim, while both its main production site in Vlaardingen (Netherlands) and its recently built complex in Dunkerque (France) are set to be decommissioned.

Importantly, the R&D efforts of EcoPhos have not been lost. Fellow Belgian company Prayon, a global powerhouse in phosphate processing technology and licensing, has acquired the rights to EcoPhos patents. This could provide further momentum for projects based on the EcoPhos process – for example, a large-scale DCP plant is expected to be commissioned by Evergrow in Egypt in the second-quarter of next year.

Further feed phosphate capacity growth is also expected over the next years in:

- Russia (PhosAgro)
- China (various players, notably Chanhen, Lomon and Anning Jindi)
- Brazil (ex-Yara, now EuroChem)
- Potentially Kazakhstan (EuroChem), although much of the resulting DCP is likely to be dedicated to the production of phosphoric acid using the EcoPhos *Module 4* process.

We expect the scenario of lukewarm demand growth mixed with growing capacity to put pressure on high-cost producers, particularly those reliant on purchasing phosphoric acid. The recent rise in phosphoric acid prices, primarily driven by fertilizer market dynamics, is causing a major headache in Europe, as feed phosphate producers are not always able to transfer higher input costs to their customers by raising prices (Figure 5).

These cost pressures have been compounded by the parallel rise in crop prices, as these add to production costs, even for manufacturers of feed blends who are the main actual buyers of feed-grade phosphate additives. Prices of livestock products (meat, dairy, eggs), meanwhile, have also increased. While this has increased the ability of farmers to pay for their feed needs, the prolonged nature of the price hike for animal nutrition products (including phosphates and crops) is starting to affect margins for distributors and farmers alike. This may well cause a significant degree of demand disruption, adding yet further pressure onto feed phosphate suppliers.

Conclusions

In summary, the feed phosphates industry is caught between conflicting trends currently. While the long-term demand-side fundamentals look broadly stable, there is likely to be a fight for market share due to competition from substitute products and the emergence of new projects. In the meantime, sensible expectations of short-term demand disruption will provide a window of opportunity for industry restructuring.

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New policy approaches to food security and soil health

Apatite phosphate mine in Kirovsk on the Kola Peninsula.

PhosAgro's **Evgeniya Mescherova** and **Boris Levin** explain how new EU and Russian regulations, designed to safeguard the environment and human health, are improving global support for both soil health and food security.

Delivering food safely & sustainably

The much-needed shift to sustainable development is not proceeding fast enough. That was the conclusion of the UN's *Global Chemicals Outlook II* published in 2019. This stated that countries would not achieve the global goal to minimise the adverse impacts of chemicals and waste by 2020. The Outlook, originally mandated by the UN Environment Assembly in 2016, noted that workable solutions exist and called for more ambitious worldwide action by all stakeholders.

Until relatively recently, the role of mineral fertilizers in agriculture was relatively simple and straightforward. The main priority for crop production was to ensure a sufficient supply of food for the world's growing population.

This remains a central objective – with risks to global food security actually increasing in 2020 under the shadow of the Covid-19 pandemic. Indeed, the number of people going hungry in 2020 was 15 percent higher than in 2019, owing to the combined impact of Covid-19 and armed conflicts[1].

Nevertheless, equally pressing priorities have emerged and risen up the policy agenda. In particular, public health goals have shifted in recent years towards establishing effective functioning food systems able to deliver safe and nutritious foods in a sustainable way[1].

There has also been growing awareness that the different forms of contamination in agricultural production, including those arising from fertilizers and pesticides, can have serious environmental and health consequences. Crop additives and inputs that contain harmful contaminants can endanger human health by moving along the food chain, starting from soil and finally ending up in food products.

As the world learns how to live with Covid-19, the global food system is undergoing comprehensive renewal. This is having profound impacts on policies and institutions and prompting major social, business and technological changes in the agricultural sector[2].

Global instruments

Over the past few decades, the international community has launched initiatives and put in place a range of policy measures governing the use of pesticides and fertilizers. A greater awareness of the need for an adequate regulatory framework for soil and crop management has led to the introduction of a number of voluntary policy instruments. These include the *International Code of Conduct on Pesticide Management*, the *International Code of Conduct for the Sustainable Use and Management of Fertilizers* and the *Codex Alimentarius*.

These international instruments have an important role to play in global food security. They also provide a framework for addressing key aspects of agricultural sustainability, nutrient management and the safe use of agrochemicals.

The EU's regulatory framework for food and agriculture

In recent times, EU policymakers have made major efforts to enact legislation that balances the need for increased food production with the need to conserve natural resources and protect human health. As a result, the European Commission has notably formulated several regulations that apply quality schemes to the EU agricultural and food sector.

The bloc's flagship *Green Deal* policy, for example, sets ambitious zero pollution targets to ensure a sustainable EU by 2050. To achieve this, the *Green Deal* incorporates several subsidiary policy initiatives such as the *Chemicals Strategy for Sustainability*, the *Zero Pollution Action Plan*, the *Farm to Fork Strategy* and the *EU Biodiversity Strategy for 2030*. Furthermore, to address health issues related to pollution, the European Health Union has proposed further health measures such as the *Beating Cancer Action Plan*.

EU regulation of cadmium in foodstuffs

Speaking in support of Europe's *Beating Cancer Action Plan*, Stella Kyriakides, the European Commissioner for Health and Food Safety, said: "We know that an unhealthy diet increases the risk of cancer. Today's decision aims to put consumers first by making our food healthier and safer, as we have committed to doing in Europe's Beating Cancer Plan."

This speech was delivered in August 2021. This was the date when the European Commission set new maximum levels on two potentially carcinogenic food contaminants, cadmium and lead, in a range of food products as part of Regulation (EU) 2021/1323[3]. The Commission has applied these new stricter limits to different types of food products, ranging from beverages, such as wine, to foods including fruits, vegetables, cereals and oilseeds. This move has been recognised, at EU level and by member states, as a crucial step for safeguarding European agricultural sustainability and food security.

The Commission implemented these changes based on a European Food Safety Authority (EFSA) scientific report[4] on dietary exposure to cadmium. This report found that, for EU adults, the average dietary exposure to cadmium slightly exceeds the permissible weekly intake, while cadmium exposure for both vegetarians and children could exceed the advised weekly intake by about two-fold.

Furthermore, a more recent study published this year by Public Health France[5] states that cadmium levels in the French population increased in the period from 2006-2007 to 2014-2016 – and are higher than in other European countries or North America. One of the main sources of dietary cadmium was found to be breakfast cereals. Nearly half the French population show cadmium levels higher than that recommended by the French Agency for Food, Environmental and Occupation Health & Safety (ANSES). In an official 2019 study (ESTEBAN), ANSES recommended reducing cadmium exposure to the population, including that derived from mineral and organic phosphate fertilizers.

In 2014, the European Commission also introduced new restrictions on the levels of cadmium in baby foods and chocolate[6].

The EU's *Farm to Fork* strategy

The EU's *Farm to Fork* strategy, part of the *Green Deal* legislative package, aims to ensure the sustainable development of EU food systems. It makes an expicit link between sustainable food production processes and the protection of the environment and public health.

As part of the *Farm to Fork* strategy, the European Commission has set a target for reducing nutrients losses – especially for nitrogen and phosphorus – by at least 50 percent by 2030, while ensuring that there is no deterioration in soil fertility. The Strategy also includes a target to reduce fertilizer use by at least 20 percent by 2030.

In our view, to achieve the above goals, it would make sense to begin by restricting the use of fertilizers with high levels of hazardous contaminants, while simultaneously developing nutrient reduction plans. Such actions would help to reduce contaminants in the soil as well as improve the quality of plant-based food products.

EU's Fertilising Products Regulation

Additionally, European legislators are currently establishing concentration limits for contaminants in mineral and organic fertilizers sold in the EU market. Their introduction is designed to further protect the health of food consumers. Studies have already shown that current levels of contamination in food systems constitute a risk – a risk that may increase if fertilizers containing high levels of toxic contaminants are used.

The EU's Fertilising Products Regulation, adopted in June 2019, introduces common standards for the content of heavy metals in fertilizers for all member states. The Regulation will bring into force a harmonised EU-wide cadmium limit of 60 mg Cd/kg P_2O_5 from the middle of next year.

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Green certification for Russian fertilizer products

PhosAgro recently became the first Russian company to receive certification for its products under new federal legislation (see main article). Following an independent conformity assessment, *Certificate No 1 for fertilizers with improved characteristics* was awarded to the low-cadmium fertilizer products manufactured by this major incumbent Russian producer, currently celebrating its 20th anniversary year.

Also known as the green certificate, *Certificate No 1* demonstrates that the fertilizers produced by PhosAgro – which are currently exported to over 100 countries around the world – are considered safer for the environment and can be used on any type of soil. It also shows that using PhosAgro fertilizers minimises the risk of contaminating soils and crops with toxic elements. Crops grown with these certified fertilizers should therefore also produce safer food products.

It is important to note that the standards introduced by the Russian Federation on the levels of heavy metals and toxic substances in fertilizers are several times stricter than EU standards being introduced next year: in fact, three times lower for cadmium and twice as low for arsenic. The maximum concentration of cadmium, chromium and other heavy allowed in mineral fertilizers in Russia is limited to 20 mg/kg of P_2O_5.

Green certification is a strategic development both for Russian agriculture and for those industries which supply this sector. That's because improving the quality of crops and food produce also requires improvements in agricultural inputs, such as low-cadmium fertilizers and environmentally-safe crop protection products. Improving the characteristics of crops and food produced by conventional agriculture is also in harmony with (and complements) the organic food sector, which also aims to minimise the ecological footprint of its products.

In our view, the new legislative and regulatory conditions now created in Russia will accelerate the production of more environmentally-friendly fertilizers and, consequently, higher quality foodstuffs with improved characteristics.

Several member states, however, have already moved to put in place more stringent national limits on the cadmium content of phosphate fertilizers. In summer 2020, for example, the European Commission formally approved national provisions (derogations) limiting cadmium content in phosphate fertilizers for Hungary (20 mg Cd/kg P_2O_5)[7], Slovakia (20 mg Cd/kg P_2O_5)[8] and Denmark (48 mg Cd/kg P_2O_5)[9]. Furthermore, shortly before the Fertilising Products Regulation was published, Lithuania[10] passed a law introducing a cadmium limit of 40 mg Cd/kg P_2O_5, while Sweden (44 Cd/kg P_2O_5) and Finland (22 mg Cd/kg P_2O_5) retained their previous national limits[11].

These national derogations speak for themselves – the heavy metal content of fertilizers is clearly an issue of concern to both consumers and European lawmakers alike. Because of this, it is likely that reductions in fertilizer contaminants will be actively pursued for the foreseeable future. The expected launch soon of further European policy initiatives, such as the EU's new soil strategy, nutrient management plan and regulation on a sustainable food system, are harbingers of tighter regulation in future. Indeed, EU member states appear to be generally supportive of new initiatives and policies designed to keep arable land and the food supply free of toxic contaminants.

EU green labelling of fertilizers

To inform consumers, the EU is proposing a voluntary labelling system for fertilizers with a cadmium content of less than 20 mg/kg P_2O_5. The label is likely to be green in colour and accompanied by appropriate wording (e.g., low-cadmium content) and a recognisable graphic. By providing additional information, the purpose of this 'green' label is to help consumers make more informed choices about fertilizers when they make their purchasing decisions. Under the guidelines, companies that produce or sell 'ultra-low' cadmium fertilizers will be permitted to use this green label. This will signal to consumers that the risk of cadmium accumulating in soils or entering the food chain is minimal.

The EU-sanctioned green label for low-cadmium fertilizers will offer farmers the choice to promote sustainable agriculture, in keeping with *Green Deal* objectives. In our view, EU farmers should also be incentivised through CAP eco-schemes to reduce the amount of cadmium entering soils via fertilizer application. This would be beneficial by promoting further significant reductions in heavy metals in soil.

Phosphate fertilizers are known to be among the main sources of heavy metals in soil. However, phosphate raw materials have a wide range of heavy metal contents and – consequently – different phosphorus fertilizers will affect the accumulation of heavy metal in soils to varying degrees.

Nevertheless, the intake of cadmium in soils should not exceed 2 g Cd/ha/year, according to a comprehensive environmental risk assessment conducted by ANSES, regardless of the cadmium source. Furthermore, ANSES recommended lowering the levels of cadmium in input sources to 20 mg Cd/kg P_2O_5 when phosphate mineral fertilizers are used.

When combined together, all of the various EU policy measures – including voluntary green labelling, the ban on sales in member states of phosphate fertilizers containing over 60 mg of Cd/kg P_2O_5 and national derogations establishing even lower cadmium limits – should promote soil safety and protect consumer health.

Green transition in Russia

Across the world, there is rising consumer demand for products and services which cause minimal harm to the environment throughout their life cycle. The Russian Federation is one country actively 'greening' various sectors of its economy – including food and agriculture and the industries which supply this sector.

In Russia, a new federal law (*On agricultural products, raw materials and food with improved characteristics*) will come into force on the first of March next year. This law will create a single regulatory framework governing the safety and quality of agricultural and related products. It introduces improved characteristics, certification and conformity criteria for these products, alongside higher raw materials quality requirements.

The improved characteristics certificate (see box) is being introduced in Russia as an indicator of quality and safety. It covers agricultural produce, raw materials and food, and implements environmental standards (both national and interstate) in force in the Russian Federation.

The product certification introduced under this law is expected to raise consumer demand in Russia for 'green' products which comply with the new regulations. Certification requires compliance with a range of quality criteria covering the whole supply chain, including production, storage, transportation and sales.

The law also introduces maximum permissible limits for toxic substances in fertilizers. These limits, by making fertilizers more environmentally-friendly, will help reduce the amounts of pollutants introduced into the food system via crop nutrients. Making this a specific requirement in federal law will ensure that agricultural products are safer – for both the Russian population and for consumers of exported Russian products globally.

Conclusion

Crucially, about 95 percent of the food we eat comes from the soil[12]. Consequently, as the medium in which nearly all crops grow, soils are recognised as the foundation of global agriculture and the world food system. To preserve the quality of food products and the health of the population, our first priority is therefore to safeguard and take care of crop conditions and the cleanliness of arable land. In this article, we provide real world examples of how regulatory action in the EU and Russia, by prioritising the environment and human health, is improving global support for both soil health and food security for future generations.

Authors

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