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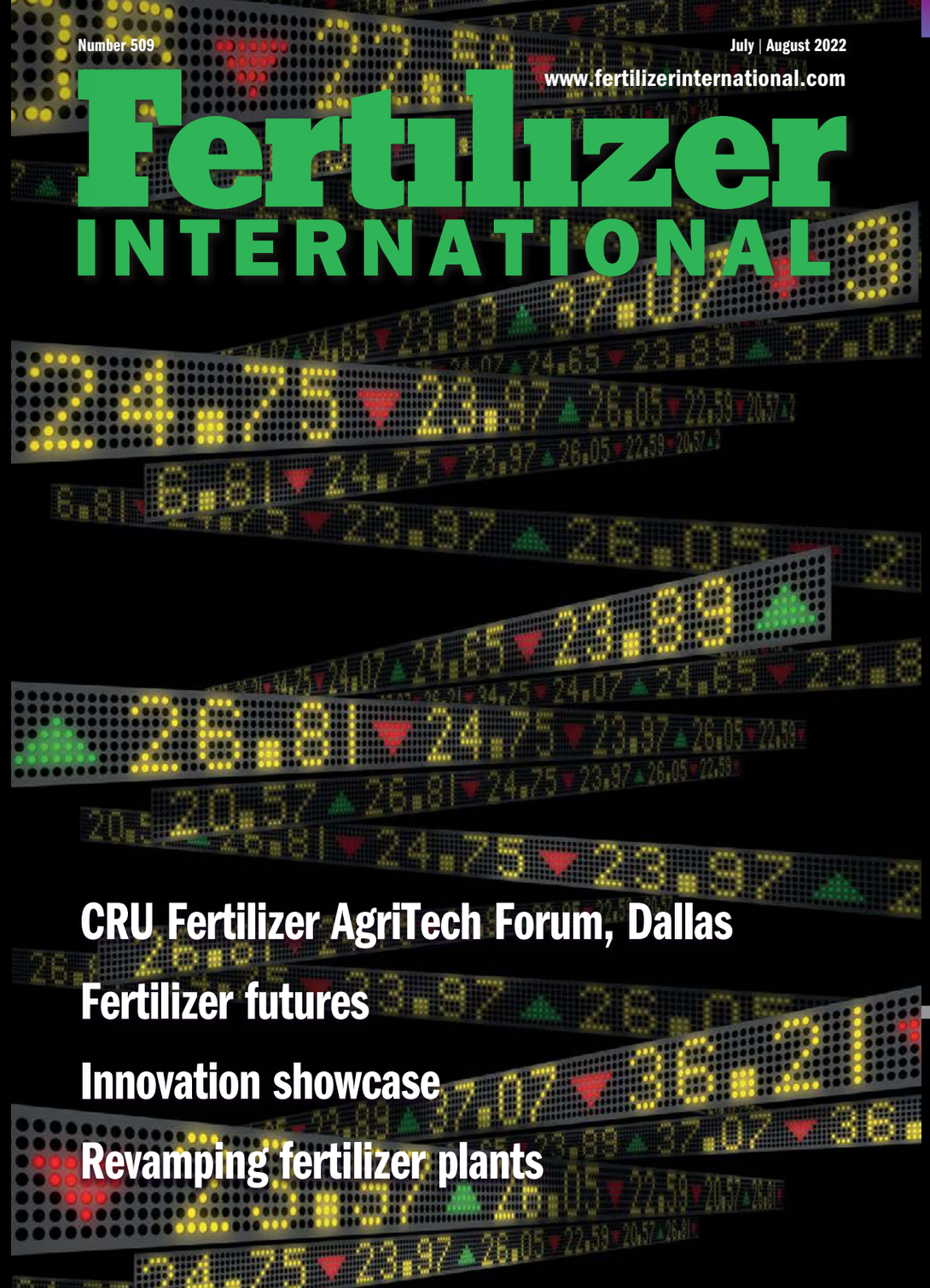

Number 509

July | August 2022

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Fertilizer INTERNATIONAL

CRU Fertilizer AgriTech Forum, Dallas

Fertilizer futures

Innovation showcase

Revamping fertilizer plants

FERTILIZER INTERNATIONAL
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JULY/AUGUST 2022

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PHOSPHATES AND POTASH INSIGHT

REGULARS

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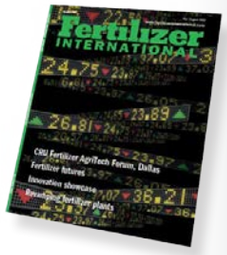
And then there was one



In a major blow to the British fertilizer industry, CF Fertilisers UK announced the closure of its Ince production site in north-west England in June (see p8).

Ince is the UK's largest compound fertilizer producer, operating three NPK+S units. It also manufactures large volumes of ammonium nitrate (AN) for Britain's farmers. At the heart of the Cheshire complex is Ince's long-standing ammonia plant. Unfortunately, high natural gas costs have kept this shuttered since September last year.

The planned closure of Ince ends 50-60 years of ammonia and fertilizer production at the site. Its ammonia plant was originally built and owned by ShellStar (Shell/Armour Star) in 1965 and compound fertilizers have been produced on-site since 1969. Subsequently, Ince has been Dutch-, Finnish-, Norwegian- and latterly US-owned.

The closure will leave Billingham as the UK's sole manufacturing site for ammonia-based fertilizers. CF believes that Billingham is better positioned than Ince as a sustainable UK fertilizer production centre. It says the site has enough capacity to meet all of Britain's forecast demand for AN fertilizer. Billingham is also more efficient than Ince with 10-20 percent lower production costs, according to the company.

The planned closure of Ince is the latest in a series of shutdowns and consolidations that have marked the long decline of the once mighty UK ammonia industry. British production of this basic chemical has a proud history and – under former corporate giant Imperial Chemical Industries (ICI) – the UK was also a leading global centre for innovation in ammonia technology and catalysis.

Notable ICI innovations and breakthroughs include the leading concept ammonia (LCA) and the low-pressure, low-energy ammonia V (AMV) processes, as well as the company's renowned nickel and high-activity cobalt catalysts.

The rise and fall of UK ammonia manufacturing – and the central role of (ICI) – was dissected last year in a fascinating monograph* by Dr Anthony Travis of Jerusalem's Hebrew University. He quotes a typically forthright Sir John Harvey-Jones, ICI's former chairman, from a mid-1980s BBC lecture entitled 'Does industry matter?'.

At that time, Harvey-Jones could boast that ICI was the world's most profitable chemical company, contributing £2 billion a year to the UK economy. He said:

"It is manufacturing industry whose praises I want to sing. It is often suggested that tourism offers salvation. It is equally clear that this cannot be…. if we imagine the UK can get by with a bunch of people in smocks showing tourists around medieval castles we are quite frankly out of our tiny minds."

Yet within 20 years, ICI's name had completely vanished from Britain's business landscape when what remained of the company was sold to Netherlands-based AkzoNobel in 2008.

Large-scale commercial ammonia production began in Billingham in 1924, under ICI's predecessor Brunner, Mond & Co. By the 1960s, when ICI was the world's largest ammonia producer, it operated four other ammonia plants at Heysham, Wilton, Severnside and Immingham. As Dr Travis notes:

"By the 1980s… ICI's engagement in the relevant technologies, including novel high-activity catalysts, and two low-pressure ammonia processes, had an almost mythical provenance, at least among chemical engineers. This, however, has received scant attention from historians of the chemical industry."

At its zenith in the 1980s, ICI operated eight ammonia units in the UK. But this seemingly unassailable position was not to last. With profits from commodities dwindling, the company subsequently sold off its ammonia and nitrogen fertilizer production assets in the 1990s as part of a divestment programme.

CF Industries ultimately gained complete ownership of Billingham and Ince, the UK's two remaining ammonia-based fertilizer production sites, seven years ago. The Illinois-headquartered company renamed the business CF Fertilisers UK in 2015, having bought Yara's 50 percent equity stake in the two operations.

Dr Travis compares the story of the modern chemical industry to the histories of nations in that it reveals a complex tale of landmark – yet often unrecognised – achievements. "A case in point is ammonia production, in which ICI, notwithstanding its disappearance, played a prominent role," Travis writes.

ICI's legacy remains. Its spirit lives on via the continuing success of Britain's Johnson Matthey, for example, which continues to develop acclaimed catalysts.

Billingham also remains an enduring symbol for the global nitrogen industry, still producing ammonia some 98 years after its inception. Here's hoping it remains operative into its centenary year in 2024 and well beyond.

> **"Billingham remains an enduring symbol of the global nitrogen industry, still producing ammonia some 98 years after its inception."**

Simon Inglethorpe, Editor

*Travis, A., 2021. Historiography of chemical industry: technologies and products versus corporate history. *Bull Hist Chem*, 47(1), p50

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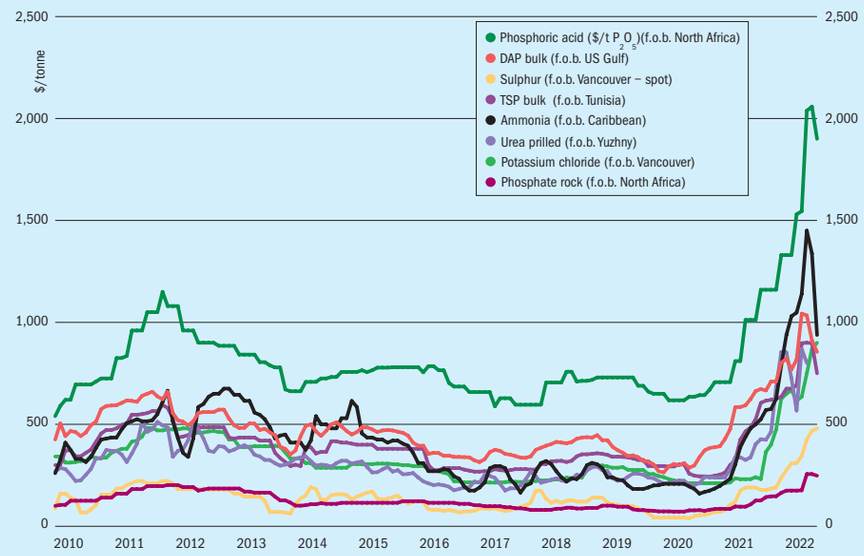
Market Insight

Historical price trends $/tonne



Source: BCInsight

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: Trading generally slowed at the end of June from the frenetic pace earlier in the month. While steady trade continued in Brazil, with around 200,000 tonnes of granular urea changing hands at $640-660/t cfr, activity was more sporadic elsewhere. Southeast Asian markets remain mostly dormant, forcing regional producers to look further afield with sales to Australia and India. The US continues to provide re-export opportunities, as its domestic market seeks to clear inventory after a slow spring, with barge trades having an export cost of around $575-580/t f.o.b. US Gulf.

Key market drivers: Western sanctions are still disrupting Russian export flows and dampening values into certain markets like the US.

Ammonia: a $40/t drop in the Tampa July contract price prompted spot price falls of $25-55/t across key regions at the end of June. The market is witnessing demand destruction in east Asia. Escalating European production costs are, however, limiting price depreciation – and could re-ignite spot demand from European demand hubs in July and August. With the potential for further European production curtailments, the region's producers are continuing to weigh up import availability. Europe's buyers have been making inquiries East of Suez, although no sales to markets west of Suez have been confirmed. Middle East producers, to compete with Caribbean delivery prices to northwest Europe, would need to offer cargoes at $900/t f.o.b., and possibly below this, to secure sales into Morocco.

Key market drivers: The Tampa July contract price between Yara and Mosaic fell $40/t to $960/t cfr, the lowest agreement since November 2021 ($825/t cfr). The risk of European shutdowns also continues. Rises in month-ahead TTF gas prices at the end of June (up more than $3/mn Btu on the week to $43.92/mn Btu) equate to ammonia production costs of nearly $1,600/t – more than $500/t higher than today's delivered price. East Asian spot demand for July, meanwhile, is almost non-existent.

Phosphates: MAP prices in Brazil slipped by as much as $10/t to $1,000-1,020/t cfr at the end of June, with sales of Chinese and Russian material falling within this price range. DAP barges at Nola also fell by $20/st to $780-785/st f.o.b. Prices east of Suez remained stable, buoyed by Bangladesh private-sector awards in late June. The need to satisfy Bangladesh contract commitments are expected to keep Chinese and Jordanian producers busy in coming months.

Elsewhere, Ma'aden sold 25,000 tonnes of DAP to Thailand for July loading. There were no new DAP purchases on the subcontinent, although an Indian buyer did book 25,000 tonnes of Turkish NPS through a trading firm. DAP and MAP prices in Europe were flat and activity was limited to small volumes. West of Suez, traders made DAP sales in Argentina at $1,005-1,010/t cfr.

Market price summary $/tonne – End June 2022

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	885-910	485-540	f.o.b. E. Europe 260-350	f.o.b. US Gulf	853-891	-	-
f.o.b. Yuzhny	Port closed	Port closed	-	f.o.b. N. Africa	1,000-1,085	700-800	1,800-1,950
f.o.b. Middle East	880-970	535-650**	-	cfr India	920-930	-	n.a.*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	850-950	-	cfr US Gulf	200-275	f.o.b. Vancouver	450-500	-
f.o.b. Middle East	850-950	-	-	-	f.o.b. Arab Gulf	428-500	-
f.o.b. Western Europe	-	925-1,000	-	-	cfr N. Africa	440-520	-
f.o.b. Baltic	800-945	-	-	-	cfr India	463-535+	-

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

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Key market drivers: Market participants are awaiting a possible change to China's export policies from July – and assessing their options – although there has been no official confirmation to date.

Potash: Prices were flat at the end of June, reflecting the seasonal lull in key markets. An overall bearish sentiment prevails as the market awaits the return of Brazil. How strong forthcoming Brazilian buying will be is questionable, given that importers purchased heavily earlier this year and stocks remain high. These factors helped push down granular MOP prices in Brazil to $1,000-1,075/t cfr at the end of June.

Key market drivers: Brazilian importers are expected to return to the market later than anticipated and may purchase less than usual. Granular MOP inventories continue to build in the country, with over 500,000 tonnes of product being lined up for port unloading in July, while downstream demand remains lacklustre. New shipments to the US are likely to signal that Russian MOP is becoming more acceptable in the market. Two potash vessels from Russia set sail for the US in late June, the country's first shipments to North America since the start of the Russia-Ukraine conflict in February.

NPKs: Turkish NPS has been sold to India for the first time. A trader sold a 25,000-30,000 tonne lot of Turkish 20-20-0+13S to a buyer in India at around $700/t cfr duty unpaid. In Africa, the Smallholder Farmers Fertilizer Revolving Fund of Malawi (SFFRFM) has received offers from four companies for its 110,000 tonne NPK and urea tender which closed in late June. The lowest offers were $879-916/t for three 23-10-5+6S+1Zn lots. Elsewhere, NPK markets were largely quiet, ensuring steady prices.

Key market drivers: In China, exporters of complex fertilizers have held back from issuing offers due to uncertainties over customs inspections and raw material prices. European gas prices continue to rise. Front-month prices of natural gas on the TTF hub closed at $43.92/mn Btu on 30th June, up from $40.72/mn Btu the previous week. This could prompt European fertilizer producers to cut or halt production.

Sulphur: The market correction of recent weeks provided more clarity on f.o.b. price levels at the end of June. The announced monthly lifting price of $428/t f.o.b. Qatar was $62/t down on June's peak. This was followed by the Kuwaiti KSP for July being set at $427/t f.o.b. Kuwait – a $63/t fall on the previous month. Cfr offers have followed suit. Brazil has booked tonnes priced at the lower level of $435/t cfr west of Suez, while an offer level of $450/t cfr has failed to attract Chinese buying interest. The spot market remains subdued while contract negotiations continue.

Key market drivers: Middle East monthly announcements for July have fallen by more than $60/t on peak June levels. Initial third-quarter price agreements at $420/t f.o.b. Middle East, although up by $15/t on the previous quarter, are down substantially on peak spot market prices seen in the interim.

OUTLOOK

Urea: While the risk of European shutdowns due to natural gas shortages remains, the urea market is well supplied for now. Large tonnages of urea booked by importers and traders in mid-June have satisfied short-term needs. Producers and importers, being mostly covered for July and into August, are now happy to trade at a slower pace.

Ammonia: Speculation over further production cuts in Europe is firming market sentiment for August. Further tightness is expected as seasonal demand starts to creep back into the market.

Phosphates: Prices west of Suez have begun to stabilise, despite the seasonal lull. Brazil will need to jump back into the market in coming weeks, although plenty of product remains in warehouses. Importers also remain cautious. Russian producers and OCP appear to be holding cfr Brazil levels firm. China is tied up with Bangladesh and its window for shipping product to Brazil for the safra season is practically over. Rumours continue to swirl about the tightening of China's export policies, a move that would pressure DAP buyers in India and Pakistan.

Potash: All eyes are on the expected return of Brazil and the US to the market in coming weeks. The strength of this demand should prevent further price declines, as well as signalling future price direction. Europe's summer lull should see prices stay flat, while falling CPO prices in Asia will continue to support bearish sentiment in that region.

NPKs: Limited demand in southeast Asian markets is likely to pressure complex fertilizers prices, as will offers that undercut general market levels. However, the knock-on effect of soaring gas costs in Europe may keep NPK prices steady, despite off-season quietness.

Sulphur: The market is expected to stabilise, following the corrections of recent few weeks, as new price levels for the third quarter become clearer. Further softening in the phosphate market could, however, strengthen the downside on sulphur pricing. ■

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UNITED KINGDOM

Fertilizer production to end at Ince

CF Fertilisers UK is to permanently close its fertilizer production site at Ince in north west England with the potential loss of 238 jobs.

The company, a subsidiary of US-headquartered CF Industries, is proposing to consolidate UK fertilizer production at its sole remaining manufacturing site at Billingham on Teesside.

Ince is located on 124 acres of land next to the Manchester Ship Canal in Cheshire. It employs around 400 workers and produces one million tonnes of fertilizers annually. The site is the UK's largest producer of compound fertilisers (NPK+S). It also manufactures ammonium nitrate for agriculture (Nitram) on a large scale.

The production complex at Ince includes a 380,000 t/a capacity ammonia plant, together with 575,000 t/a of downstream ammonium nitrate (AN) production capacity, and three NPK plants with a combined capacity of 415,000 t/a. The site has not produced ammonia since September last year due to high feedstock costs.

CF's other manufacturing operation at Billingham is the UK's largest ammonia, AN and carbon dioxide (CO_2) producer. The Teesside complex combines a 595,000 t/a capacity ammonia plant with 625,000 t/a of ammonium nitrate and 410,000 t/a of nitric acid capacity.

The planned closure of Ince ends 50-60 years of ammonia and fertilizer production at the Cheshire site. Its ammonia plant was originally built and owned by ShellStar (Shell/Armour Star) in 1965 and compound fertilizers have been produced on-site since 1969.

Announcing the decision to close the Ince production site, Brett Nightingale, CF Fertilisers UK's managing director, said:

"The people and facilities that make up CF Fertilisers UK are part of a proud, 100-year history of providing customers in the UK with products vital to the country's food security and industrial activity. However, as a high-cost producer in an intensely competitive global industry, we see considerable challenges to long-term sustainability from our current operational approach.

"Following a strategic review of our business, we believe that the best way to continue our legacy of serving customers in the UK is to operate only the Billingham manufacturing facility moving forward while addressing cost pressures throughout our business."

CF halted operations at Billingham and Ince in September 2021 after unprecedented rises in natural gas prices made ammonia production at both sites unprofitable. Billingham did, however, restart later that month, after the UK government agreed to cover the costs needed to restart the ammonia plant so it could produce vital supplies of industrial CO_2 for the UK market.

The amount of funding received from the UK government has not been disclosed. However, CF Fertilisers UK said that its £35 million employee costs (salaries, bonuses and payroll expenses) since September were "several times larger than the government support provided".

CF believes that Billingham is better positioned than Ince as a sustainable British production centre. It says the site has enough capacity to meet all of the UK's forecast demand for AN fertilizer. Manufacturing is also more efficient with production costs per tonne around 10-20 percent lower than at Ince.

CF Fertilisers UK's Ince production site in Cheshire.

Billingham also has industrial contracts in place for ammonia and nitric acid. These provide a mechanism for passing on natural gas costs to customers, so helping to ensure profitability. The presence of a 40,000-tonne ammonia storage tank at the site, and the ability to import lower-cost ammonia if necessary, also provide Billingham with greater operational flexibility.

Ince's fundamentals, in contrast, were much less attractive, according to CF Fertilisers. "The company offers products manufactured at Ince – NS and NPKs – that have historically made a minimal contribution to gross margin. This is a situation that is not expected to improve due to a significant increase in the price of the raw materials – ammonium sulfate, phosphoric acid, potash – used to make these products," it said.

CF's domestic sales of AN fertilizer are on the decline, having fallen by nearly 30 percent since 2017/18 due to intense competition from lower-cost imports. As a result, even with both its UK plants producing AN at minimum levels, CF has not been able to sell its entire production volume domestically at a profit for the last four years.

CF Industries gained complete ownership of Billingham and Ince, the UK's two remaining ammonia-based fertilizer production sites, seven years ago. The Illinois-headquartered company renamed the business CF Fertilisers UK in 2015, having bought Yara's 50 percent equity stake in GrowHow UK.

Looking ahead, CF expects operating conditions to remain challenging for nitrogen producers in the UK and Europe.

"For many producers globally, more than 70 percent of the total cost to produce ammonia is from the cost of natural gas. Natural gas forward curves suggest that nitrogen facilities in the UK and Europe will be the world's high-cost marginal producers for the foreseeable future, presenting a constant challenge to the sustainability of current operations," the company said in a statement.

The Dutch TTF gas price soared to the third highest level ever on 6th July, ICIS reported, closing at $51.20/MMBtu in response to maintenance in Norway and news of reduced Russian gas flows. This price level translates to a production cost increase of 60 percent, according to ICIS, potentially making nitrogen fertilizer production in Europe unviable. ■

UNITED STATES

$500 million fertilizer production grant

The Biden administration has doubled the funding for a US fertilizer production grant programme to $500 million.

The grant is designed to remedy the effects of high fertilizer prices and reduce reliance on supplies from Russia, the world's top fertilizer exporter.

As part of a package of new measures, the US Department of Agriculture (USDA) is also streamlining its precision agriculture service. This offers expert advice to farmers and provides access to funds for switching to precision fertilizer, pesticide, and seed applications.

Speaking on a farm visit in Illinois on 11th May, President Biden said: "It's critical to get this done," referring to the grant to boost US fertilizer production.

"Farmers are worried about rising fertilizer costs. That's why, earlier this year, the US Department of Agriculture announced it would invest $250 million to boost fertilizer production. Literally on the plane out here, I said double that – make it $500 million – it's so desperately needed. We can't take chances," Biden added.

He was speaking ahead of a G7 agriculture ministers meeting in Germany in May. "They're going to see what actions we can take to increase fertilizer suppliers globally, and identify how we can work together to prevent export restrictions on food and agricultural inputs and bring more global production to market, which will stabilize prices and bring more certainty to our farmers and keep people from dying of hunger," Biden said.

Biden described US farmers as "the breadbasket of democracy" and announced new steps to expand farm production. "We're reducing the red tape so it's easier for farmers to conserve inputs and double-crop."

The new measures announced in May include a 50 percent expansion in counties where USDA offers insurance for double-cropping. This should help growers who harvest wheat in early summer and then plant soybeans for harvesting in the fall.

If there's bad weather or other trouble, "then the timing of everything is off," said Biden. "But it's a risk we need to take. That's why my administration is looking at how to extend crop insurance coverage to give financial security to farmers… who practice double-cropping."

Nutrien planning world's largest blue ammonia plant

Nutrien is carrying out an engineering study for a large-scale 'blue' ammonia plant at its Geismar, Louisiana manufacturing site.

This will look at the feasibility of combining the latest process technology with carbon capture and sequestration (CCS) to achieve a reduction in CO_2 emissions of at least 90 percent. Nutrien has commissioned an initial front-end engineering design (FEED) study before making a final investment decision next year.

If go ahead is given, the new Geismar plant will produce 1.2 million t/a of ammonia from low-cost natural gas using autothermal reforming (ATR) to achieve the lowest carbon footprint. This will then be combined with downstream CCS infrastructure to capture at least 90 percent of production emissions, permanently sequestering more than 1.8 million tonnes of CO_2 annually in a dedicated geological storage site.

Nutrien says there is potential for this plant to move to net-zero emissions in future with further modifications.

"Our commitment to the development and use of both low-carbon and clean ammonia is prominent in our strategy to provide solutions that will help meet the world's decarbonization goals, while sustainably addressing global food insecurity," said Ken Seitz, Nutrien's

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Interim president and CEO. "Leadership in clean ammonia production will play a key role in achieving our 2030 Scope 1 and 2 emissions reduction goals, as part of our Feeding the Future Plan."

The ATR plant and associated CCS infrastructure is expected to cost approximately $2 billion. If approved, construction would begin in 2024, with full production of blue ammonia expected by 2027.

Nutrien has signed a 'term sheet' with its carbon capture partner Denbury allowing it to expand the existing volume of carbon sequestered from the Geismar site. Nutrien has also signed a letter of intent to collaborate with Mitsubishi for the offtake of up to 40 percent of the plant's expected blue ammonia output. This will supply the Asian fuel market, including Japan, when the plant eventually enters production.

NETHERLANDS

OCI triples Rotterdam terminal size

OCI will proceed with the large-scale expansion of its ammonia import terminal at the Port of Rotterdam.

The Netherlands-headquartered nitrogen producer made the final investment decision for the initial phase of the expansion project in mid-June. This will increase the ammonia throughput capacity of the terminal from 400,000 t/a to 1.2 million t/a.

The cost of the project's first phase is expected to come in below $20 million with completion slated for 2023. The project's second phase, if this proceeds, would further increase annual throughput capacity to more than three million tonnes, and includes the construction of a new world-scale ammonia tank at the terminal. OCI has already completed the basic engineering for this storage tank.

"As a global leader in ammonia production, trading and distribution, this project is a very logical step," said Ahmed El-Hoshy, OCI's CEO. "We are pleased to announce this milestone, enhancing a key ammonia import and future bunkering hub and aggregation point for low-carbon ammonia at a world-scale port, which will serve as an important avenue for clean ammonia imports from our global facilities."

Allard Castelein, CEO of the Port of Rotterdam Authority, added: "OCI's decision to invest in tripling its ammonia import capacity in Rotterdam perfectly fits our plans. Our ambition is to be a carbon neutral port in 2050.

"Ammonia is not only a hydrogen carrier and a feedstock for the chemical industry, it's also an important renewable fuel for the shipping sector. We're working hard together with the business community and public authorities to have the regulations and safe handling procedures for ammonia bunkering operations in place in time."

INDIA

HURL commissions Sindri plant

A new 1.27 million tonne capacity urea plant at Sindri in Jharkhand state is on course to begin commercial production in August, according to its operators Hindustan Urvarak and Rasayan Ltd (HURL)

The plant is currently at the commissioning and testing stage. Initial production is expected to begin at the end of July and then ramp-up during August.

The plant is due to be formally inaugurated by India's prime minister Narendra Modi at a ceremony in the first week of September.

FRANCE

Agrofert to buy Borealis nitrogen business

Borealis Group has received a binding €810 million offer from Agrofert for its fertilizer, melamine and technical nitrogen business.

The purchase by Agrofert includes production sites across Europe and an accompanying sales and distribution network.

Austrian-headquartered Borealis is a key European producer and supplier of straight nitrogen and complex NPK fertilizers. The company manufactures ammonium nitrate (AN) in France and calcium ammonium nitrate (CAN) in Germany. It is also a significant supplier of complex fertilizers and operates around 60 warehouses across the continent with a holding capacity of 70,000 tonnes.

Borealis is jointly owned by Austrian petrochemicals company OMV (75%) and Abu-Dhabi based Mubadala (25%). It has been seeking a buyer for its European nitrogen business since February 2021. Earlier this year, Swiss-headquartered but Russian-owned fertilizer producer EuroChem Group made an offer to acquire the business for €455 million (*Fertilizer International* 507, p8). But Borealis declined the offer on 11th March following Russia's invasion of Ukraine.

Borealis owns and operates five European fertilizer production plants. Three of these plants are located in France with another each in Germany and Austria. Sales volumes from these sites totalled 3.9 million tonnes in 2020, generating revenues of €908 million. This sales volume includes approximately 0.8 million tonnes of technical nitrogen solutions and around 150,000 tonnes of melamine. The five nitrogen production sites supply the market through an established distribution network across Europe.

Agrofert owns a diverse range of chemicals, agriculture and food production businesses in central Europe. These had a combined turnover of €7.5 billion in 2021. The Czech company is already one of Europe's leading nitrogen fertilizer producers, with manufacturing sites in Germany, the Czech Republic, and Slovakia.

Completion of the sale is expected in the second-half of 2022, subject to customary closing conditions and regulatory approvals.

SENEGAL

Coromandel acquires stake in BMCC

Coromandel International is buying a 45 percent equity stake in Baobab Mining and Chemicals Corporation (BMCC), a Senegalese rock phosphate mining company.

The leading Indian fertilizer producer is investing $19.6 million in the part-acquisition of BMCC and is also providing the company with a $9.7 million loan.

These investments are designed to strengthen Coromandel's production integration and secure a long-term supply of phosphate rock. BMCC's mine has been regularly producing phosphate rock since last year and, at full capacity, could meet up to one-third of Coromandel's requirements.

Coromandel has been looking for investment opportunities to secure its phosphate rock needs. Phosphate rock is a key feedstock for manufacturing phosphoric acid, an intermediate in the production of phosphate fertilizers. Coromandel currently produces around three million tonnes of phosphate fertilizers annually from three production plants in India.

Coromandel already has strategic agreements with Tifert (Tunisia) and Foskor (South Africa) to meet its phosphoric acid requirements. Currently, it also sources phosphate rock from various countries for phosphoric acid production at its Vizag plant.

Arun Alagappan, Coromandel International's executive vice chairman, said: "India is working towards achieving self-sufficiency in phosphatic fertiliser production. Given the high dependence on rock phosphate imports, which is a key raw material for manufacturing phosphoric acid, the proposed investment will be a step towards achieving long term sustainability and supply security goals for meeting the country's fertilizer needs."

He added: "The investment in Senegal is in line with the company's long term strategic objective of strengthening its sourcing capabilities to deliver superior value to all its stakeholders."

The transaction is expected to be completed in the third-quarter of 2022, subject to the completion of agreed conditions.

BRAZIL

New OCP feed phosphates plant

Morocco's OCP Group plans to build a feed phosphates plant in Maranhao state in north east Brazil.

The company's CEO Mostafa Terrab announced the project in mid-May following a meeting with Marcos Mentes, Brazil's agriculture minister, during an official visit to Morocco.

During a meeting at OCP's headquarters in Rabat, the pair discussed OCP's international investment priorities, particularly in the Brazilian market. "Having a plant in Brazil would be very valuable," Terrab said.

Mentes said his country wished "to encourage foreign investors to produce fertilizers while encouraging local production at the same time."

The proposed phosphate plant will be built at Sao Luis, the capital of Maranhao state, and consume phosphate rock imported from Morocco. Sao Luis is located on the Ilha de Sao Luis, an island in the Baia de Sao Marcos on Brazil's Atlantic coast.

Olivio Takenaka, the president of Brazilian subsidiary OCP Fertilizantes, said: "The project is in progress. We already have the land, six kilometres away from the Port of Itaqui."

Takenaka said that, under current plans, the plant would produce dicalcium phosphate (DCP) for animal feed. The project was close to obtaining Brazilian government approval, he added.

Brazil has a large domestic animal feed market. The country is world's largest beef exporter and home to the second-largest cattle herd globally.

Yara to make green ammonia

Yara Fertilizantes expects to deliver the first batch of green ammonia from its Cubatao plant in Sao Paulo state by the end of 2023.

Under a purchase agreement, Raizen's under-construction biomethane plant in nearby Paracicaba will supply the Cubatao complex with 20,000 m³/d of biomethane for green ammonia production. Raizen is a joint venture between Shell and Brazilian biofuel company Cosan. The biogas will be distributed to Yara's plant via a pipeline network operated by Comgas, a subsidiary of Cosan.

Although the currently agreed volume only represents three percent of the gas consumed at Cubatao, Yara's aim is to run the entire plant on biomethane by 2030. It calculates that the production of nitrates from biomethane should reduce greenhouse gas (GHG) emissions from their manufacture by 80 percent.

Yara Fertilizantes, the Brazilian subsidiary of Yara International, is also working on a companion project to install an electrolysis unit near the Cubatao plant. This will generate green hydrogen using solar, wind and hydro power.

"We strongly believe in the role of hydrogen in the energy transition, especially in the production of ammonia to produce low-carbon fertilizers, since agriculture has a significant share in GHG emissions," said Yara Fertilizantes vice president Daniel Hubner.

FERTILIZER INDUSTRY NEWS

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People

Zain Ajlouni.

CRU has appointed **Zain Ajlouni** as its regional director of sales, marketing and customer services for the Middle East and Northern Africa (MENA). She will be Dubai-based and cover the mining, metals and fertilizer sectors across the region.

Zain, who was previously an associate vice president at Guidepoint, has more than 10 years' business development experience within the MENA region, having worked with banks and other financial institutions. Zain's role at CRU will be to maintain and grow current client relationships and win new clients for its analysis and consulting businesses.

"Zain brings a combination of region-specific business development and language skills which are the perfect fit for us as we look to consolidate our position in the mining, metals and fertilizer segments – all major growth sectors in the MENA region," said Glenn Cooney, CRU's head of licensing and vice president of sales, Europe, Middle East India and Africa. "New and existing customers alike will benefit from Zain's experience, and we're delighted to welcome her to the team."

In reply, Zain Ajlouni said: "This is a great opportunity to bring to bear my experience and networks in the Middle East and Northern Africa to bring CRU's expertise to some of the most important and vibrant sectors of regional economies. I look forward to supporting my new clients to get the insights they need to support their strategic decision making."

Fertilizer Canada has appointed **Dan Demers** as vice president (VP), government relations. Dan brings with him over 30 years of government relations and public affairs experience. He will lead the trade body's advocacy work at federal, provincial, and municipal level.

Dan was formally VP for government relations and regulatory affairs at the Canadian Health Food Association. His career has involved advocacy on behalf of various industries, including health and pharmaceuticals and the non-profit and governmental sectors.

"We are excited to welcome Dan to the team," said Karen Proud, Fertilizer Canada's president and CEO. "We look forward to the expertise and experience he will bring to the role and to our organisation."

Dan Demers.

Birgitte Ringstad Vartdal stepped down from Yara's board of directors at the start of July. She resigned to avoid potential conflicts of interest with Statkraft, following that company's updated strategy and its increasing focus on green hydrogen and allied areas. Birgitte continues in her role as executive vice president for European wind and solar at Statkraft.

Hakon Volldal became Nel Hydrogen's new CEO at the start of July. Hakon was previously CEO of Q-Free, a tolling and traffic management company. He has also worked for consultancy company McKinsey and the leading recycling machine manufacturer TOMRA previously.

"I have looked forward to this day for a long time," Hakon Volldal said. "Nel is an exciting company with a bright future, not only commercially, but also as a vital part of the green energy transition."

He added: "We will further develop our company and technology offering, help our customers decarbonize their businesses and keep our position as the leader in green hydrogen technologies."

To coincide with Volldal's appointment, Nel's outgoing CEO **Jon Andre Lokke** has joined the company's board of directors. He welcomed the new CEO's appointment.

"Hakon has achieved remarkable results in his previous positions. He is an analytical and knowledgeable leader and is now fully up to speed on Nel," Jon Andre Lokke said. "I am convinced that the transition will be very smooth, and that he has the capabilities required to take our company to the next level." ■

Calendar 2022

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

SEPTEMBER

7-9

CRU Fertilizer AgriTech Forum,
DALLAS, Texas, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

12-13

TFI World Fertilizer Conference,
DALLAS, Texas, USA
Contact: Valerie Sutton
Tel: +1 202 962 0490
Email: vsutton@tfi.org

28-29

12th GPCA Agri-nutrients Conference,
DUBAI, UAE
Contact: Samereen Bukhari,
Conference Producer
Tel: +971 4 451 0666 ext. 127
Email: samereen@gpca.org.ae

OCTOBER

5-7

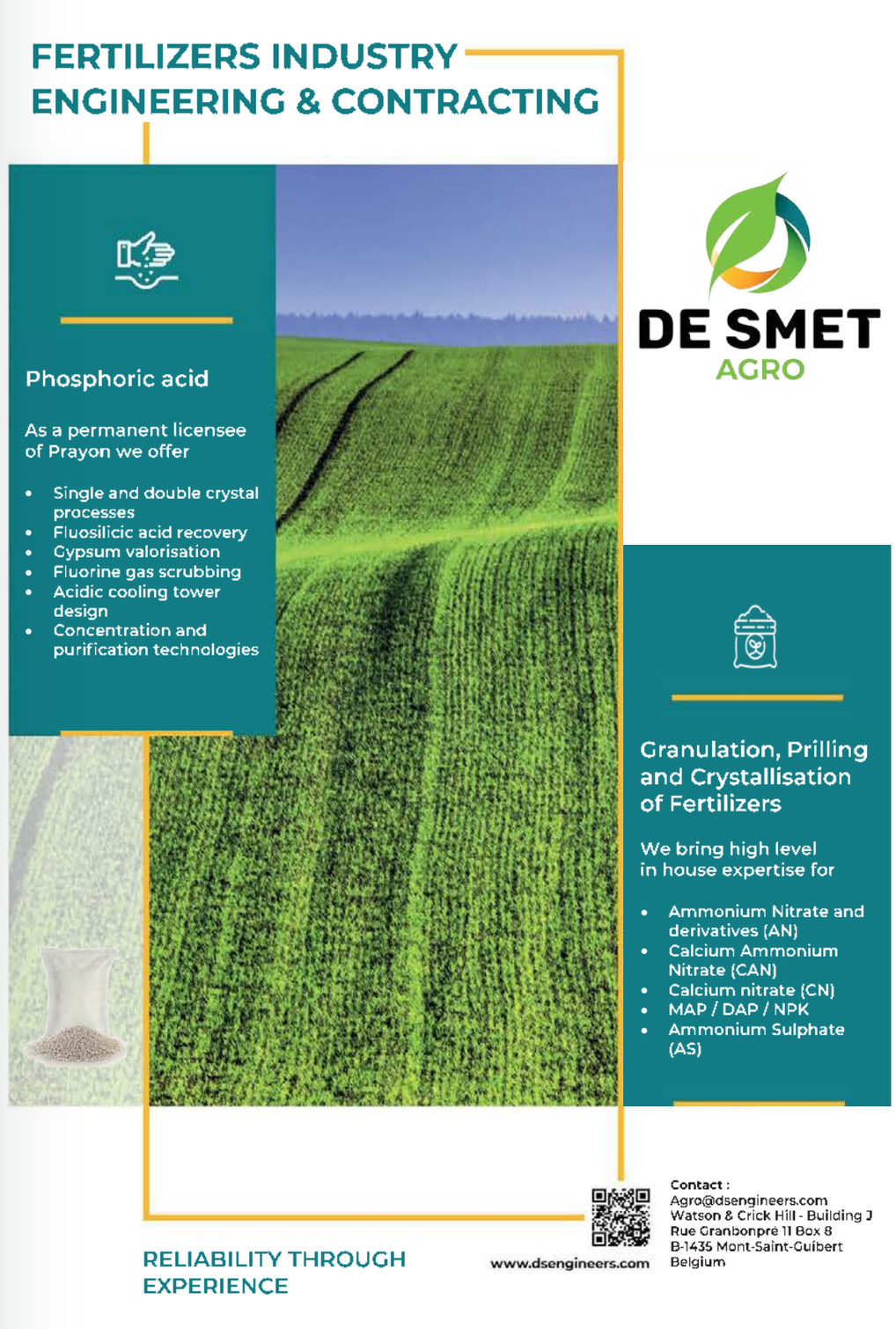
IFA Asia Pacific Crossroads, SINGAPORE
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

17-19

Argus Fertilizer Europe Conference,
MADRID, Spain
Contact: Argus Media
Tel: +44 (0)20 3923 0741
Email: conferencesupport@argusmedia.com

31-2 NOVEMBER

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



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Fertilizer futures and price risk management

PHOTO: ANDRIY BLOKHIN/SHUTTERSTOCK.COM

The iconic Chicago Board of Trade (CBOT) building. CBOT merged with the Chicago Mercantile Exchange (CME) in 2007 to form CME Group.

In increasingly volatile times for commodity markets, companies up and down the fertilizer supply chain are being left financially exposed to price fluctuations. **Alison Coughlin** and **Tom Crane** of CME Group explain how derivatives allow fertilizer market participants to protect themselves from the risk of adverse price movements.

Table 1: **The seven fertilizer futures offered by CME Group by product type and code**

Product Name	Clearing & Globex Code
Urea (Granular) FOB US Gulf Futures	UFV
Urea (Granular) FOB Egypt Futures	UFE
UAN FOB NOLA Futures	UNO
DAP FOB NOLA Futures	DFN
Urea (Granular) CFR Brazil Futures	UFB
Urea (Granular) FOB Middle East Futures	UME
MAP CFR Brazil Futures	MFC

Source: CME Group

Fertilizer derivatives – in the form of cleared swaps and futures – have been in existence and offered by CME Group since 2011. They enable market participants to hedge their exposure to dynamic shifts in fertilizer supply and demand. As well as mitigating risks, fertilizer futures also provide a signal to the broader industry about where fertilizer prices are today and, importantly, where they might be heading in the future.

Benefits of cleared derivatives

In general, cleared futures markets serve several purposes. Firstly, derivatives allow anyone in the world to access transparent prices for any listed commodity. For example, any interested party can understand where the market is pricing fertilizer for immediate or deferred delivery by consulting CME Group's website and looking at the listed settlement prices for fertilizer products over the last twelve months.

CME Group offers seven different fertilizer futures covering a range of different commodity types and geographic pricing points (Table 1). Their diversity allows the entire marketplace to understand the pricing relationships between urea, UAN, MAP, and DAP across the globe.

Table 2: **Hypothetical example of a short position – showing how a cash loss can be partially offset by a futures gain**

	Cash market	Futures market
March	$700/t	Sell @ $710/t
July	$500/t	Buy @ $550/t
	Loss = $200/t	Gain = $160/t

Source: CME Group

Secondly, because the cash market and futures market for fertilizers are highly correlated, firms with any physical exposure – typically fertilizer producers, distributors and buyers/consumers – can effectively lock in prices for any product they hold by taking a position in the futures market.

For example, any increase in the actual cash purchase price of urea in the US Gulf will be reflected by a rise in the Urea FOB US Gulf Futures price. In effect, this enables those who are exposed to volatility in the US domestic urea market to take a position in the futures market to offset those movements and stabilise their bottom line.

In entering the futures market, participants have a choice of taking either a long position or a short position. Those who might benefit from an increase in the futures price, or who are looking to mitigate any potential increases in cash prices, can hedge by buying futures. Generally, these hedgers are actual fertilizer buyers in the cash market. If prices do increase, they end up paying more for their physical fertilizer purchases. Yet, through hedging, such losses are offset by corresponding gains in the futures market – by selling the position at a price higher than they bought it for.

Conversely, those who produce fertilizers and could be negatively impacted by fertilizer price reductions can sell futures, also known as taking a short position. If prices do decrease, these producers, while receiving lower prices in the cash market for their product, will have made gains in their futures position.

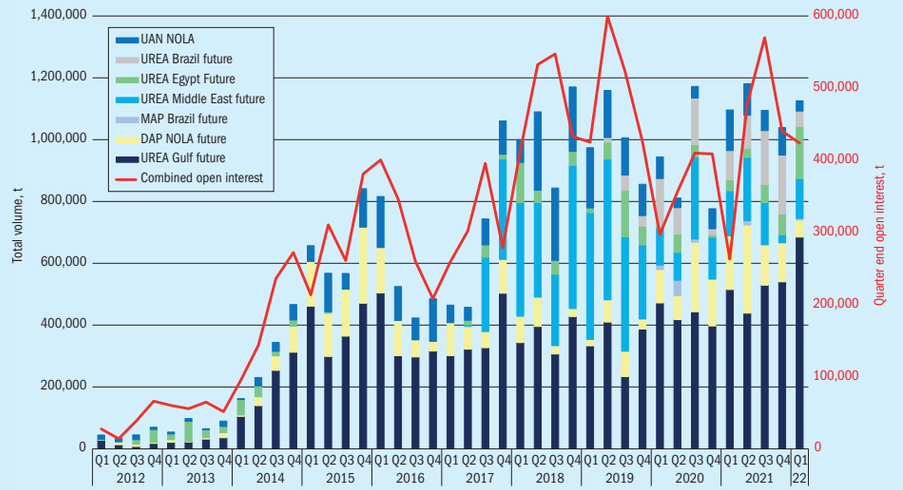
As shown by the example short position provided here (Table 2), gains from the futures position will not necessarily cover all of the producer's losses in a cash price movement. However, on a net basis, this producer's hedge position will have limited their losses to $40/t – as opposed to $200/t if they had remained unhedged.

Lastly, while over-the-counter transactions can help participants hedge price risk, CME Group's cleared fertilizer futures also offer the additional benefits of central counterparty clearing and anonymous execution. That's because the Clearing House, operated by Chicago Mercantile Exchange Inc, acts as the buyer to every seller and the seller to every buyer. This guarantees the cash flow between counterparties and assesses mark-to-market margins on a daily basis. Essentially, central clearing – because it stands in the middle of every single trade – performs a valuable function by mitigating the default risk between counterparties.

Fertilizer futures

As already stated, CME Group has offered fertilizer derivatives since 2011. The fertilizer futures market has seen tremendous

Fig. 1: **Traded volume (tons) of CME Group fertilizer futures, 2011 to end-May 2022**



Source: CME Group

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Fig. 2: **Urea price (US Gulf) volatility since the start of 2021**

Source: CME Group

growth since its inception, with compound annual growth of 42 percent (2012-2021) in the average daily traded volume (Figure 1).

In 2021, more than 16,000 metric tonnes of fertilizers were traded on average daily. The first quarter of 2022 set a new quarterly record for Urea US Gulf, the most active contract in terms of volume, with a total traded volume of more than 620,000 metric tonnes. This leading type of fertilizer future has traded nearly 910,000 metric tonnes so far this year, with May 2022 alone accounting for over 68,000 metric tonnes of these transactions.

CME Group currently lists futures for urea, UAN, MAP, and DAP fertilizer commodities, these covering important pricing points in the United States, Brazil, Egypt, and the Middle East. Each contract has a volume size of 100 tons – metric tonnes for the international contracts and short tons for the domestic US-based contracts.

All fertilizer contracts are cash settled. This means that no physical product flows through the Exchange when the contract expires. A final settlement price is determined at expiry and – instead of the seller transferring ownership of the product to the buyer – each entity settles their position by simply paying money or receiving money. In this way, no one with a position in the expiring futures contract is at risk of being compelled to either make or take delivery of physical product.

The Exchange determines the final settlement price from the Olympic average of the underlying weekly ranges for each product, as provided by two price reporting agencies (PRAs). These weekly numbers are averaged on the last Thursday of the month with Profercy and ICIS acting as the two PRAs for all fertilizer futures.

Although many agricultural futures traded on the Exchange are physically delivered and traded through the Central Limit Order Book (CME Globex), the vast majority of fertilizer participants access the contracts through private negotiated trades executed off-exchange.

Any entity wanting to engage in a fertilizer trade can contact a brokerage firm. These brokers will then find a counterparty, aligned on quantity and price, and submit the trade to CME ClearPort. The minimum transaction size for these block trades is two contracts. In practice, however, US-based contracts tend to trade in increments of 15 lots and international contracts tend to trade in increments of 50 lots.

Brokers by providing a forward curve for daily settlement prices play another important role in the fertilizer futures market. Approved brokers submit daily quotes to the Exchange. These indicate the price of a given commodity at a specific time of day. The Exchange then determines the daily settlement price for the expiry of each individual product by aggregating and blending all the submitted broker contributions. Daily settlement prices are an absolutely crucial input in mark-to-market calculations and provide the major tool for alerting the broader industry to price movements.

Current fertilizer fundamentals

The fertilizer market has seen astounding volatility in recent months linked to profound shifts in underlying global supply and demand. Fertilizer prices in general have increased rapidly across the board since the third quarter of 2021. The US Gulf urea price, for example, climbed from below $450 per metric tonne at the start of September 2021 to over $800/t by mid-November (Figure 2). After a brief respite, fertilizer prices then underwent unprecedented increases in spring 2022, going above $950/t and topping previous record price levels set in 2008. Although urea isn't always representative of the overall market, it can act as a signal for all fertilizer prices and is the most liquid futures contract on the Exchange.

Taking a position in the fertilizer futures market is a proven way of protecting against cash market exposure. Such hedging becomes vitally important during periods of immense volatility – by offsetting the price shocks that would otherwise have deeply adverse impacts on company profits and losses.

A series of supply shocks have driven fertilizer prices to record highs over the last year. Several factors such as labour shortages, transportation difficulties and falls in production capacity (linked to adverse weather conditions and plant shutdowns due to soaring energy prices) have snowballed to create worldwide supply shortages. Just as the market was working to rebalance supply and demand, the start of war in the Black Sea this year – a region that is usually a steady fertilizer supplier – has created yet more uncertainty about global inventories and fertilizer availability.

There are suggestions that the unprecedented rise in fertilizer prices this year has prompted a drop in demand across the world – so called 'demand destruction'. Reports indicate that fertilizer applications in Southeast Asia are down, for example, because fewer people are willing to pay the current price of fertilizer. The total acreage for planted corn in the United States is also expected to fall significantly this year, despite corn prices in the $8 per bushel range, as farmers shift away from corn to less fertilizer-intensive crops like soybeans.

In summary, the suite of fertilizer futures offered by CME Group offers the fertilizer market access to transparent prices and provides risk managers with the opportunity to stabilise their price exposure during increasingly volatile markets. The continuing growth of CME Group's fertilizer portfolio over time is improving price discovery for the whole industry and enlarging the potential pool of liquidity for those looking to enter the marketplace. ■

CRU Fertilizer AgriTech Forum welcomes you to Dallas!

CRU Events will convene the Fertilizer AgriTech Forum in Texas at the Aloft Dallas Downtown, 7-9 September.


PHOTO: ALOFT

Right: The Aloft Dallas Downtown is the 2022 venue for CRU's Fertilizer AgriTech Forum.

CRU is pleased to announce it will be hosting its first Fertilizer AgriTech Forum in Dallas, Texas, in September 2022. The event links innovation with sustainability – a theme which continues to rise up the fertilizer industry's corporate agenda.

A meeting of minds

The aim is to bring together established fertilizer producers and emerging AgriTech companies under one roof.

"This is a new fertilizer matchmaking event encouraging collaboration between producers and start-ups," comments Chris Lawson, CRU's Head of Fertilizers. "It's all about promoting nutrient use efficiency and sustainability through AgriTech advancements."

High fertilizer costs spur innovation

Farmers are not alone in embracing innovation and changing their practices. Fertilizer producers and distributors are now establishing in-house venture capital funds and innovation teams. Their job is to identify new technologies and new product opportunities – such as those those offering biologically assisted improvements in nutrient use efficiency, for example.

Now is the ideal time for market participants to come together and share ideas. Fertilizer prices have skyrocketed over the past two years, as has been well documented. These high prices have led to soaring profitability and improved cash balances for incumbent producers. At the same time, established industry players are now taking a real interest in innovative products and services that until recently were sceptically dismissed – at least by some.

Hear from the key players

Some of the biggest fertilizer producers in the industry will be sharing their approach to investing in innovative AgriTech via an 'experience exchange' panel, a key highlight of the event. The panel is a who's who from the fertilizer industry and includes:

- **C Ryan Bond, Sr**, Director, Global Business Development & Innovation, Nutrien
- **Kim Nicholson**, VP AgTech and Innovation, Strategy and Growth, Mosaic
- **Hadar Sutovsky**, Vice President External Innovation, ICL Group
- **Samuel Taylor**, Executive Director, Rabobank.

This authoritative panel will discuss:

- How industry incumbents are positioning themselves to address the risks and opportunities of disruptive technologies
- The timelines and levers for systemic innovation
- Geographical disparities within the sphere of agricultural innovation
- How innovation will evolve and change the fertilizer industry.

In addition to this panel, the forum will highlight the role AgriTech innovation will play in reducing the environmental footprint of the fertilizer industry, while ensuring it continues to meet its core aim of global food security. The World Trade Organization, The Fertilizer Institute and others will be present to offer their insights.

Start-up showcase – a platform for innovation

Thursday's agenda offers a view of today's industry and recent moves to embrace and invest in innovation. Friday's focus, in contrast, is on start-ups and emerging fertilizer AgriTech players. Individual AgriTech companies will have the chance to pitch their technology to the industry – and have the opportunity to talk about what they do, their formula for success, their ambitions on partnerships and investment, and how the industry can benefit from collaboration. Confirmed presenters for the start-up showcase include:

- Solving the nitrogen equation – OpusMAX technology as an alternative or complement to biological approaches. Presented by **John Appel**, President and Board Member, BPS Agriculture.
- Bridge building – renewable power and fertilizer. Presented by **Nico Pinkowski**, CEO, Nitricity Inc.

Keep an eye on the event's website for the latest announcements on start-ups presenting at the forum.

See you in Dallas

Rising interest rates and the cost of capital could potentially scale-back investment in new technologies. But with food security and sustainability hot on the business and political agenda, the outlook for continued investment in and collaboration on AgriTech remains positive. ■

For more details on how to participate in this event, please see the website: www.fertilizeragritech.com

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Iodine: the newly recognised plant nutrient

PHOTO: ARTJAZZ/SHUTTERSTOCK.COM

New research findings strongly suggest that iodine behaves as a plant nutrient. SQM International has been quick to follow up on this discovery by launching a new speciality iodine fertilizer for fertigated crops.

SQM has demonstrated the efficacy of its new iodine speciality fertilizer Ultrasol®ine K Plus on a range of crops including tomato.

Breakthrough research

"Results are strongly suggestive of the role of iodine as a plant nutrient." That was the main conclusion of a landmark paper published by Italian scientists last year[1].

It has long been known that iodine is essential for human and animal health. But these researchers have now demonstrated that plants need micro doses of iodine as well. For the first time, they identified and described the presence of 82 naturally-occurring iodine-containing proteins in higher plants.

Their research has shown – based on phenotyping, genomics and proteomics studies – that plants need iodine for

- Leaf and root growth
- Efficient photosynthesis
- Timely flowering
- Increased seed production
- The activation of an early warning system that defends the plant against damage from abiotic and biotic stress.

Iodine deficiency may also cause lower crop yields and poorer fruit quality, particularly in growing regions where the soil and water are naturally low in iodine.

To make it easier and safer for growers to provide the right source of iodine, at the right dose and at the right time, commercial products are now available that combine iodine with potassium nitrate in a single speciality fertilizer. This is a useful combination as the plant's iodine demand is well-synchronised with the uptake of nitrate and potassium from nutrient solutions.

Breakthrough product

SQM, the leading global speciality fertilizer producer, has been quick to follow up on these latest discoveries. In response to new information highlighting the importance of iodine as an essential plant nutrient, the Chilean-based company has developed a speciality fertilizer with iodine for fertigated crops. This allows growers to apply iodine as a plant micronutrient in a form that is guaranteed to be safe and at an effective science-based dose.

The newly-launched product, known as Ultrasol®ine K Plus, combines two essential plant macronutrients – potassium and nitrate nitrogen – with iodine. The product ensures that they are applied at well-defined application rates. This makes it easy for the grower to maintain an effective and safe concentration of iodine in the root zone. As a result, Ultrasol®ine K Plus can prevent iodine deficiency in crops without the risk of excessive iodine application.

The product has already been extensively tested globally and is backed by more than 100 well-documented trials with growers. The experience of these growers has confirmed that iodine can deliver distinct benefits – including improvements to:

- Root growth
- Above ground plant growth
- Photosynthesis
- Nitrogen metabolism
- Tolerance to abiotic stress
- Flowering and fruit quality with less fruit rot and better shelf life.

Typically, the application of iodine to crops delivers 10 percent more marketable yield. This is the average yield improvement from trials on 34 farms located in nine countries with coverage of 10 different crops. These trials compared Ultrasol®ine K Plus to potassium nitrate without iodine for the same crop, on the same planting date with the same fertilizer programme. Crops included: tomato, lettuce, sweet pepper, cucumber, musk melon, sugarcane, pomegranate, papaya, banana and coffee.

Overall, the trials demonstrated that Ultrasol®ine K Plus enables iodine to be easily applied and improve crop performance – with this leading to higher yields, improved quality and therefore better rev-

Power your innovation with PENXCEL Technology

PENXCEL™ Technology is a unique, patented formulation system to deliver EEF additives for dry and liquid fertilizer. Discovered by a PhD who used similar compounds in human pharmaceutical formulations, the technology has been harnessed to deliver innovative ingredients for agriculture. The PENXCEL system delivers many performance benefits over industry standard formulations.

Penetrates Deeper For More Consistent Results

PENXCEL technology delivers active ingredients deeper into solid fertilizer granules more consistently. This innovative formulation allows the use of active ingredients previously deemed "impossible to be coated" on fertilizer. It also works well in liquid fertilizer providing an advantage over powders that stubbornly float on the surface and blow off granules in a cloud of dust.

Blends Faster Even In Challenging Cold Weather

Products using PENXCEL technology have low viscosity, so handling is easy. They pump or pour quickly, even in freezing cold temperatures, accelerating blending up to 25% faster than industry standard formulations. Saving time is critical during application season. PENXCEL provides superior performance in high-volume, high-speed mixers. The result is consistent fertilizer products that flow freely and perform in the field.

Excels In The Field, Excels In Safety

Field trials have demonstrated superior performance for PENXCEL technology, which has been attributed to more consistent coverage and deeper penetration of the active ingredients. Lab tests show that PENXCEL Technology is safer than the industry standard formulations. The key ingredient's safety profile, as proven by its use in human medicine, is evident in the results.

Leverage PENXCEL Technology In Your EEF Products For 2022

Want to drive innovation forward? PENXCEL Technology allows you to maximize your existing infrastructure to offer value-added EEF products with minimal investment. For more information visit InnovarAg.com today.

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INNOVAR AG™

Ask us about our new INNOSOLVE™ PKME broad spectrum efficiency additive

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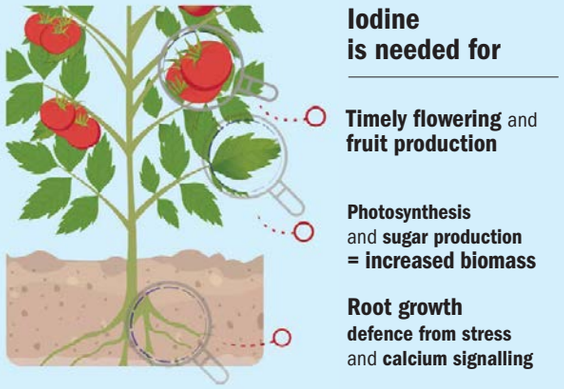
Fig. 1: **The nutritional role of iodine in plants**



Source: SQM/Kiferle et al. (2021)

enues. The product will be available on the European market from mid-July 2022.

Iodine as a new plant nutrient

Previously, elements classed as plant nutrients include:

- Primary nutrients (C, H, O, N, P, K)
- Secondary nutrients (Ca, Mg, S)
- Micronutrients (Fe, Zn, Cu, Mn, B, Cl, Mo, Co and Ni).

Research suggests that this list of plant nutrients can now be expanded to include iodine. This would be the first new micronutrient to be added since nickel in 1987.

The case for classifying iodine as a crop nutrient was made in a recently published paper by a mainly Italian team of plant scientists[1]. This was led by Professor Pierdomenico Perata and Dr Claudia Kiferle of the Plant Lab at the Institute of Life Sciences, Scuola Superiore Sant'Anna, Pisa, Italy. Other scientists from Italy's National Research Council were also involved. Katja Hora and Harmen Tjalling Holwerda from SQM International also participated. The research was jointly funded by the Scuola Superiore Sant'Anna and SQM.

The scientists concluded that[1]: "Iodine has a nutritional role in plants. Considering that plant nutrients are chemical elements that are components of biological molecules and/or influence essential metabolic functions. Further studies… will help to complete the picture on the functional role of iodine as a plant nutrient."

> **"Crop trials have demonstrated that Ultrasol®ine K Plus leads to higher yields, improved quality and therefore better revenues.**

This compelling evidence for classifying iodine as a plant nutrient (Figure 1) is backed by a new scientific definition recently proposed by leading scientists[2].

The paper by Dr Kiferle and colleagues has made public the new discovery that plants bind iodine in 82 different proteins. These proteins have an important role in biological processes and compounds such as:

- The protein rubisco for efficient photosynthesis in leaves
- Peroxidase enzymes which defend the plant from abiotic and biotic stress
- The enzyme ATPase which supplies energy for plant growth and the transport of nutrients.

Consequently, iodine deficiency in crops is expected to cause yield losses, like those experienced by plants suffering from other micronutrient deficiencies. This new research also suggests that plants will need to be supplied with the right dosage of iodine to optimise crop production.

Plants can accumulate iodine

The presence of iodine in the biosphere is widespread, albeit usually in tiny quantities. The highest amount of iodine is found in seawater, with an average concentration of 0.5 micromole per litre. Rainwater, soil solutions and irrigation water, in contrast, contain lower concentrations, typically less than 0.2 micromole per litre. Furthermore, less than 10 percent of the total iodine present in soils is usually available for plant uptake.

It has been known for a long time that plants do take up iodine through their roots and store this in their leaves and fruits. Indeed, its benefits, in terms of plant growth and in providing resilience to stress, have been observed in many previous studies. Having reviewed the published evidence, the Italian scientists agreed that plants accumulate iodine because of its benefits to[1]:

- Plant growth
- Nitrogen metabolism
- Resistance to salinity stress in the root solution
- And, in particular, the production of antioxidants by the plant.

Providing both the right dose (not too little, not too much) and the right form of iodine is also important. For example, the type of iodine present in disinfectants (free iodine, I_2, and iodide, I^-) may have harmful effects at a lower dose compared to other forms.

Why do plants need iodine?

Until now, iodine's value as a plant nutrient – when applied at the right dose – has not been fully recognised, despite the published evidence. Perceptions are, however, beginning to change following the publication of the landmark paper by Dr Claudia Kiferle and colleagues[1].

They described the results of experiments carried out on *Arabidopsis thaliana*. This plant species is quick to grow in the laboratory – its growing cycle taking only six weeks from seed-to-seed. *Arabidopsis thaliana* has also been extensively studied. This means that knowledge about its genes and metabolism is freely available and widely shared by plant scientists globally.

The Italian researchers found that plant growth and blooming were much slower in the absence of iodine compared to plants that were given a dosage of 0.2-10 micromole of iodine per litre. Experiments suggest that the application of iodine at micromolar concentrations increases root and shoot growth, seed production and advanced flowering.

The scientists also investigated the genetic response of the plant to the presence or absence of iodine in the root solution. They discovered that iodine specifically regulates the expression of several genes involved in:

- Photosynthesis
- The salicylic acid (SA) stress response pathway
- Plant hormone response
- Ca^{2+} signalling
- Plant defence to pathogen attack.

These results confirm and further explain the previously published observation that iodine helps prevent plant damage from biotic or abiotic stress. Repeat experiments with bromine, a similar type of halogen element, also demonstrated that the observed plant growth and gene responses were unique to iodine[1].

Finally, a series of experiments using radioisotope labelling showed how iodine is incorporated in plant proteins. These include the enzymes or structural building blocks that are needed for all cell functions, as well as for collaboration and communication between cells and between plant organs.

A total of 82 iodinated proteins were identified in *Arabidopsis thaliana*. In plant shoots, these are mainly associated with the chloroplast and are involved in photosynthesis. Those in the roots, meanwhile, are essential for root growth and include peroxidase enzymes (important in stress-signalling) or enzymes involved in peroxidase activity. Other iodinated proteins were discovered with a crucial role in nitrogen metabolism, phytohormone regulation and energy production in both root and leaf cells[1].

These iodine-containing proteins occur widely in the plant kingdom. They were discovered not only in *Arabidopsis thaliana*, but also in tomato, maize, wheat and lettuce, for example[1].

These latest research findings open a new window on the pivotal role of iodinated enzymes. This is undoubtedly a discovery that will trigger renewed interest in the importance of iodine in crop production. ■

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Innovation showcase

PHOTO: ICL

Left: Application of ICL's new NPKpluS product (16-8-16) at a citrus orchard, Yichang City, Hubei Province, China.

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

Croptune from AgrIOT

Israeli Ag-tech company AgrIOT is the developer of the Croptune™ digital farming tool. This provides the grower with accurate, real-time measurements of plant nitrogen content for a broad range of field crops and orchards.

Croptune was launched commercially in March 2022 and is calibrated for use with the following crops:

- **Field crops:** Wheat, corn, tomato, potato, rice, carrot, lettuce, pepper, onion, cotton, cucumber
- **Orchards:** Pears, cherry, banana, avocado, peach, nectarine, citrus.

It is an effective, affordable, and easy-to-use tool that provides real-time data on the crop's NPK status, together with relevant fertilization recommendations.

Croptune can increase nitrogen use efficiency (NUE) and improve agricultural sustainability by optimising nitrogen management. Positive sustainability impacts include:

- Reduced nitrous oxide (N_2O) emissions
- Reduced soil salination, so mitigating low crop yields
- Reduced nitrate-contamination of aquifers and water resources – commonly caused by overdosing with nitrogen fertilizers.

Croptune integrates three disciplines: optical sensing, agronomy, and computer science. It operates using a sophisticated and advanced decision support system (DSS) that combines big data/artificial intelligence (AI) with machine learning. These capabilities provide the grower with real-time fertilization recommendations. These are based on the measured nitrogen content and the crop's characteristic nutrient requirements.

Croptune reports a holistic NPK fertilization recommendation – the required amounts of potassium and phosphate being calculated from the measured nitrogen content of the plant.

The technology can be used with any type of RGB (red, green, blue) camera, including standard cellphone cameras and aerial cameras. Depending on the resolution, Croptune can also analyse satellite RGB photos.

Although AgrIOT's main customer base is currently in India and Israel, Croptune is being rolled out to new customers in Africa, New Zealand, Australia, Romania, Austria, and the Middle East from June this year. The company also plans to improve Croptune's functionality in future and expand its range of services to include:

- Irrigation recommendations
- Yield predictions for selected field crops
- Pest and plant disease image analysis, with treatment recommendations.

Haifa Group has formed a strategic partnership with AgrIOT – having identified Croptune as a technological breakthrough. The company is pursuing further strategic partnerships to aid its global expansion.

Tracegrow micronutrient fertilizers

Tracegrow is a Finnish cleantech company that manufactures liquid micronutrient foliar fertilizers from recycled alkaline batteries. Billions of these batteries are produced each year. These are hard to recycle conventionally and are often treated as a hazardous waste. Tracegrow's patented environmentally-friendly process, in contrast, can safely recycle valuable materials from alkaline batteries at high efficiency.

Turning alkaline battery black mass into valuable fertilizer helps address two pressures. Firstly, the life cycles of raw materials, their environmental impacts and the depletion of natural resources are receiving increased attention from legislators. Secondly, agricultural demand for micronutrients, meanwhile, keeps on rising.

SOURCE: TRACEGROW

Tracegrow foliar fertilizers being applied to crops. These liquid products incorporate zinc and manganese recovered from recycled alkaline batteries.

Correcting micronutrient deficiencies – due to their association with lower crop yields and financial losses – are becoming increasingly important for farmers. Foliar fertilization is recognised as an effective way of correcting micronutrient deficiencies quickly. The foliar application of micronutrients also enhances the plant's ability to absorb other nutrients more efficiently. Manganese, for example, has a significant effect on the uptake of nitrogen, an essential nutrient that affects plant growth.

Tracegrow's 'circular economy' process separates zinc and manganese from recycled alkaline batteries (see photo) to create three sulphate-based organic foliar fertilizers:

- ZM-Grow is a zinc, manganese and sulphur foliar fertilizer
- ZMC-Grow is a zinc, manganese, sulphur and copper foliar fertilizer
- Zimaco-PRO is a zinc, manganese and sulphur foliar fertilizer that incorporates IDHA (biodegradable) chelated copper.

These liquid products can also be used to coat granular NPK fertilizers and as a seed dressing. They are currently available in 15 countries around the world and offer the following benefits and features:

- True 'circular economy' products
- Foliar fertilizers suitable for conventional and organic growing of both field and greenhouse crops
- Liquid products that are easy to pour, measure and mix
- Do not block sprayer nozzles and filters or cause equipment wear as no solid particles are present
- Excellent mixing properties with plant protection products and agrichemicals
- Sulphate-based solutions that are immediately absorbed through the plant leaves
- Backed by extensive field testing
- Certified for organic farming.

PHOTO: TRACEGROW

Control room of Tracegrow's battery recycling and fertilizer manufacturing plant in Finland.

CleverFarm's precision agriculture platform

The new digital platform offered by Czech AgTech company CleverFarm is designed to guide users through the entire precision farming process. Its goal is to increase crop yields while at the same time optimising the usage of inputs.

CleverFarm's precision agriculture platform has valuable capabilities, such as the evaluation of sowing plans, the creation of variable maps, and the assessment of variable rate applications. Crucially, the platform helps growers evaluate where and when to apply fertilizers and at what dose. This makes the administration of fertilizers as efficient as possible and helps deliver target crop yields.

By providing crops with nutrients in the correct amounts and the composition needed, the platform also helps growers reduce soil and water pollution, and prevents the generation of greenhouse gases such as nitrous oxide.

The platform monitors and evaluates the current state of the crop in terms of chlorophyll content, biomass volume, and water level in the vegetation. CleverFarm – thanks to the use of an AI (artificial intelligence) model – can immediately identify the absolute value of these parameters, based on satellite images, and then compares these to the normal values for individual crops at a given phenophase (growth stage).

Growers also receive information about whether their crops are doing better or worse than average across the growing area. This monitoring is often used to determine the variable rate application of nitrogen fertilizers and the use of growth regulators. Chlorophyll content, in particular, accurately detects where supplementary nitrogen fertilization is needed.

CleverFarm complements these crop data with additional information on weather and soil conditions. For example, it can import soil sample data to create macro- and micro-element maps. As an open platform, CleverFarm can integrate any relevant third-party data. This helps growers reach the right farm management decisions (for fertilizers and other inputs) by providing them with the most complete set of information.

Precision agriculture aims to deliver higher crop yields combined with savings on fertilizers, water, and seeds.

"Thanks to satellite monitoring of the current state of the crops, our system will evaluate and recommend when, with what intensity, and in which place of the land to perform input applications," comments CleverFarm's co-founder Adam Zlotý.

CleverFarm can also be used by crop advisors and fertilizer distributors. The platform – by providing an excellent overview of what is happening at farm level – helps them advise their clients on where, how much, and what fertilizers to apply. Fertilizer distributors are interested in cooperating with CleverFarm as the platform creates personalised fertilization plans that can achieve higher returns for their customers.

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Calciprill from Omya

Securing food production for a growing population is one of the world's greatest challenges. Globally, acid soils with a pH below 5.5 occupy about 30 percent of land surface and are estimated to reduce crop productivity by around 40-50 percent.

The effects of acid soils on crops

Soil pH has a direct effect on the solubility and/or availability of nutrients and other deleterious soil components. For example, the solubility of toxic elements such as aluminium and manganese in acid soils, where the pH is below 5.5, directly affects crop health and growth. The macronutrients essential for plant growth (NPK) are inaccessible to the crop in acidic soils. For example, only 77 percent of the soil nitrogen is plant-available at pH 5.5 – the remainder being locked in forms that plants find hard to assimilate or is lost through leaching. Soil phosphates are also tied up and inaccessible at low pH. Potassium, which is even more sensitive to soil pH, remains fixed to soil particles with only 52 percent available at a soil pH of 6.

In acids soils, therefore, the plant's productive potential is severely hampered. Because of this, the unnecessary use of extra inputs (fertilizers) is often required to compensate for the low nutrient availability – resulting in higher economic and environmental costs.

Aglime – the traditional approach

Traditionally, liming has been the most common method for neutralising widespread soil acidity and keeping soil pH within a range that is favourable for crop production. This typically involves the addition of calcium- and magnesium-rich materials to soils such as chalk, limestone, burnt lime or hydrated lime.

It is not uncommon for farmers to apply large quantities of limestone (aglime) to their land every 5-10 years – with the general aim of improving soil productivity. This approach can be very hit-and-miss, however, as applications are imprecise and poorly targeted. Consequently, as agriculture has become more efficient, there has been a need to improve the liming process and develop better aglime products that provide growers with more effective and precise neutralisation options.

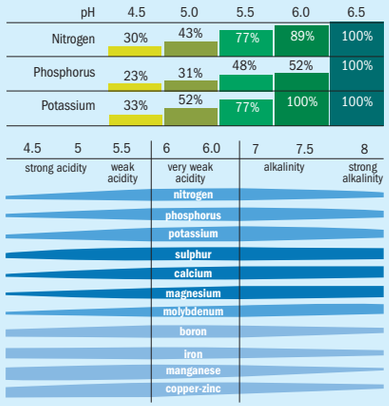
Advanced soil amendment technology

Omya Calciprill® is a recently developed soil amendment product designed for precise applications that can effectively and efficiently correct soil acidity.

Calciprill is a high-quality form of natural calcium carbonate. It consists of micronised ultrafine particles (0.7-100 µm) that have been granulated into 2-6 mm diameter prills for ease of application. Calciprill's purity means it has a high neutralising value that is equal to or better than traditional aglime (Table 1).

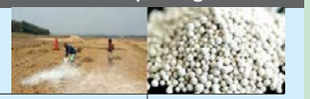
However, it is Calciprill's ultrafine particle size – compared to traditional liming materials – that is key to improving distribution in the soil. The much higher surface area of these micronised particles increases the opportunities for the chemical bases they contain to meet and neutralise the hydrogen (H^+) ions that cause acidity. This corrects soil pH faster and more effectively at lower rates.

Fig. 1: **The effects of pH on NPK assimilation by plants (top) and nutrient availability (bottom)**



Source: Omya

Table 1: **Key characteristics of Calciprill vs aglime**



	Aglime	Granules Calciprill
Particle size	100-60 mesh (150-250 µm)	25,000-150 mesh (0.7-100 µm)
Neutralising value*	medium-high	high
Surface area	low	high
Reactivity	low	high

**Neutralising value is a relative value using the calcium oxide content, magnesium oxide content and fineness to express the effectiveness of an agricultural liming material in neutralising soil acidity.*

Source: Omya

Suitable for precision agriculture

Calciprill granules can be applied in precision agriculture with standard fertilizer spreaders or by air. They do this without creating clouds of dust and avoid the hit-and-miss approach of traditional aglime applications. Granules can be applied before, during or after planting at times when the change in pH most benefits crop growth. Once in the soil, the granules disintegrate easily, enabling the ultrafine particles to move through the soil and increase pH where it is needed, especially in zones where crop roots are growing.

By correcting soil pH, Calciprill gives plants full access to the available soil nutrients. It also provides crops with essential calcium throughout their growth cycle, enhancing crop health and quality.

Omya, by making Calciprill available to growers, is hoping to increase cropland productivity and also help make fertilizer use more efficient by correcting soil acidity. ■

InnoSolve PKMe from Innovar Ag

With the current state of the global economy and threats to the environment, the efficiency and economic benefits of a good crop fertilization programme are of increasing importance, according to Innovar Ag.

Based in Bradenton, Florida, the company's team has spent over 20 years developing and improving enhanced efficiency fertilizer (EEF) technologies for the agricultural and turf markets. Today, Innovar Ag's wide range of EEF products are available in 32 countries and rapidly rising.

By bringing these value-added fertilizers to market globally since 1996, the company's CEO Andrew Semple has helped to change the way fertilizers are used. He explains how the value-added market has developed:

"It is good to see the large-scale adoption of EEF technologies in agriculture worldwide today. We have all come to a point where these easy-to-use technologies are available, are simple to implement as part of a fertilization plan, and still get a good return on investment of between 3-1 and 10-1 in many cases.

"Urease and nitrification inhibitors did a wonderful job with nitrogen conservation, efficiency and profit – for farmers and the distribution chain. Right now, we are happy to say that a new broad-spectrum efficiency additive named **InnoSolve PKMe** has been the fastest growing segment of our ag and turf technology business."

InnoSolve PKMe is a negatively-charged, biodegradable polymer with a high cation exchange capacity (CEC) that is available in liquid or dry powder form. Dr Ray Asebedo, Innovar's VP of R&D Technology explains how it works:

"When fertilizer is treated with PKMe and then applied to the soil, PKMe will delay the formation of precipitates that move many essential nutrients into a non-plant available form. Thus, PKMe will keep your essential nutrients – such as phosphorus, potassium and many other micronutrients – available to the plant for a longer period time, which will result in increased nutrient uptake and potentially higher yields."

Clear and simple messaging with growers is vital, says Semple:

"It is important to understand the way this technology works and be able to explain it to our customers in a way that the whole chain can understand and then relay. From a commercial perspective, the adoption is well accepted. Because not only does it help the uptake and availability of phosphate and potash in the soil, it also effects a positive uptake of micronutrients."

Differences in the root mass of young canola plants with starter fertilizer only (left) and starter fertilizer plus InnoSolvePKMe (right).

Customer demand for innovative fertilizers has spurred product development, says Luciano Lucero VP of Technical Sales:

"After solving nitrogen problems for more than two decades, we constantly were challenged by our customers to bring the next novelty to the market. InnoSolve PKMe came to close that gap – fitting perfectly into our core business of liquid additives for fertilizers.

"Some of the benefits that PKMe brings to the table include the logistics and storage benefits of a liquid additive, more than 20 years of positive field research, and broad-spectrum fertilization that makes macro and micronutrients more available to crops.

"In the last two years, we've expanded the business with PKMe in seven countries from North to South America and listed amazing results from citrus to soybeans crops. These have shown not only yield improvements, but superior nutrient uptake as well, and faster recovery from adverse weather conditions – all proving that InnoSolve PKMe is perfect for distributors, dealers and especially farmers looking for enhanced efficiency fertilizers."

The increasing adoption of such products will be important, says Innovar, by helping to feed the world's growing population and keeping food affordable.

ICL adds two newcomers to its FertilizerpluS range

ICL has expanded its FertilizerpluS product range by adding two new product lines – ICL NPKpluS and Polysulphate Premium.

FertilizerpluS are high quality Polysulphate-based granular fertilizers. The Polysulphate is sourced from ICL's Boulby mine in the UK and contains the natural mineral polyhalite.

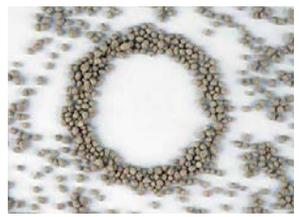
NPKpluS is a new NPK line with Polysulphate inside. It has been developed in response to rising demand for magnesium and calcium, the increasing importance of sulphur as a nutrient, and the need for new approaches to balanced fertilization.

The nutrient composition of NPKpluS – with three soluble sulphates of magnesium, potassium, and calcium – guarantees more complete and efficient crop fertilization. By balancing efficient raw materials with advanced technology, NPKpluS offers farmers improved yields compared to traditional fertilizer practices, according to ICL.

NPKpluS allows farmers to apply six essential nutrients – nitrogen, phosphorus, and potassium along with sulphur, magnesium, and calcium – in one single application. Thanks to its Polysulphate content, NPKpluS simultaneously provides crops with all the essential elements they require for their development. It is able to offer much more balanced nutrition, suggests ICL, in comparison to products which supply nutrients with different degrees of solubility.

NPKpluS is produced by ICL at plants in China (prilling) and Ludwigshafen, Germany (blending) and is available in a variety of formulations. Blends can be tailor made and, if required, can incorporate zinc and/or boron. Recommended application rates are based on crop nutrient requirements and the site-specific nutrient supply from the soil.

Polysulphate Premium is granulated from powdered polyhalite to form uniform, robust spheres. Its smooth surface protects granules from abrasion, humidity and damage, while its spherical shape provides a steady flow rate and a consistent broad spread during application. The product easily blends with other granulated fertilizers and gives an attractive appearance.



Polysulphate Premium is granulated from powdered polyhalite to form uniform, robust spheres.

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PHOTOS: ICL

Citrus orchard trial, Yichang City, Hubei Province, China. Traditional NPK 15-15-15 application shows magnesium deficiency (left) compared to ICL NPKpluS 15-15-15 application (right). Application rate of 0.5 kg/tree for both.

Polysulphate Premium is produced at ICL's Ludwigshafen plant in Germany and has the following composition:

- 45.6 percent SO_3 (18.2% S) as sulphate
- 13 percent K_2O (10.7% K) as sulphate of potassium
- 5.6 percent MgO (3.4% Mg) as magnesium sulphate
- 16.4 percent CaO (11.8% Ca) as calcium sulphate.

Polysulphate Premium inherits all the valuable characteristics of Polysulphate. This multi-nutrient, natural fertilizer is mined in the UK and has a low carbon footprint. It provides four plant nutrients – sulphur, potassium, magnesium, and calcium – and delivers dependable high value at a low environmental impact.

Polysulphate is suitable for all crop types and is certified for organic use in many different countries. It has a neutral pH and, being a low chloride fertilizer with a very low salinity index, can also be applied to more sensitive crops. Polysulphate releases its nutrients gradually over time, functions over a wide soil pH range, from acidic to alkaline, and is suitable for both sandy and clayey soil types. It provides plants with prolonged sulphur availability, while reducing the risk of leaching in sandy soils and under high rainfall conditions.

The major difference between Polysulphate and Polysulphate Premium, aside from their appearance, is a faster mode of action. Polysulphate Premium is granulated from powdered polyhalite into smooth, uniform, and robust spheres. This ensures consistent product quality. It also becomes soluble as soon as this premium fertilizer reaches the soil – making essential plant nutrients available for crop uptake immediately and for a prolonged period of time.

Enhanced efficiency fertilizers (EEFs) from Soilgenic

Canada's Soilgenic Technologies offers innovative products designed to improve fertilizer production, soil health and plant nutrient uptake. The company has developed a suite of enhanced efficiency fertilizers (EEFs) for nitrogen fertilization, as well as a technology that improves phosphate fertilizer availability.

Soilgenic has over 40 EEF patents and has developed a portfolio of what it calls 'Gen 2' (second generation) technologies which significantly improve on the previous first generation of EEFs. These Gen 2 products add greater value to the market at around half the cost of today's EEF technologies.

"The fertilizer industry is in a state of change, and there is pressure to reduce emissions and runoff. Adding to the situation is fertilizer supply issues and costs have risen quickly, so interest is very high in getting more applied fertilizer into the plant for higher protein and crop yield, and less into the air and water," comments Jeff Ivan, Soilgenic's CEO.

"That is what the next generation Soilgenic products deliver, and at a significant reduced price point to hit mass market adoption, and not just a high value niche," he adds.

Soilgenic's formulations are more cost effective as they can be added at lower application rates due to their highly active ingredients. They are also designed to perform well in extreme cold or hot and humid climates. The company's suite of retail EEF products covers all nitrogen sources and includes:

- **Visio-N Total** for urea is a balanced, high activity formulation that offers nitrogen protection both on the surface and in the soil. It incorporates Soilgenic's patented NitroBlock™ dicyandiamide (DCD) inhibitor. The company believes this will set a new standard for below ground protection against leaching and denitrification losses.
- **Diamond-N** is an effective, low-cost option for protecting urea ammonium nitrate (UAN). It has the highest activity level of any UAN protection product on the market and dissolves readily to form a solution not a suspension. Its solubility allows Diamond-N to be added to UAN at the retail level. It also means the grower doesn't have to worry about the settling out of active ingredients that can occur with a suspension.
- **Knifed-N** is the industry's first non-corrosive EEF technology for protecting anhydrous ammonia. This patented and water-free formulation is safer for users and improves equipment life. Incorporating Soilgenic's NitroBlock DCD inhibitor, Knifed-N also offers significant savings by reducing input costs by up to 50 percent compared to other types of anhydrous ammonia protection.
- The **Drive-N** formulation for ammonia-based fertilizers improves protective coverage and penetration when coating hard granular products such as ammonium sulphate and DAP/MAP. It also keeps ammonia stable in manure management. This formulation again incorporates Soilgenic's NitroBlock DCD inhibitor which lower costs and improves the overall value of Drive-N.

Soilgenic also offers **Phosgain**, a patented polymer technology that shields and protects phosphate fertilizers. This creates a polymer of a specific molecular weight that moves with the phosphate and creates a protective shield against 'strong' cations such as potassium, magnesium, calcium and iron. This protective polymer improves phosphate fertilizer availability and performance by making phosphorus available to the crop for much longer.

Phosgain is also cost effective, offering a 7-10 times return on investment, and delivering an average increase in crop yield of 17 percent based on trials over a three-year period. It also helps to free phosphate from the soil and functions over a wide pH range – properties which make it widely applicable globally.

Phosgain can be added upstream during phosphate manufacturing or downstream at distribution/retail level. ■

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Levity Crop Science: growing more with less

The overuse of limited natural resources and excessive contributions to climate change are just two of the criticisms currently levelled at global agriculture. Plant scientist **David Marks** is addressing these criticisms head-on through the company he founded, Levity Crop Science. He believes that, with better access to the right products, farmers can bring agriculture back into balance.

"Most farmers don't want to use harsh chemicals if they can help it. And whatever chemicals they do use, they want to minimise what they need to apply."

It's on this principle that Dr David Marks founded his UK-based 'functional fertilizer' company, Levity Crop Science. The company's ethos is to make crop production more sustainable, without compromising yield, production or quality, and – crucially – make more efficient use of the planet's limited resources.

"When it comes to crop nutrition, a lot of our thinking and practices haven't really kept pace with other technologies and agricultural advances," Dr Marks says. "The approach, because it's what has always been done, is that if we supply the right nutrients onto the crop, they'll find their way into the crop.

"But this can be wasteful. Look at the example of nitrogen. First, we persist in talking about 'nitrogen', when in fact we should be talking about a range of nitrogen-containing molecules, each of which is used differently by the crop.

"And second, too often we don't distinguish between those different molecules – nitrate, ammonium, amine – and their optimum time for application, so a lot of the nitrogen applied to crops ends up not in the crop but in water and the atmosphere. On average, growers apply two-thirds more nitrogen than the crop receives."

With current supply constraints and fertilizer prices reaching record highs in March, it's a practice that farmers can ill afford at present. It's not just nitrogen either. Dr Marks also draws attention to the "sheer unsustainability" of triple superphosphate (TSP) – a form of phosphate from which, he says, crops extract as little as four percent.

Levity Crop Science's planned new HQ and fertilizer research centre in northern England.

IMAGE: LEVITY CROP SCIENCE

Bioactive benefits

In pointing out the shortcomings of applying fertilizers in forms that crops cannot use efficiently, Dr Marks is not simply sniping. To his credit, he's used this critique as a springboard for positive action, by developing crop nutrition products that allow crops to make better use of the nutrients they contain (see box).

"They're what we describe as 'bioactive' compounds," he explains. "Plants are very complex structures, underpinned by sophisticated biochemistry to make them grow and flower, and produce leaves, fruit, tubers, nuts, seeds – the basis of all food on our planet.

"When we apply a crop nutrition or crop protection product, it's usually this chemistry we seek to interact with for the applied product to take effect.

"Most nutrition products are passive, reliant on uptake through roots or leaves to be transferred to the plant's transport system. But plants treat each nutrient differently. Some, like calcium, can only move upward through the plant. Unfortunately, that means an awful lot of foliar calcium applications are largely wasted, because the calcium stays in the leaves and doesn't move around the plant."

The first objective of Levity's research is to understand the behaviour of different nutrients within the crop. Armed with this information, Dr Marks' team can then identify the biochemical pathways responsible for nutrient uptake and transport.

But that's only the beginning. What then follows is an extensive search to find compounds that can either stimulate nutrient uptake – such as the company's LoCal calcium technology – or improve transport within the plant itself. An approach Dr Marks describes as 'supercharging' the plant's existing metabolic pathways.

"We know farmers are frustrated," acknowledges Dr Marks. "Crops often don't respond to these very simple trace elements and micronutrients, despite their influential contribution to overall and marketable yields.

"Our approach is to alleviate that frustration, while also improving resource use efficiency. We get the plant to do the heavy lifting – by using existing pathways to help the crop to help itself. That's why we use the bioactive moniker, and why we call our products 'smart'."

But it's not just about resource use efficiency. While that's a prime driver for Levity's products, Dr Marks comes back to his point about 'harsh' chemicals

"There's an increasing accept
a well-fed plant is a healthy plan
in humans, failure to observe a
diet not only inhibits some of th
ways, but also lowers the plant's

"In addition, most of the c
applied nitrogen fertilizers favou
tive growth, which can make pla
and more susceptible to dise
turn, that might necessitate a
programme to control disease
commonly, a growth regulator to
plant's 'legginess'."

Dr Marks believes that taking more appropriate steps earlier, such as choosing the right form of nitrogen, could reduce the need for such interventions. Growers would benefit, with crops requiring fewer inputs and less complicated plant protection programmes. He also highlights the concerns around dwindling active substances and the ever-present threat of resistance development.

PHOTO: LEVITY CROP SCIENCE

Dr David Marks, founder and managing director of Levity Crop Science inspects a Dutch onion trial.

Export oriented

While active in the UK, most of Levity's customers are found in global markets. Exports account for more than 70 percent of company revenues, with products distributed across the Americas, Africa, the Middle East, the Far East and Australasia, in addition to its 'home turf' in Europe.

"It's a real adventure and a great privilege to be able to help the farmers that grow the world's food," says Dr Marks. "Levity's products are used not only on staples such as wheat and rice and potatoes, but on many other economically significant crops – soft fruits, citrus, tomatoes, cocoa, for instance – to help deliver more, higher quality produce, closing the gap between potential and average yields, and helping the environment at the same time.

"With an additional 2.5 billion mouths to feed globally by 2050, it's essential that we find new ways to increase crop yields and make the agricultural sector as efficient as possible. The importance of resilient supply chains has been thrown into stark relief after the twin 'black swan' events of Covid and the Ukraine invasion.

"On top of that is the growing threat and uncertainty of climate change. If global temperatures rise as anticipated, crop growing will become more difficult – that's why many of our products also focus on alleviating plant stress."

Prestige research centre

It's against this background that the company has recorded year-on-year growth of 40 percent, despite the pandemic's well-publicised effects on global shipping and logistics. These export successes, coupled with Dr Marks' ambition to increase the flow of products through the company's development pipeline – he already holds more than 30 patents – are now taking shape in the form of a new company HQ and crop science research facility in northern England.

The multi-million-pound investment, which is due to break ground imminently, will give Levity several new glasshouses and research laboratories, plus a new head office and a 'showcase space' where the company's products and technologies can be demonstrated to customers.

"The whole set-up will be tailored to the development of smart fertilizers and on completion will stand out as one of the best fertilizer research facilities in Europe," says Dr Marks. "While that 40 percent growth may have been unprecedented, we still have many countries where we'd like to be present but haven't yet been able to identify a distributor – our products are increasingly in demand.

"With the new facility will come more staff, both R&D and commercial, and we'll be able to make more of that growth opportunity."

Diverse product offering

Distributors are keen to stock Levity's product range, reports Dr Marks, because they value its diversity. "We hear feedback that not only does it fill important gaps in their portfolios, but growers like the products because they can see clear results.

"That's very important. Too many crop nutrition products, particularly those targeting trace elements and micronutrients, are not built on sound science.

"They're also very wasteful – yet, with the right science, we can be measuring crop nutrition in grams, not kilograms. Agriculture can't afford to be wasteful, neither with the food it produces nor the resources it uses," he concludes. ■

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Matching products to nutrient behaviour

Understanding how nutrients behave within the crop is the starting point for Levity's products.

Calcium

Calcium gives cell walls rigidity and strength, providing protection from physical damage as well as a first line of defence against fungal and bacterial pathogens. Calcium deficiency is behind diseases such as bitter pit in apples and cavity spot in carrots. Strawberries low in calcium exhibit reduced shelf life and brix, for example, and are prone to mould.

Unlike most nutrients, calcium only moves upwards through the plant. It's transported to the leaves when absorbed through the roots, while foliar applications go no further than the leaf. Complicating things further, calcium absorption by plant cells requires high levels of the hormone auxin.

Levity's LoCal technology contains a naturally occurring 'calcium transport stimulant' which mimics auxin and therefore promotes calcium uptake.

Boron

Many crops are heavily reliant on boron for yield, quality and plant health. Because it's readily absorbed and stored, tissue testing often indicates ample levels. But transport issues, again, make plant utilisation difficult, as boron's mobility varies between crops, and even according to the crop's growth stage. This immobility can encourage over-application – with a fine line between boron deficiency and toxicity.

Levity has formulated a low-rate boron product to avoid phytotoxicity. This is coupled with a specially developed stimulant that triggers the plant to use and direct boron according to need (*Fertilizer International* 504, p28).

Silicon

This element is implicated in several metabolic functions, such as hormones and biotic stress protectors, as well as plant structures. Recent research has also revealed silicon's role in unlocking the yield potential of crops. It's instrumental in the distribution of phosphates, zinc, manganese, iron and copper, for example, and improves nitrogen recovery in low-availability situations.

Plants also use silicon for physical protection, building a thin layer of 'opal' crystals within the leaf cuticle. Once deposited, this silicon becomes biologically inactive. The challenge, then, is to encourage the plant to use the silicon before it's locked away. An added obstacle is that silicon isn't mobile in the phloem, so it must be actively moved in and out of the xylem.

Levity embarked on what was to become a 12-year research programme on silicon, identifying the substances responsible for its transport and then emulating them. The resultant Si-X technology has demonstrated a yield response of up to 1.2 t/ha in wheat trials.

Nitrogen

Extra to its calcium expertise, Levity is also an acknowledged leader in nitrogen efficiency. The company is encouraging growers to think about the type of nitrogen they apply – nitrate, ammonium, amine – not just the quantity. Because all forms of nitrogen degrade to nitrate after application, most research focuses on nitrate uptake and utilisation. However, when the plant absorbs nitrates, it must expend energy to convert it back to ammonium to synthesise essential compounds such as amino acids and chlorophyll. Nitrate applications can also be wasteful, being susceptible to volatilisation and leaching.

Applying the right nitrogen product at the right time, as well as being more usable by the plant, can influence the right kind of growth, such as grain fill over height in cereals, root and tuber development over top growth in potatoes.

Levity's LimiN nitrogen technology delivers amine direct to the plant and, by using stabilised amine urea, prevents its breakdown to nitrate. LimiN features a cross-linkage between the NH_2 amine and a monovalent or divalent cation which renders the NH_2 nitrogen invisible to soil bacteria. This allows growers to apply less nitrogen but achieve the same results.

Manganese

This is an essential element for chlorophyll formation. Deficiency manifests as pale green leaves and reduced photosynthesis capacity. Levity's scientists have combined their LimiN technology with another in-house development, known as Catalyst, to promote the uptake and usage of manganese. This approach enables crops to develop an optimised structure for light capture and to sustain this over an extended period.

Molybdenum

Molybdenum is essential for nitrogen processing and fixation. It's also a component in abscisic acid (ABA) which, alongside ethylene, is the hormone involved in fruit ripening. Unfortunately, ethylene ripens fruit by removing calcium from the cell wall, leaving softer fruit more susceptible to damage, while – advantageously – ABA is able to lift brix and colour without affecting softness. Nevertheless, ethylene will control ripening if the plant's molybdenum levels are low and therefore insufficient ABA is available.

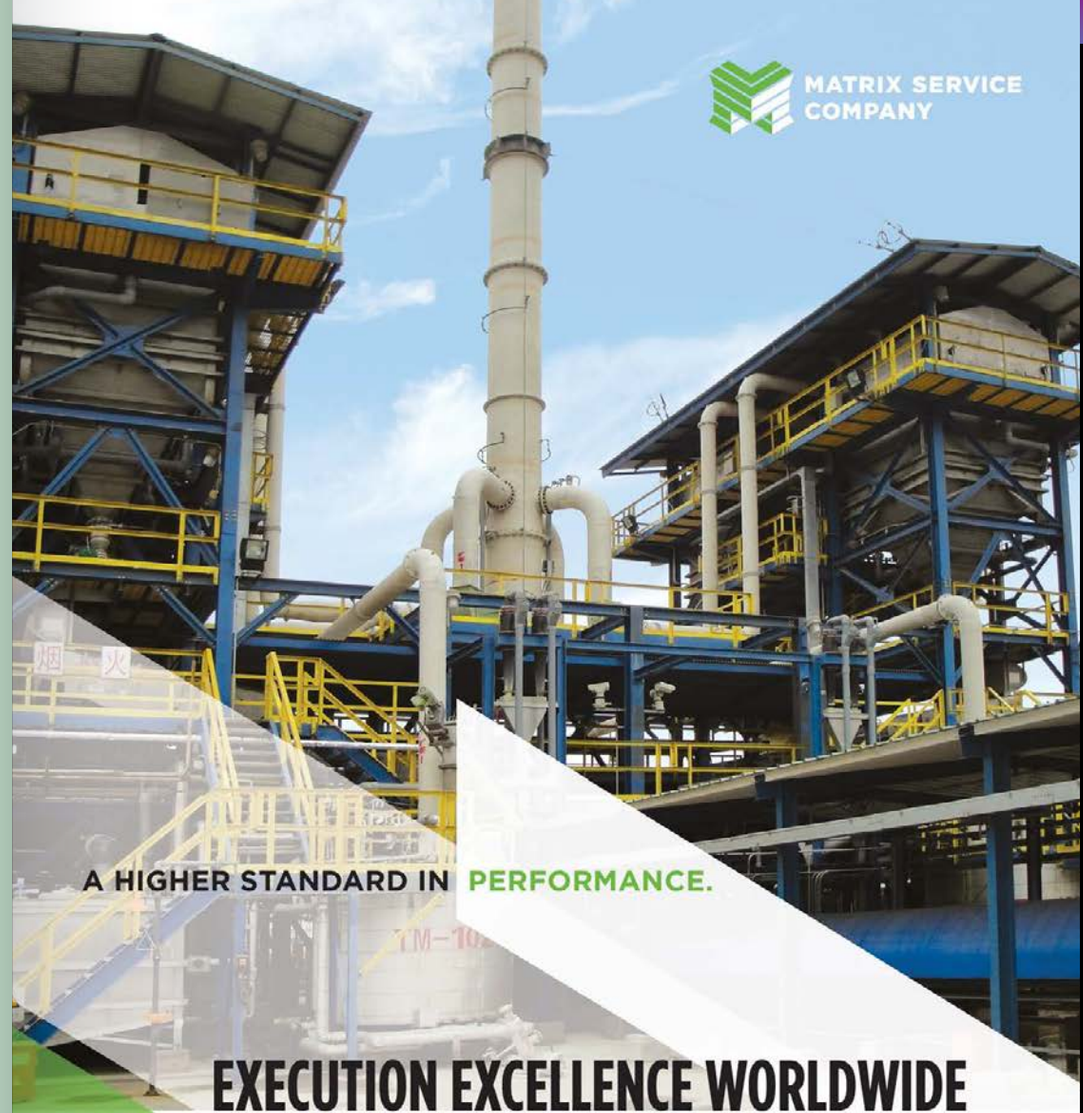
Levity's solution was to use a 'building block' formulation to encourage the plant to make better metabolic use of molybdenum. By applying this micronutrient in 'supercharged' form, the plant is forced into using molybdenum to produce ABA as soon as the fruit enters its maturation phase.

Iron

This is another constituent of chlorophyll and is also involved in several metabolic functions. Iron can often be a problem for farmers on calcareous, high pH soils. Deficiency displays as chlorosis – yellowing leaves – due to poor chlorophyll production. Growers are typically encouraged to use iron chelates to make iron available to the crop.

A strong link, however, exists between nitrogen inputs and iron deficiency. That's because iron is used as an enzyme co-factor when plants reduce nitrates to proteins. As a consequence, crops can use up to 70 percent of their iron in nitrate processing.

Levity's approach involves reducing the plant's need for iron by improving its harvesting of locked-up iron instead. Stabilised amine nitrogen was again the solution – as this allows iron to be reserved for other uses by cutting the plant's need to process nitrates. Moreover, linking the iron to the stabilised amine means that the plant pulls in iron alongside the amine. Finally, supplying nitrogen in amine form also improves the crop's access to other nutrients by promoting better root development. ■



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IFA Global Sustainability Conference

Some 410 delegates from 208 companies and 45 countries participated virtually in the IFA Global Sustainability Conference, 28-31 March 2022. We report on the main highlights of this four-day event.

Above: Green ammonia generation from renewable power will be essential if the fertilizer industry is to drive down its production emissions.

Fireside chat

The conference began with a 'fireside chat' on business sustainability. In his opening remarks, **Svein Tore Holsether**, IFA's chair and the CEO of Yara International said: "We, as an industry, have a huge responsibility to limit hunger crises while also building resilient food systems."

Greater resilience, in his view, would require closing crop yield gaps, investing in renewable energy and regenerative agriculture – and the recycling and recovery of nutrients to 'close the loop'.

Sustainability is an existential issue for a company like Nespresso, said its CEO **Guillaume Le Cunff**: "We'll never be successful selling empty [coffee] capsules in future. We're either in or out of business." That made sustainability both a business necessity as much as an opportunity, in his view.

What also emerged from the fireside chat was the central role fertilizers play in the sustainability of the whole food system. Farm livelihoods – and creating value in general – depend on greater crop yields, for example, while net zero could only be achieved by reducing the carbon footprint of crop nutrients.

For his business, Guillaume Le Cunff gave the example of the 100 grams of CO_2 (Scope 1, 2 and 3) emissions associated with a single seven gram cup of coffee. Coffee itself generated 50 percent of these emissions, the packaging 15 percent, while crop inputs – notably fertilizers – were responsible for the remaining 35 percent.

Guillame believes the coffee industry can make it to net zero within the next decade by actions such as switching to regenerative agriculture and the circular economy. Nevertheless, driving down fertilizer emissions would be key.

"If we don't manage to turn around that [crop] input footprint, we're not going to get to net zero. It's going to be make or break," said Guillame. "We have a common responsibility to get to net zero. Your industry [fertilizers] is critical. Now is the right time to partner."

Because crop yields are crucial for farmer incomes, yield improvements, not just yield stability, are needed to make a difference.

"We have to reward the work and efforts of farmers, including being able to guarantee some kind of yield stability and consolidate a living income to keep farmers on the farm," said Guillaume.

Svein Tore agreed that a new approach was necessary: "Commodity thinking is hurting the whole food system. For a £3 cup of coffee, in general, the grower of coffee beans gets one penny – the farmer is marginalised."

He also believed that crop nutrients have a clear role in making food heathier and more sustainable: "Fertilizers help quality, nutritional value and carbon footprint. By adding micronutrients we can make food more nutritious."

Mobilising the necessary finance for sustainability was a key issue for **Tensie Whelan**, the director of NYU's Stern Center for Sustainable Business. "Finance in companies has been late to the table on sustainability and have seen it more as a cost than an opportunity," she said. "It's not about affordability vs sustainability. The two can go hand-in-hand."

Roads to net zero carbon emissions

The role of blue, turquoise and green ammonia in delivering a net zero ammonia industry was discussed by **Vinod Patel** of Intercontinental Energy, **Bjorgulf Eidesen** of Horizont Energi and **Rob Hansen** of Monolith Materials.

InterContinental Energy is major developer of gigawatt-scale renewable fuel projects globally. The company's portfolio is building a total of 200 gigawatts of green hydrogen and 80 million tonnes of green ammonia capacity. Its announced projects include the Asian Renewable Energy Hub and the Western Green Energy Hub located in Western Australia, as well as Green Energy Oman in central Oman and the Saudi Arabia Renewable Energy Hub.

Norway's Horizont Energi is part of Barents Blue, the largest clean energy project in Europe. It is seeking to build Europe's first world-scale (three million tonne capacity) blue ammonia plant by 2025.

Monolith Materials is developing a number or turquoise ammonia (methane pyrolysis) projects globally. These include Olive Creek 2, an expansion to its existing Olive Creek 1 project in Nebraska. The company also has tens of other projects in the pipeline in the US, South Korea and Japan.

Moderator Trevor Brown of the Ammonia Energy Association asked whether colour-coded green, blue and turquoise labels for ammonia were actually valuable.

Monolith's Rob Hanson said he was "technology agnostic" on low-carbon ammonia production: "To be nuanced and precise, I prefer carbon intensity, not colour or production method. We should make CO_2 going into the atmosphere the metric, not colour."

Bjorgulf Eidesen was similarly sceptical: "We have found colours troublesome. In the EU there's a focus on green. But green is not always green, blue is not always blue. It not about colour, it's about carbon intensity, water resources etc."

Looking ahead, all three panellists agreed that action on ammonia decarbonisation was necessary, both now and over the longer term.

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"We overestimate what we accomplish in a year, but underestimate what can be achieved in a decade," said Rob Hansen. "Climate change is the challenge of our time. It's a century long challenge. We need to think longer term."

"The coming four years are the years for action for low-carbon ammonia," added Vinod Patel: "There are challenges still to be addressed – new technologies can help address these."

Summing up, Bjorgulf Eidesen said: "We believe that blue and green ammonia are key enablers of net zero. The 2030 [EU] goal is particularly challenging. We need the political will and innovation to see that happen."

Scope 1, 2 and 3 emissions

Driving down emissions will be necessary to place global agriculture on a low-carbon trajectory. But how will this be delivered? In this conference session, **Rupert Simons** of SystemIQ and **Tony Siantonas** of the World Business Council for Sustainable Development (WBCSD) unveiled the latest results of two pioneering collaborative projects with IFA.

SystemIQ is developing a 'fertilizer in-use roadmap' for cutting fertilizer Scope 3 emissions. This is due to be completed by the end of June.

Mineral fertilizer use globally generates (in the form of N_2O) around 0.6 gigatonnes of CO_2 equivalent emissions, or about 30 percent of total agricultural N_2O emissions. This is equivalent to around one percent of world greenhouse gas (GHG) emissions – roughly the same amount generated by Germany. In terms of total life cycle impacts, fertilizer production and transport (Scope 1 and 2) is responsible for 20-50 percent of fertilizer GHG emissions, while downstream use (Scope 3) is responsible for 50-80 percent.

Fertilizer Scope 3 emissions currently stand at around 650 million tonnes CO_2 equivalent. Looking ahead, SystemIQ has identified opportunities for 84 Mt CO2e emissions savings across six global crop systems. These are primarily achieved by adopting best fertilization practices and changing crop rotations, with better nutrient use efficiency (NUE) delivering about 70 percent of the abatement potential. Many measures offer cost savings, although barriers to adoption by famers were also identified.

"Over half of projected CO_2 emissions could be abated by 2050 by increasing nutrient use efficiency, crop rotating and land sparing, all while ensuring that people do not have to reduce their consumption of protein," said Rupert Simons.

SystemIQ's fertilizer in-use roadmap is part of the wider 'Fertilizer 1.5' project. This project, a collaboration between IFA, WBCSD and SystemIQ, is described as a "pre-competitive initiative to align the fertilizer sector to a 1.5°C pathway". It consists of three workstreams:

- Sectoral Decarbonisation Approach (SDA)
- Fertilizer in-use roadmap
- Climate Action Leadership Coalition.

As part of the SDA, the fertilizer sector needs a credible, independent science-based method for aligning to a 1.5°C trajectory by 2050. "We are looking at the development of a robust standard for the fertilizer sector while making sure that these pathways are inclusive and relevant for the whole industry," said Tony Siantonas.

Game changers

Game changers for sustainability were the subject of a panel discussion between **Olivier Noterdaeme**, a partner at McKinsey & Company, World Bank economist **Dominik Englert** and **Olivier Mussat**, the CEO of green hydrogen/ammonia company Atome.

The green hydrogen market represents a $10 trillion market opportunity according to Olivier Mussat. The 0.4 GW of green hydrogen capacity currently available is projected to increase to around 465 GW by 2050.

Atome is developing its first green ammonia project in Paraguay. This 50MW project will capture excess hydropower and use this to generate 45,640 t/a of green ammonia by 2023/24. It is also pursuing a second 31,000 t/a green ammonia project in Iceland

Such projects will need to be developed rapidly. "Over the next five years there will be a shortfall between the supply and demand for green ammonia and hydrogen," said Olivier Mussat.

The decarbonisation of global shipping could be done in collaboration with the fertilizer industry's ammonia producers, suggested Dominik Englert. "In the future ship fuelling will much more decentralised as ammonia-powered ships will fuel more frequently and fuel production will be more democratic. Shipping moving to ammonia is a $1.4-1.9 trillion business opportunity," he said.

Financing sustainability

To help decarbonise its business, CF Industries' is pursuing a number of green and blue ammonia projects currently. Commenting on these, CEO **Tony Will** said: "Finding new, disruptive opportunities to expand business – it's not cheap, it's not without risk."

But the key question on sustainability in his view was: "Do you want to lead or be led?" Answering his own question, Tony Will suggested that CF industries was very much positioning itself as a leader by introducing a new vision for the company as a provider of clean energy to feed and fuel the world. He described this as "a very noble purpose" that staff could be proud of and connect with.

Embracing sustainability is also going to require corporations to redefine their purpose, in his view. "Stakeholder capitalism will support employees, vendors, the community and shareholders," he said.

The IFC's **Irina Likhachova** highlighted the scale of biodiversity loss currently: "One million species are threatened with extinction and 14 of 18 assessed ecosystem services are in decline."

Fortunately, business is starting to take action to address this. In 2021, for example, a total of 89 financial institutions from 19 countries with over €13 trillion in assets signed the Finance for Biodiversity Pledge.

Around $44 trillion of economic activity globally depends on nature to a high or moderate degree, according to the World Economic Forum. Because of this, the scaling up of finance to address biodiversity loss could eclipse climate finance. "Get ready for biodiversity as a topic. It's coming faster than you think. Nature finance is climate finance on steroids," said Likhachova.

Carbon markets

Globally, soils remove five gigatons of carbon every year – with potential for carbon farming to increase this by a further one gigatonne annually.

Agoro Carbon Alliance, a new start up owned by Yara International, is helping bring this about by launching a carbon credit schemes for farmers. "It's a new way of bringing capital to the farm... [and] seize the benefits of carbon farming," said its CEO **Alex Bell**. "I believe carbon farming is the future in so many ways."

Companies can buy credits to offset their emissions through the voluntary carbon market (VCM). There are currently around 5,800 VCM projects globally. About 44 percent of these are land-use projects and 31 percent renewable projects. These projects avoid or reduce about 1.1 billion tonnes of CO_2. They are certified by an authorised third party to assess their capacity to sequester, reduce or avoid CO_2 emissions.

Pablo Verra of Deloitte was confident that they have a future: "VCMs are here to stay. The fastest way for a company to go carbon neutral is to buy carbon credits."

ESG-related loans

ICL's **Kobi Ilia** presented a case study on a €250 million sustainability-linked loan (SLL) secured by the company. SLLs enable companies to capitalise on their environmental, social, and corporate governance (ESG) performance and use this to benefit their bottom line.

The granting of SLLs is linked to verifiable sustainability commitments and their associated key performance indicators (KPIs). ICL, for example, had already committed to a reduction of its Scope 1 & 2 emissions of more than 20 percent by 2025. It was also assessed for the SLL on two other KPIs: supplier score cards and the number of female senior employees.

Chief Finance Officers have a key role to play in delivering company sustainability, concluded Kobi Ilia. Internal cooperation is also necessary. "Alignment between ESG and finance teams is essential to get results," he said.

Bank of America's **Lizabeth Bronder** discussed ESG debt instruments and the choice of loans versus bonds. This market is no longer fringe and instead is becoming an increasingly popular investment choice. "Investors are increasingly making requests to invest in the sustainability debt market," Bronder said.

CEO roundtable discussion

Sustainability success was the topic under-discussion in this session.

"Sustainability is about doing the right thing. Optimising the use of resources for the long term as we now we have another stakeholder – the planet," said ICL's CEO **Raviv Zoller**.

Tip O'Neill, IRM's CEO, agreed that to become more sustainable the industry needed "stakeholder capitalism over shareholder capitalism" as it was "important that money follows mission" and not the other way around. He also said the industry was going to have to "figure out a way of tracking carbon".

"In a few years from now we will all need to know the carbon footprints of our operations and projects. Products will have carbon labels on them," O'Neill said.

OCI's CEO **Ahmed El-Hoshy** agreed. "Environmental tracking will be very important. By labelling carbon intensity you can incentivise people to invest in lower carbon products via open markets."

ESG reporting

Reporting on environmental, social, and corporate governance (ESG) is becoming a bottom-line issue for business. "75 percent of financiers, for example, are now looking at ESG performance when making investment decisions," said OCP Group's **Bachir Mouhy**.

The top three risks faced by business over the next decade – climate action failure, extreme weather and biodiversity loss – are also all ESG risks, according to the World Economic Forum.

Asking "who is your key audience?" was important, according to **Kelvin Roth** of CF Industries. "When it comes to ESG reporting, the numbers are important but so are the stories," he said.

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Being open to scrutiny and external benchmarking is also becoming standard practice in ESG reporting. This requires transparency and engagement with external organisations such as the Global Reporting Initiative (GRI), the UN Global Compact, the Task Force on Climate-Related Financial Disclosures (TCFD) and ratings agencies. "Don't do this on your own," urged Kelvin Roth. "Sustainability and ESG are a collective effort."

"ESG reporting is a learning process," said Bachir Mouhy. So start where you're comfortable, as you can't go to 100 in months. Sustainability is a moving target – you just need to reach for the stars!"

Carbon cutting commitments

Netherland-headquartered nitrogen producer OCI is decarbonising its operations by reducing its Scope 1 & 2 emissions by 20 percent by 2030, from a 2019 baseline. Up to three-quarters of this target will be met through operational improvements, while much of the remainder will be achieved via green and blue ammonia projects.

"OCI has a 20 percent emissions reduction target and its transition pathway will use blue and green hydrogen and bio-methanol among other solutions," said OCI's **Hanh Nguyen**.

The Mosaic Company, meanwhile, has set itself a net zero target for its Florida operations (Scope 1 & 2) by 2030. This target has been extended to 2040 for the company's operations elsewhere. "We will achieve net zero by addressing the emissions from our four walls – harnessing low carbon energy, optimising operations and capturing carbon through our land holdings," said Mosaic's **Natali Archibee**.

Reducing Scope 3 emissions

"Companies with highest exposure to nitrogen fertilizers have the highest exposure to [Scope 3] emissions," said Nutrien's **Matthew Salens**. This was because of their association with agricultural N_2O emissions.

Nutrien is addressing its Scope 3 emissions through actions such as its 75 Mha farmland initiative and carbon farming programme. It is also committed to the IFA/WBCSD sectoral decarbonisation approach (see above), as well as developing a vessel powered by low-carbon ammonia with Exmar.

Shipping is responsible for three percent of global emissions and these are currently on a trajectory to increase by 17 percent by 2050. Bulk carriers alone generate 440 million tonnes of CO_2 emissions annually. Although not covered by the Paris Agreement, the International Maritime Organization (IMO) has set an emissions reduction goal of 50 percent for global shipping by 2050.

"The biggest sustainability challenge the shipping industry faces today is the lack of availability of alternative fuels," says Nitron's **Felix Dostmann**. Consequently, to kick-start action on Scope 3 emissions, Nitron has set up a carbon offset pilot programme for the shipping industry. The pilot is backed by two offset projects in Colombia and Chile.

Circular economy

EasyMining is helping Europe to recover valuable phosphorus present in sewage sludge ash (SSA). The company is currently planning a 15,000 tonne capacity calcium phosphate plant in Germany, based on its proprietary Ash2Phos process. "We have a responsibility to ensure that the SDGs are really implemented. Phosphorus recovery can reduce pressure on the market and help the poor get access to fertilizers," said EasyMining's **Christian Kabbe**.

Aleff Group's **Julian Hilton** gave an update on progress towards phosphogypsum (PG) reuse. "Of all the nutrients, phosphorus is the most recyclable and essential for life. I'm increasingly optimistic. My view is that by 2035, we might get to 100 percent [phosphogypsum] use," he said.

Julian listed the countries that are "clearing the way" for complete PG reuse: "Indonesia is using all its PG. Belgium and Brazil are at 100 percent use; India is about 70 percent, China 40 percent."

Phosphogypsum by promoting afforestation also offers clear climate benefits. "PG works very well as a man-made soil to improve forest growth that can help improve carbon sequestration," said Hilton.

Soil carbon sequestration

The '4 per 1,000' initiative was launched at the COP21 climate conference in France in 2015. It is working with a consortium of 310 signatories to implement better farm practices for sequestering carbon. These include integrated soil, fertilizer and water management, greater use of cover crops, conservation agriculture and agroforestry.

"We need to get inspiration from the way nature performs to help us to redesign our farming systems," said 4 per 1,000's **Paul Luu**.

Evidence that, in future, nitrogen fertilizers can act as a sink instead of a source of greenhouse gas (GHG) emissions was presented by **Holger Kirchmann** of the Swedish University of Agricultural Sciences (SLU).

"As long as you can increase crop yields you can increase soil carbon. If yields stagnate you get no soil carbon increase. Through nitrogen fertilization, more carbon is actually sequestered than by no-tillage," he said.

Nutrien has launched a pioneering carbon pilot programme, as **Sally Flis** explained: "We looked at five main carbon practices in our pilot schemes based on nitrogen management, soil health and optimised productivity."

The nitrogen management practices being adopted as part of the pilot include the use of slow- and controlled-release fertilizers (SRFS/CRFs), urea inhibitors and variable rate fertilization (VRF). The costs and returns on investment are being evaluated. This will take time, though, as the benefits of some practices (cover crops, no-till) can take more than five years to fully emerge.

The measurement and verification (MRV) of the rapidly expanding voluntary carbon market (VCM) presents challenges, according to the Environmental Defense Fund's **Emily Oldfield**. "There is substantial investment going into carbon credit programs and a rapidly expanding voluntary carbon market but there are many complexities and challenges involved," she said. The solution, in her view, was to ensure that MRV was based on consistent measurements and standards – as this would guarantee high-quality soil carbon credits.

Verra runs Verified Carbon Standard (VCS), the world's leading voluntary GHG programme. The company is refining its accounting methodologies for VCS to improve measurement and verification.

"We are looking to implement 4Rs best management practices (BMPs), update and expand applicable emissions factors (EFs) and have a stronger focus on biological nitrogen fixation in our agriculture methodologies," said Verra's **Viridiana Alcantara-Shivapatham**.

Summing up

IFA's director general **Alzbeta Klein** thanked the organisers, sponsors, presenters and delegates for contributing to a successful event.

"Reducing and reversing biodiversity losses and reducing carbon emissions will come with costs. But these are outweighed by the priceless benefits of helping to ensure the future wellbeing for the planet," she said. ■

Sulphur forming technologies

It is generally necessary to solidify sulphur into a robust form suitable for handling and long-distance transport. Granulation, pastillation and prilling are some of the technologies used to produce solid sulphur from molten material. Similar technologies are also used to manufacture sulphur fertilizers.

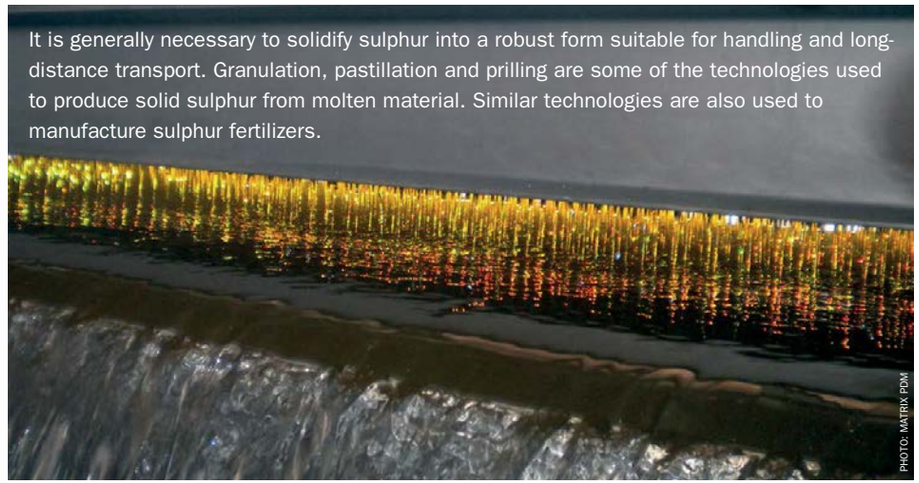

PHOTO: MATRIX PDM

Molten sulphur in a forming tray above a water column.

KREBER

Developments in sulphur prilling

Family-owned and Rotterdam-based prilling company Kreber was founded in 1902. The company offers prilling equipment and technology for sulphur and fertilizers such as urea ammonium nitrate and calcium ammonium nitrate.

Kreber has a strong focus on innovation and operates both a prilling laboratory and pilot plant facilities. The company's in-house R&D team also collaborates with Delft University of Technology and other research institutions. These collaborative efforts resulted in the development of Vibro prilling. This major breakthrough – by adding a vibration to the melt – produces more uniform prills with a narrow size distribution.

Kreber has been monitoring new developments in sulphur prilling and has highlighted the challenges that remain (*Sulphur* 389, p30), as summarised on the next page.

PHOTO: KREBER

A modern sulphur prilling tower.

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Prilling and other sulphur-forming technologies

Sulphur forming – the transformation of large volumes of molten sulphur into solid particles suitable for transport – has always been a challenge. Forming was originally achieved by crushing solid sulphur blocks into smaller pieces. But the industry soon started looking for new technologies to form sulphur due to the dust formation and handling problems associated with this approach.

One of these technologies was air prilling, a method already successfully employed by the fertilizer industry. Prilling generates large quantities of small yet perfectly spherical pellets as a finished product. Advantageously, these sulphur prills are free-flowing with a polished surface and a relatively narrow particle-size distribution. Prilling went on to become the dominant method of producing solid sulphur. This led to the widespread introduction of the SUDIC (Sulphur Development Institute of Canada) specification as a market standard for all sulphur finishing technologies.

A range of other sulphur solidification processes, including granulation, (steel belt) pastillation and wet prilling, have become more prevalent over time. This shift to new sulphur forming methods resulted from two main concerns.

Firstly, prilling towers operated in the 1960s were based on an open-air design. These immediately ejected all the cooling air used for solidifying prills into the atmosphere. This air was laden with dust from the prilling process and vapours from the sulphur melt – causing environmental problems downwind of the prilling plant.

Secondly, it was concluded that dry prilling should be classed as a high-risk technology following a major fire at a prilling tower in the Middle East. This disastrous incident demonstrated how two factors – low ignition energy and the potential build-up of static charge in solidifying prills – can cause dangerous sparks, especially in the hot, dry climate of the Middle East.

Safer and more sustainable prilling

In the last few years, prilling has been developed to handle a wide variety of products. Air treatment sections were also widely incorporated into designs from the late 1980s onwards. These use either a dry filter or wet scrubber to drastically reduce prilling tower dust emissions.

Nevertheless, more stringent regulations have been applied to prilling towers as the environmental impacts on their surroundings have become more apparent. This has resulted in a surge of new research – with the development of the closed loop prilling process being one of the main outcomes.

Closed loop prilling

In a closed loop process, the cooling medium (air) is reused after firstly being cleaned in a treatment section and then cooled down in a heat exchanger. One of the main benefits from closing the loop is that emissions are reduced to zero. Additionally, the heat removed from the cooling medium can be reused elsewhere in the plant, leading to better overall heat integration and efficiency.

Prilling is widely applied in other industries where similar fire and dust explosion hazards exist – these usually being associated with the air treatment section. One advantage of the closed loop prilling process is that the complete recycling of the cooling medium eliminates the need to use ambient air. As wastage is very limited, practically any gas can be chosen as a cooling medium. Consequently, prilling towers which use inert nitrogen gas as a cooling medium have started to emerge. They offer an intrinsically safe method of prilling with no emissions and a low fire hazard.

Looking ahead, closed loop prilling towers are showing promise for sulphur forming, due to their growing reputation as a safe and high-capacity production process for converting melts into finished solid products. The main challenge now, suggests Kreber, is to adapt the closed loop processes used in plastics and fertilizer prilling into systems that can safely handle sulphur.

Latest innovations

Prilling has gone through many developments since its emergence in the 18th century. The latest innovations are mainly in the off-gas section and improved process control. These have led to a safer and more reliable production of sulphur prills from melt.

Prilling – by providing desirable product qualities such as a narrow particle-size distribution and free flowing behaviour – has distinct advantages over the other main sulphur finishing technologies, according to Kreber. Looking ahead, closed loop prilling using an inert cooling medium shows great promise as a method for prilling sulphur in the safest and most economical way (*Sulphur* 389, p30). ■

PHOTO: ENERSUL

Enersul wet prilling unit.

Wet prilling

The Canadian sulphur technology company Enersul offers the WetPrill forming method as an alternative to its well known the GX granulation process. Wet prilling allows sulphur forming to take place at a higher temperature and, according to Enersul, is associated with lower operational costs and a smaller plant footprint. The process generates low friability, low moisture content and high bulk density prills. These high-quality end products are small, round and uniform with few entrained fines and are easy to handle and transport.

In the WetPrill process, molten sulphur is pumped into perforated streams at the top of a forming tower. This generates small droplets of liquid sulphur in a controlled manner which then fall into the top of a tank of cooling water to instantly solidify into uniform pellets.

The process has been continuously refined and improved by Enersul over the past three decades through in-plant operational development and pilot plant research. WetPrill units are individually designed to meet customer requirements and available in capacities of up to 2,500 t/d. ■

IPCO

Advances in drum granulation

IPCO is a world leading manufacturer of sulphur processing and handling equipment. The company has successfully delivered hundreds of complete end-to-end systems around the globe since 1951. In addition to granulation drums, more than 700 IPCO Rotoform sulphur processing systems have been installed worldwide to date. Rotoform is an environmentally-friendly sulphur pastillation system designed to meet small to medium capacity requirements. It produces premium quality pastilles of uniform shape and size.

PHOTO: IPCO

IPCO has installed its innovative SG20 sulphur granulator in Italy.

New showcase drum granulator

IPCO recently commissioned a groundbreaking new SG20 drum granulator in Italy (*Sulphur* 395, p28). This fully automated, once-through sulphur granulation system is based on rotating drum technology. The unit has been delivered to a long-standing Italian customer operating multiple sulphur solidification lines. IPCO has an agreement in place that enables prospective customers to visit the site and observe a fully functioning unit working under operational conditions.

The SG20 is a scaled-down version of the company's 2,000 t/d capacity SG30 model. This medium-size unit offers a solidification capacity of up to 800 t/d and is noted for being easy to monitor, its quiet operation and good maintenance access.

The SG20 and SG30 models use the same design and operating principles. Both are based on single-pass granulation process that eliminates the need for screens or recycle conveyors. They also incorporate an innovative approach to sulphur nucleation. Sulphur seed particles are created outside the granulation drum by freezing a liquid sulphur spray in a water bath. Generating these particles externally, while also consuming sulphur recycled from the downstream wet scrubbing system, simplifies the process. It also allows more flexibility over the temperature of liquid sulphur entering the granulator.

SG series units deliver high-quality sulphur granules that satisfy the shape crite-

Table 1: **Advantages and benefits of the SG system**

Feature	Advantage	Benefit
Minimised build-up	Reduced housekeeping	● Increased equipment availability ● Less labour
Heated sulphur nozzles	No frozen nozzle tips	● Increased equipment availability ● Less labour
Completely level drum	Minimal shearing forces on rollers	● Increased equipment life ● Less maintenance (no alignment)
Combustion of wet scrubbing with external seed generation	Lowest sulphur dust emissions	● Easier environmental permitting
	Recycled scrubber waste	● Eliminates scrubber waste stream ● Lower steam consumption
H_2S scrubbing solution for drum granulator	Reduced H_2S emissions	● Easier environmental permitting
Operator guidance system	Precise control in all scenarios	● Reduced training and experience requirements ● Efficient use of utilities
	Simple operation of equipment	● Easy to maintain product quality and efficient use of utilities

Source: IPCO

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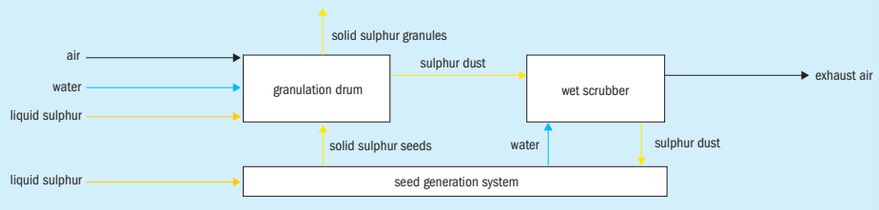
Fig. 1: **Basic process flow diagram**



Source: IPCO

ria and friability requirements (Stress Level I and II) of the SUDIC product specification. This ensures that formed sulphur can be stored handled and transported efficiently, cleanly, and safely. The SUDIC specification also limits moisture content. This is important as excess moisture, by adding weight, creates avoidable extra transportation and melting costs. The presence of moisture also raises acidity and therefore increases the corrosion risk for storage, handling and transportation equipment.

Enhanced capabilities

In designing the SG series, IPCO has taken the inherent advantages of drum granulation – i.e., its combination of large capacity and high product quality – and added to these by overcoming the challenges previously associated with this sulphur forming method (Table 1). For example:

- Equipment availability has been increased by significantly reducing cleaning and maintenance requirements.
- Reductions in sulphur dust and H_2S emissions ensures these are kept well within the limits set by prevailing environmental legislation, while noise levels are far below standard limits.
- A new drum design increases equipment life by cutting roller stress and wear.
- Operations have also been simplified – allowing the units to be stopped and started at the touch of a button.
- Finally, a game-changing operator guidance system enables high-quality products to be generated at all times, regardless of operator experience and process conditions.

Key innovations and operational advantages

A simplified drum granulation process is shown schematically in Figure 1. The IPCO patented SG system has been designed to overcome the drawbacks often associated with traditional drum granulation, especially cleaning, maintenance and process control. The main operational advantages are listed below.

Substantial reduction in sulphur build-up. The SG20 can run continuously for a full week before a shutdown is required. Even then, cleaning requirements are minimal compared with traditional drum granulation systems.

Heated sulphur nozzles. Liquid sulphur has to be maintained at a specific temperature range (around 120 to 160°C). Any liquid sulphur remaining in the nozzle when the system is shut down will freeze and block flow at the next start-up. IPCO has overcome this potentially time-consuming maintenance issue by incorporating the industry's first heated sulphur spray nozzles in the SG series drum granulators. This completely eliminates the need to send maintenance crews into the drum to fix freeze up problems.

Redesigning the drum to minimise roller wear. IPCO's SG series granulators (see overhead photo), instead of rotating at an angle, operate on a completely level base and use angled internal flights to advance the product instead of gravity. This prevents unnecessary wear and tear on the rollers, and avoids the regular maintenance needed to keep the unit properly aligned.

Dust emissions and scrubber waste. IPCO chose a wet scrubbing system for the SG series due to its ability to deliver the lowest sulphur dust emissions and therefore have the lowest environmental impact. The waste stream from the scrubber is also recycled directly into the external seed generation system (see photo).

Managing H_2S emissions. The spraying of liquid sulphur through nozzles as part of the drum granulation process releases H_2S. Therefore, to comply with strict European regulatory limits, preventative measures need to be taken to prevent H_2S from entering the atmosphere. This can be achieved by the addition of an H_2S scrubbing system to reduce stack emission levels and ensure compliance with the most stringent regulations globally (see photo).

Consistent operation. Operating conditions, such as throughput, liquid sulphur feed temperature, ambient temperature and humidity, all need to be taken into account during the solidification process. While a drum granulator can be set to operate at fixed parameters, this is likely to result in sub-optimal performance when these conditions change. SG series units therefore incorporate an operator guidance system – an industry-first for sulphur drum granulation. The system uses process simulation to ensure that the granulator is working at its full potential under different operating conditions. An accurate simulation was developed by analysing real operational data generated by both the SG20 and SG30 units. ■

PHOTOS: IPCO

The SG20 drum granulator operates on a completely level base instead of rotating at an angle.

The waste discharge from the wet scrubbing system is recycled to the upstream sulphur seed generation system.

The addition of an H_2S scrubbing system ensures that stack emissions comply with the most stringent regulations globally.

Rotoform pastillation for sulphur fertilizers

Sulphur-bentonite pastilles

Sulphur-bentonite pastilles combine elemental sulphur with 10 percent bentonite. This special clay swells in wet soil, breaking apart the pastilles and releasing dust-size particles of elemental sulphur. These can then be easily oxidised into plant-available sulphate by soil microbes.

Rotoform pastillation

IPCO's Rotoform process is ideally suited to the small/medium capacity pastillation of sulphur fertilizer products. It is simple and versatile, with low investment and operating costs, and minimal environmental impacts.

Multi-nutrient fertilizers can be created by combining sulphur with macronutrients (such as nitrogen from urea) or micronutrients, opening up new opportunities for producers in the speciality fertilizer market. The range of suitable speciality products includes:

- Sulphur-bentonite + micronutrients, e.g. zinc, iron, boron
- Urea + sulphur
- Urea + ammonium sulphate.

The Rotoform process has been used to successfully mix sulphur with urea to produce Special S and Urea-ES products.

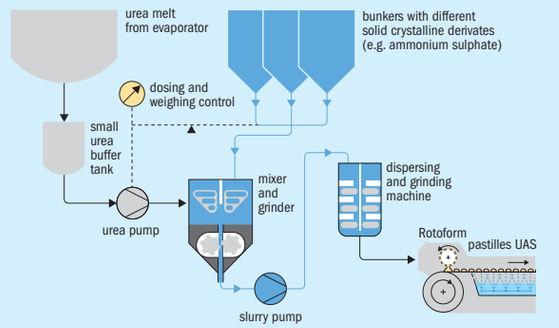
The Rotoform process, when linked to an upstream dosing and mixing plant, can be delivered as an automated continuous process for fertilizer production. An example of an IPCO plant for blending and mixing urea with sulphur is shown in Figure 2.

Additional benefits provided by the IPCO Rotoform process include:

- High-quality uniform and free-flowing pastilles with high crushing strength
- Very low dust, vapour and gas emissions
- Low power consumption.

The superior performance and operational flexibility offered by IPCO's Rotoform process allows fertilizer producers to develop and launch innovative new sulphur-enhanced fertilizers. These can boost profit margins by adding value to existing commodity products, while at the same time helping farmers to achieve the higher crop yields they need. ■

Fig. 2: **IPCO mixing and blending plant – for efficient dosing, weighing, mixing and grinding with accurate control and easy maintenance**



Source: IPCO

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MATRIX PDM ENGINEERING

Sulphur forming for a global market

David Savage, project manager & sulphur subject matter expert, and Vikas Moharir, VP, business development

As world markets continue to reel from supply chain issues first triggered by Covid-19, the impacts on both producers and consumers of sulphur – a vital raw material used in the creation of sulphuric acid and the subsequent production of fertilizers – have been no exception.

For fertilizer manufacturers, the price of molten sulphur is up more than 400 percent compared to a year ago, while transportation and other operating costs are also on the rise as diesel and other utility prices increase. Now, geopolitical events also threaten further supply chain disruption and increases in material costs. These includes the worldwide sanctions placed on Russia (the largest global exporter of fertilizer) in response to its invasion of Ukraine, and China's recent lockdowns in Shanghai and Beijing.

In this environment, producers and consumers are looking for ways to:

- Lower capital outlay and operating costs
- Ensure sufficient product moisture to minimize the dangers associated with dust formation
- Minimise logistical issues associated with long-distance shipment
- Maximise longer-term storage.

The method chosen for sulphur forming, a process used to solidify molten sulphur, is critical when it comes to achieving these objectives.

Exploring the options.

Technologies available for sulphur forming include granulation, pastillation, and wet prilling.

- **Granulation** is a process where molten sulphur is sprayed onto a seed curtain within a rotating drum and water is then sprayed into the drum to cool the sulphur, forming sulphur granules.
- **Pastillation** occurs when water is sprayed under a steel belt onto which liquid sulphur drops have been deposited, producing pastilles or small lozenge-shaped sulphur pills. During pastillation, water and sulphur do not come into direct contact during the forming process.

PHOTO: MATRIX PDM

Above: Two Devco II wet prilling units, central China. These 8,600 t/d capacity units have a space-efficient, modular design.
Below: The formed sulphur prills from the Devco II system after screening.

PHOTO: MATRIX PDM

- **Wet prilling** is the other option. It is provided through modern technology like the Devco II system, a proprietary prilling technology offered by Matrix PDM Engineering. In wet prilling, molten sulphur travels through a counter-current forming tank where it is exchanged with water to produce uniformly sized prills. These are withdrawn from the bottom of the forming tank after which the correct amount of water is removed on dewatering screens.

As forming methods, granulation and pastillation both require the addition of proper dust control during handling and transportation due to their similar environmental and safety risks. Both methods often require sulphur preconditioning too. This is to ensure that sulphur is maintained at an optimal temperature and any H_2S generated – a highly toxic gas found in molten sulphur – is kept to safe, minimal levels.

Wet prilling offers maximum flexibility in moisture control. In our view, it is the only forming technology that properly maintains sulphur moisture content for global market transportation by meeting or exceeding international requirements set by global sulphur importers. The ability to optimise moisture content has also been proven for long-term storage under extreme environmental conditions (hot arid, hot humid, extremely cold) without the need for additional dust control or specialised loading equipment.

Advantageously, the technology used for wet prilling:

- Is modular in design and construction, resulting in **lower capital outlay**. Among its major components are the forming tray(s), forming tank, dewatering screen(s), fume hood, process water cooling system and atmospheric fume scrubber (when required). No intermediate molten storage, pumping or pre-conditioning is required between the sulphur recovery unit (SRU) and prilling system.
- Has **lower operating costs** – critically important in the current environment, especially in energy-intensive industries such as fertilizer production. These reduced operating costs are achieved through minimal power consumption, a gravity-driven process flow, minimal moving parts, elimination of the need for dust suppressants, and fast start-up/shut down.
- Offers flexibility in processing capacity while also offering a **substantially higher maximum single-unit capacity with a significantly smaller footprint**. For example, a single Matrix system has a capacity of 2,000-2,250 tons per day (t/d) compared to a single granulation unit which has a capacity of approximately 500-1,000 t/d and a typical pastillation unit with a capacity of 120-275 t/d. The Matrix system's footprint is just 10 metres by 8.5 metres, small compared to similar capacity systems for granulation (38 m x 22 m) or pastillation (28 m x 26.5 m).

The Devco II wet prilling system

The Devco II system, the modern proprietary wet prilling technology offered by Matrix PDM Engineering, is notable for combining high production capacity with low capital outlay and operating costs. This system is currently installed in more than 18 countries and on nearly every continent, with proven operational success under extreme weather conditions and in highly scrutinised environmentally sensitive areas. Matrix PDM Engineering prides itself on its flexibility in providing custom-based solutions to meet any client need.

Matrix PDM Engineering, the engineering division of Matrix Service Company, provides lifecycle engineering, procurement, and construction (EPC) services across the energy and industrial markets. Matrix PDM possesses more than 40 years of industry-leading expertise across the entire sulphur spectrum, including capabilities for:

- Molten sulphur storage, handling, and loading
- Sulphur forming
- Solid sulphur handling and loading
- Sulphur block pouring
- Sulphur remelting.

GRANULATION, PASTILLATION & PRILLING

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Fertilizer plant revamping: technology & projects

The refurbishment and modernisation of fertilizer plants offers the opportunity to reduce operating costs, raise production capacity, improve energy efficiency and cut emissions.

CASALE

Recent revamp success stories

Fertilizer plant revamping is a long-standing and core area of expertise for Lugano-headquartered Casale. The Swiss company's extensive revamp experience encompasses ammonia, urea, NPK and phosphate plants worldwide. This includes major interventions to improve the performance and replace obsolescent equipment at more than 200 ammonia plants globally.

Below, we highlight recent Casale revamp success stories from a track record stretching back decades.

PHOTO: CASALE

Two massive pieces of revamping equipment – an ammonia converter and BFW preheater – being loaded onto a US-bound ship in Venice at dawn.

Grey to green ammonia

In May this year, after completing hundreds of revamps that have increased production capacity and reduced emissions, Casale unveiled a ground breaking zero-emissions project to convert an existing ammonia plant from conventional (grey) to low-carbon (green) ammonia production.

Incitec Pivot Limited (IPL) asked Casale to deliver the technical know-how and the basic engineering design to convert its Gibson Island ammonia plant in Queensland, Australia, from natural gas feedstock to renewable hydrogen.

Under current proposals, IPL's project partner Fortescue Future Industries (FFI) will construct an on-site water electrolysis unit at Gibson Island and develop and operate a hydrogen manufacturing plant, while IPL will continue to operate the site's ammonia plant.

The proposed new water electrolysis unit at the site will have the capacity to produce up to 50,000 t/a of renewable hydrogen – and therefore completely replace Gibson Island's current natural gas feedstock. This renewable hydrogen will then be converted into more than 300,000 t/a of green ammonia for the domestic Australian market and for export.

Gibson Island has the potential to become the first operating ammonia production plant in Australia to be converted to 100 percent emissions-free production. However, while the project is technically feasible, IPL and FFI are currently carrying out a front-end engineering design (FEED) study ahead of any final investment decision.

"We are grateful for the trust placed in us by our long-standing client IPL and proud to provide our technology and know-how to contribute to a greener future for Australia, accelerating the decarbonisation of the industry," said Federico Zardi, Casale's CEO. "Casale has always been a pioneer in implementing cutting-edge technologies into existing plants: this project can set the benchmark for all the ammonia plants in the world that have the ambition to turn green."

New US ammonia plant revamp

Casale has six main revamping concepts for ammonia:

- Moderate capacity increases – a standard scheme for increasing plant capacity by up to 30 percent by making the maximum use of existing equipment and leaving the main process unchanged.
- Superevamp – a patented concept to increase plant capacity by up to 100 percent and deliver energy savings of more than 0.5Gcal/tNH_3.
- Saveng revamping for fixed natural gas allocation – this can reduce energy consumption at ammonia-urea complexes by 5.0 Gcal/t (urea) with an emphasis on plant integration and energy optimisation.
- Revamping for energy saving – this makes plants more competitive by increasing the efficiency of their most energy-consuming sections.
- Revamping to reduce emissions – a revamp designed to improve pollutant emissions and meet the most stringent environmental regulations.
- Revamping for production stabilisation – this revamp option enhances cooling capacity (without penalising energy consumption) to reduce the differences in production load between hot and cold seasons.

In November last year, Casale highlighted its revamping experience in North America with the thirteenth replacement of an ammonia converter pressure vessel in recent years. The company shipped a 400+ tonne reactor and a boiler feed water (BFW) preheater to the US to replace obsolete equipment (classic 105-D unit coupled to 123-C) at a MW Kellogg plant (see photo).

These replacement reactors incorporate innovative structural and technological features:

- Full-opening converter
- Single-wall converter
- Three-bed cartridge
- Cold-wall pressure vessel
- No-quench design.

This ensures they deliver tangible benefits to ammonia plant operators – including better accessibility to the internal parts of the reactor, greater safety, higher performance, energy savings and lower emissions.

New HP stripper for Grupa Azoty urea plant

Casale delivered a new high pressure (HP) stripper to Grupa Azoty Pulawy in Poland in June 2021. This was supplied as part of the replacement and modernisation of the HP stripper in the synthesis section of the company's Puławy Urea Plant 2.

The stripper replacement follows the revamping of the Puławy urea plant in 2010, and the supply of other equipment and plant modifications since then. These have improved the plant's performance and supported Grupa Azoty's CO_2 emissions reduction policy.

The stripper is made with Uremium 29 and was built with Casale technology and designed at the Villa & Bonaldi workshops, a specialised and experienced Italian manufacturer of HP shell and tube heat exchangers. Uremium 29 is recommended for the tubes of HP pressure equipment (as well as piping and fittings) as it increases reliability and operating life. This new alloy has very high resistance to carbamate-induced corrosion and was specifically developed by Tubacex, the world leading tubing manufacturer, in cooperation with Casale.

The latest delivery to Grupa Azoty means Casale has now supplied more than 35 HP strippers to date for both new and revamped urea plants. Their materials of construction range from super-austenitic to superduplex alloy (e.g., Uremium 29) to more exotic types such as titanium and zirconium.

A new high pressure stripper supplied by Casale to Yara's Ferrara urea plant in Italy also successfully achieved its first full year of operation in March 2021. This was an important milestone as the stripper is among the first industrial references to use Uremium 29 in the construction of critical urea service parts.

"This stripper is a vital part of the urea plant and has come in the wake of the complete revamp that we undertook only a few years ago." commented Federico Zardi, Casale's CEO.

New high pressure boilers for Fertiberia

In June last year, Fertiberia awarded Casale a contract to supply three replacement high pressure process boilers (RG boilers). The new Casale-Schmidtsche Schack boilers will replace the existing boilers at Fertiberia's ammonia plant at Palos, Spain.

The Palos plant is an MW Kellogg type built in the early 1970s under license. The old boilers, located downstream of the secondary reformer, are based on a traditional design with a vertical layout and bayonet-type tubes. This design configuration – although widely used in the industry – has inherent weaknesses and serious reliability issues. In particular, it is prone to:

- Sludge deposition in the pocket of the bayonets
- Erosion and corrosion of the tubes
- Overheating
- Vibration due to high velocity.

These drawbacks can damage the tube bundles which, in turn, can cause costly and unexpected shutdowns at ammonia plants. These tube bundles also need replacing frequently – typically every four years.

Casale-Schmidtsche Schack boilers are based on a well proven, proprietary 'double tube & oval header' design and offer the following advantages when used in ammonia revamps:

- No changes in plant configuration
- The re-use of existing foundations
- Easy and fast installation, minimising the downtime required
- Water-cooled tube sheet, without the use of any refractory
- No sludge/scale deposits
- Low tube skin temperature
- No crevice corrosion
- Thermal expansion compensation
- Trouble-free operation and easy maintenance.

The new boilers supplied to Fertiberia are also designed to satisfy new operating conditions at the Palos plant which is being converted to accept the addition of green hydrogen.

Casale boosts capacity at IFFCO's Kandla complex

Early in 2021, IFFCO selected Casale's dual pipe reactor (GPR+DPR) technology for debottlenecking two production lines at its Kandla fertilizer production complex in Gujarat, India.

Kandla is IFFCO's oldest NPK and phosphates production centre. Two existing lines, based on Grande Paroisse's pipe reactor technology, were originally commissioned in 1999. GPR+DPR technology is now licensed by Casale after its acquisition of Grande Paroisse's entire nitrates and phosphates technology portfolio in 2013.

As part of its agreement with IFFCO, Casale will make modifications to boost production output by 15-25 percent, and will supply granulator pipe reactors (GPRs) to replace the existing ones in the granulator for each of the two lines.

The new GPR (Figure 1) is central to Casale's revamping approach as it:

- Increases the phosphoric acid feed to the plant
- Increases the N/P molar ratio

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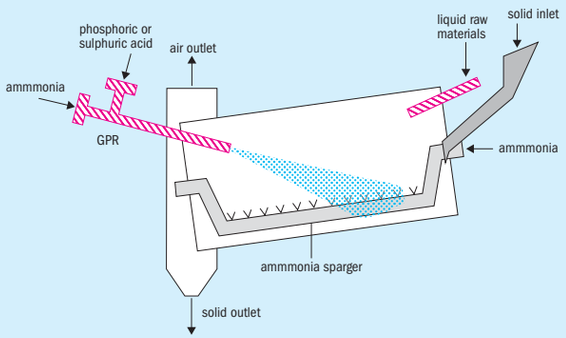
Fig. 1: **Casale's granulator pipe reactor (GPR)**



Source: Casale

- Minimises the impact on the scrubbing system and the rest of the plant – for example, the existing dryer pipe reactor (DPR) will be not replaced
- Increases operational flexibility.

Last but not least, the new GPR can be easily fitted in existing granulator drums without requiring major modifications.

Casale has carried out extensive revamps for IFFCO previously. In 2018, the company successfully completed one of India's largest ever fertilizer revamping projects. This encompassed a total of 13 IFFCO plants (five ammonia and eight urea units located across three sites) which were originally commissioned between the 1970s and the 1990s. Casale was responsible for the basic design, the supply of proprietary technologies and equipment, and checking detail engineering design. ■

THYSSENKRUPP INDUSTRIAL SOLUTIONS

Ammonia plant revamping with green hydrogen

Klaus Noelker

Germany's thyssenkrupp has extensive experience in fertilizer industry revamps. Notable recent project include:

- A contract between thyssenkrupp Fertilizer Technology, a subsidiary of thyssenkrupp Uhde, and Abu Qir Fertilizers Co for the revamp of their Abu Qir 3 urea granulation plant in Alexandria, Egypt
- A 2019 contract from India's Paradeep Phosphates Limited (PPL) to increase capacity of the existing Prayon DH phosphoric acid plant in Paradeep, Odisha, from 1,000 t/d to 1,400 t/d
- The successful completion in 2018 of a revamp project to increase the ammonia capacity of the SAFCO IV plant at the Al-Jubail complex in Saudi Arabia – then the world's largest – by more than 11 percent to 3,760 t/d.

Green hydrogen

Green hydrogen can be supplied to an existing ammonia plant as a revamp option to lower its CO_2 emissions. In this scenario, green hydrogen generated by an electrolysis unit is combined with hydrogen from the conventional front-end of the ammonia plant (*Nitrogen+Syngas* 368, p30).

Plant modifications using green hydrogen can vary between two extreme scenarios:

- Green hydrogen partially or completely replaces hydrogen from the plant's front-end without changing ammonia production capacity, or
- Green hydrogen is added to increase ammonia production capacity

The second option is, however, only possible if the plant's ammonia synthesis unit is not a capacity bottleneck.

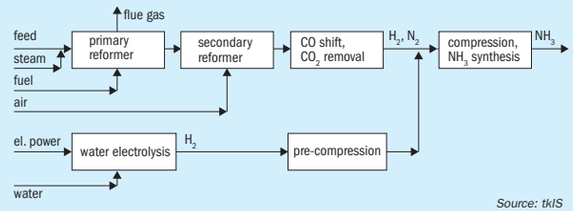
This case study describes the impact at an existing plant of replacing 10 percent of the hydrogen fed to the synthesis unit with hydrogen from an external carbon-free source (Figure 1). It examines the achievable reduction in CO_2 emissions. Obstacles to this revamp modification and how these can best be avoided are also discussed.

Impact on process units

The reference case for the simulation is an actual uhde® ammonia plant, although the results presented are equally valid for any ammonia plant based on primary and secondary reforming with stoichiometric process air and with heat recovery for high pressure (HP) steam generation. Electrolysis data are also taken from the uhde®/thyssenkrupp Industrial Solutions alkaline water electrolysis (AWE) process.

While it is clear that this modification will reduce the feed gas consumption of the reformer by about 10 percent, the following questions still need to be answered:

Fig. 1: **Green hydrogen revamp option. Conventional ammonia process (top) is modified with addition of hydrogen from water electrolysis**



Source: tkIS

Table 1: **Process parameters of reference case and modification with 10% external hydrogen**

Stream	Reference case	Modification	% Reduction
Natural gas feed, kmol/h	3,849	3,502	9.0
Natural gas fuel, kmol/h	1,272	1,131	11.1
Heat absorbed by reformer tubes, MW	185.6	155.3	16.3
Burner air ratio	1.10	1.25	n.a.
CO_2 available at CO_2 removal inlet, kmol/h	3,757	3,430	8.7
Total HP steam production, t/h	531	496	6.7

Source: tkIS

Table 2: **Plant performance parameters of reference case and modification with 10% external green hydrogen**

Stream	Reference case	Modification including electrolysis	% Reduction
Steam export, t/h	111.9	81.0	27.7
CO_2 emission (reformer and process), t CO_2/t NH_3	1.68	1.52	9.5
CO_2 emission (as above plus steam export outbalanced by aux. boiler), t CO_2 / t NH_3	1.68	1.56	7.0

Source: tkIS

- What is the change in reformer fuel demand?
- What is the change in steam export?
- Will operating parameters remain within design limits?
- Finally, referring to the main purpose of the change, what is the reduction in CO_2 emissions and plant operating costs?

Answers to these questions are covered fully by the original article (*Nitrogen+Syngas* 368, p30), allowing this summary to instead focus on overall plant performance, CO_2 emissions reduction and process control options.

Overall plant performance

Plant process and performance parameters (for the reference configuration and the green hydrogen modification) are shown in Tables 1 and 2, respectively.

The green hydrogen modification results in a significant drop (27.7%) in the steam export from the ammonia plant (Table 2). This is because less steam is produced from waste heat, yet the requirements of many steam-consuming processes (e.g., refrigeration, process air and syngas compressor turbines) are almost unchanged.

While this can be designed around at a new-build plant, the owner of an existing plant must decide how to handle this steam system shortfall. As a worst case, the reduced steam export resulting from the modification will lead to a steam deficit in another unit (e.g., a urea plant) which then need to be compensated for by higher production in the auxiliary boiler. In other cases, however, lower steam export may be acceptable, if steam consumption can be replaced by using electric power or other alternative forms of energy, for example.

CO_2 emissions reduction

The addition of 10 percent green hydrogen reduces total plant CO_2 emissions – from the reformer stack and CO_2 vent – by about 10 percent, both in absolute terms and per tonne of ammonia production. However, in cases where the lower steam export is replaced by steam generated using a gas-fired auxiliary boiler the reduction is only seven percent – if the extra CO_2 emissions are considered, which seems fair.

Process control options

In the conventional plant, adjustment of the hydrogen-to-nitrogen ratio (H_2/N_2) is made by regulating the feed flows of natural gas and process air. This is typically achieved by keeping the natural gas constant and adjusting the process air so that the H_2/N_2 stochiometric ratio of the feed to the synthesis loop is close to three. But this becomes more complicated in the modified system as – with the addition of an external green hydrogen feed – a third variable comes into play.

In one scenario, the supply of external green H_2 will fluctuate due to variations in the renewable power at the electrolysis unit. In this scenario, the ammonia plant will have to cope with and balance out greater fluctuations than usual. However, an instant reaction is not always required because the hydrogen from the conventional front-end acts as a buffer, and small changes in the H_2/N_2 ratio will only result in a slightly lower conversion.

In contrast, the other green hydrogen supply scenario, where the electrolyser has continuous renewable power without fluctuation, is perfectly suited for H_2/N_2 ratio control. This is because the electrolyser load and green hydrogen supply can be adjusted within seconds, as this system has much less inertia than the ammonia plant front-end.

Other benefits

There are other ways to add an external stream of green hydrogen to the ammonia production process, as well as the option shown in Figure 1. One option, for example, is to use this H_2 as a hydrogenation stream for desulphurisation, thereby avoiding the usual H_2 recycle. Another option is to use a dedicated compressor to compress green H_2 to synthesis pressure and combine the streams there. This could help with the steam export shortfall highlighted above by saving steam consumed by the syngas compressor train.

Conclusions

There are a number of factors that need to be considered when revamping an ammonia plant with green hydrogen and replacing part of the hydrogen from the front-end with an external source. These include:

- Secondary reformer outlet temperature
- Energy balance of the convection bank
- Gas temperature between reformed gas waste heat boiler and superheater
- The availability of CO_2 for downstream products
- Steam export
- Process control if the external H_2 feed is fluctuating.

However, there are ways to avoid any adverse impacts, as described in this summary and the original article (*Nitrogen+Syngas* 368, p30). ■

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STAMICARBON

Stepwise approach to revamping urea plants

Ron Pustjens, process engineer

Although urea plants begin their life as state-of-the-art, they inevitably age and become outdated over time. During the plant's lifetime, operators have to cope with technical challenges such as corrosion and leakage – as well as dealing with external changes in legislation, emission requirements, market conditions, and competition.

Although well known for designing new urea plants, Stamicarbon, the innovation and license company of Maire Tecnimont Group, has also successfully executed more than 100 revamping projects. This extensive experience has allowed Stamicarbon to establish a systematic and stepwise approach that gets the best out of any urea plant revamping project.

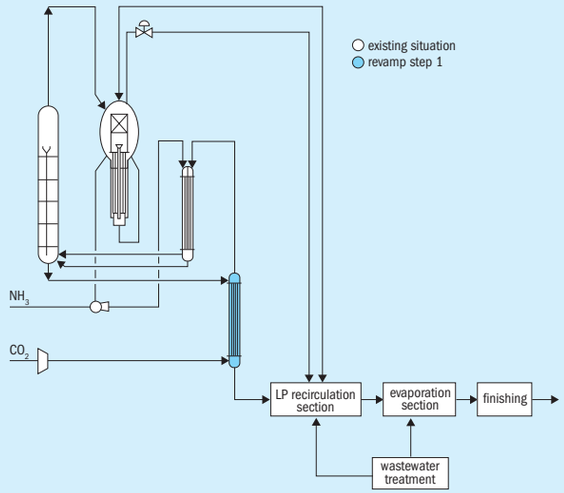
In general, a change in the *status quo* and the subsequent decision to revamp a urea plant has an initial trigger and driving force. The most common drivers and motivations that trigger the start of the revamping process are:

- Capacity increase (feedstock/utility availability)
- Product diversification (e.g., DEF, UAN)
- Reduction in energy consumption
- Equipment replacement
- Safety improvement
- Legislation and environmental restrictions
- Competition.

Each of the above drivers have different stakeholders with a range of interests and budgets. They are also subject to different boundary conditions such as: the local market, long- and short-term company vision, economics, ambitions, governmental policies, national and international standards, etc.

Before starting the revamping process, Stamicarbon advises drawing up a good plan of approach. This plan needs to include a clear overview of the overall chemical complex, the company's investment plans, boundary conditions, and limitations.

Fig. 1: **A stripper (blue) in a urea plant with CO_2 stripping technology has reached its mechanical end-of-life and needs to be replaced**



Source: Stamicarbon

A urea plant is typically part of a larger chemical complex consisting of at least one ammonia plant and a utility plant. It is often the characteristics of these plants that dictates the limitations of the urea plant revamping project. During the revamp, the scale of investment and the impact of the capacity increase will generally be higher for these plants, compared to the urea plant alone.

The constraints within the battery limits of a urea plant should also be clearly identified. Typical examples are:

- The capacity limitation of rotating equipment – such as high-pressure carbamate and ammonia pumps and the CO_2 compressor
- The mechanical integrity and capacity limits of synthesis equipment
- The layout of the revamp – if the proposed revamp design requires significant modifications to the structure and piping, this has a significant impact on the revamp's technical and economic feasibility
- The availability of excess ammonia
- Steam pressure and steam availability
- The cooling water system.

Each urea plant and its *status quo* are unique. The most successful outcomes are therefore achieved when long-term planning is included in the revamp project and its plan of approach. Thinking further ahead is beneficial as it allows the revamp design to be executed stepwise over time. Preparing a long-term plan also increases the success rate of a revamp project by ensuring it fits in with the company's investment plan and aligns with the long- and short-term company vision.

An example of a stepwise approach to urea plant revamping is provided below.

Step 1 – stripper replacement

The basis of this example is a typical urea plant with Stamicarbon CO_2 stripping technology. In this instance, the stripper in the urea synthesis section is at its mechanical end-of-life and consequently this equipment needs to be replaced in the next turnaround. This situation is shown schematically in Figure 1.

Without making a long-term plan, there are three stripper replacement options:

- **Option A.** Install an identical replacement made of similar construction material and with a similar amount of tubes. During its lifetime, it is a common for the stripper tubes to become thinner due to corrosion. Stripper performance is enhanced because these thinner tubes allow a higher tube load to the stripper with a corresponding increase in plant capacity. However, installing a new stripper with an equal number of stripper tubes will reduce plant capacity by bringing it back to its original design value. This option is therefore less favourable.
- **Option B.** It is possible to compensate for the effect of lower plant capacity, as highlighted in option A. This is achieved by installing a few more tubes while decreasing the tube pitch to keep the stripper's shell dimensions the same. Furthermore, the quality of the stripper can be increased by applying the latest design standards (e.g., a material upgrade, the use of a pressure safety valve instead of a rupture disc, installing an improved liquid distribution system etc.). After installation, this stripper will then meet the higher capacity achieved immediately prior to the revamp.
- **Option C.** The same modifications as mentioned under option B are applied. But more tubes are installed to enable future plant expansions. However, a long-term plan is required to determine the limits and the optimum number of tubes necessary to accommodate the plant's desired future capacity.

Materials of construction also have an impact. Traditionally, strippers are constructed from BC.05 (25-22-2) material. While the latest standard construction material is Safurex® (BE.06). The use of Safurex® over BC.05 has the following advantages:

- **Improved corrosion resistance:** with Safurex®, a lower oxygen concentration is used in the carbon dioxide supply for passivation purposes, extending the lifetime of equipment. A lower oxygen concentration also reduces the airflow, and thus the inert flow to the synthesis loop, creating an operational margin for further capacity increase.
- **Material thickness:** Safurex® tubes can have a thinner wall thickness compared to BC.05. Safurex® tubes therefore have a larger internal diameter. Consequently, a Safurex® stripper will have a higher tube load compared to a BC.05 stripper, assuming an equal (liquid) film layer in the stripper tubes.
- **Weight:** a Safurex® stripper is substantially lighter than a BC.05 stripper when installing the same number of tubes – resulting in economic advantages, e.g. less steel.
- **Redundancy of expansion bellows:** because the expansion coefficient for the Safurex® material approaches the expansion coefficient of the carbon steel, the expansion bellows usually used for BC.05 strippers are no longer required.


PHOTO: STAMICARBON

Fig. 2: Pool condenser in an Add-On structure that increases capacity.

In both a Safurex® and BC.05 stripper, more tubes can be installed within the same shell diameter by reducing the tube pitch. No modifications to the high-pressure piping and civil works are required when the same shell diameter is maintained. Alternatively, the scope for increasing the shell diameter, without the need for modifications of the plant structure and piping, can be investigated. This allows the installation time to be minimised, even in a short turnaround of 1-2 weeks.

Step 2 – capacity increase via a medium-pressure add-on section

Option A in step 1 can be ruled out in subsequent steps as it results in a reduction in achievable plant capacity compared to the capacity prior to revamp. That leaves options B and C.

After the replacement of the stripper in step 1, there is again scope to increase plant capacity in step 2 until the next bottleneck limitation is met. In option B, it is the stripper that becomes the next bottleneck. In option C, in contrast, the stripper will not become a bottleneck as it is designed to meet future requirements. Capacity can therefore be increased in option C up to the limitation of the CO_2 compressor.

The plant therefore requires an additional revamp step to overcome either the bottleneck of the stripper limitation (in option B) or the compressor limitation (in option C). Revamping the CO_2 compressor


PHOTO: STAMICARBON

Fig. 3: Installation of a high-pressure after-reactor.

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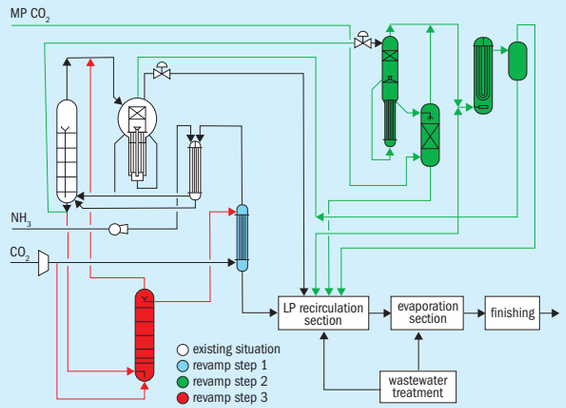
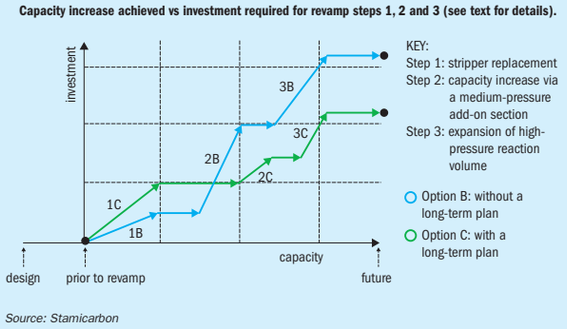
Fig. 4: **Revamped urea plant operating at the desired future capacity, after completion of three revamp steps**



Source: Stamicarbon

Fig. 5: **Comparison of investment costs for a urea plant revamp with (option C, green line) and without (option B, blue line) a long-term plan**



Source: Stamicarbon

is costly compared to the limited capacity gain this delivers. However, by applying a medium-pressure Add-On concept instead, the plant capacity can be increased without modifications to the synthesis equipment (Figure 2).

In the medium-pressure Add-On concept, part of the synthesis liquid leaving the urea reactor is processed in a parallel medium-pressure section. In this configuration, the stripper operates at maximum loading, a consideration that determines the dimensions of the medium-pressure section. The additional carbon dioxide required by the medium-pressure section is provided by a medium-pressure CO_2 compressor.

Step 3 – expansion of high-pressure reaction volume

The next revamp step for achieving the desired future plant capacity requires the installation of additional reaction volume downstream of the existing reactor, e.g. by installing a pool condenser, pool reactor, or after reactor (Figure 3).

Option B has a smaller stripper and larger medium-pressure Add-On section. As a result, option B increases the carbamate recycle sent back to the synthesis section. Therefore, to reach the same desired increase in plant capacity, option B will require more additional reaction volume, compared to option C, resulting in higher investment costs.

Completion of these three revamp steps will achieve the desired future plant capacity, as shown schematically in Figure 4.

Impact of the stepwise approach on long-term investment

The impact of revamping on investment costs, with or without a long-term plan for the urea plant, is shown in Figure 5 for comparison purposes. With a long-term plan in place, although the initial investment in the first revamp step (stripper replacement) is higher, in the end, overall investment is lower. This is because the larger stripper design is part of a stepwise plan to reach a higher plant capacity in future.

Conclusions

There are several ways to optimise operational urea plants. The choices are typically between revamping concepts for increasing capacity, reducing energy consumption, or cutting emissions. These concepts are used as the basis for the revamp design, which can also include project-specific tailored modifications.

We recommend that each revamp project should follow a stepwise approach. Using this philosophy, a long-term plan is prepared and then executed in a series of steps – to fit within a given timeline and the available budget.

Revamping is complex process based on teamwork. For a successful revamp, all elements and parties need to work together on an agreed plan and approach to project execution. Selecting a suitable and reliable licensor and contractor is also an important part of the revamp process. These partners provide the broad technological know-how and a portfolio of technological concepts. At Stamicarbon, these revamp capabilities are being improved through continuous innovation and development based on proven experience. ■

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phosphates & potash INSIGHT

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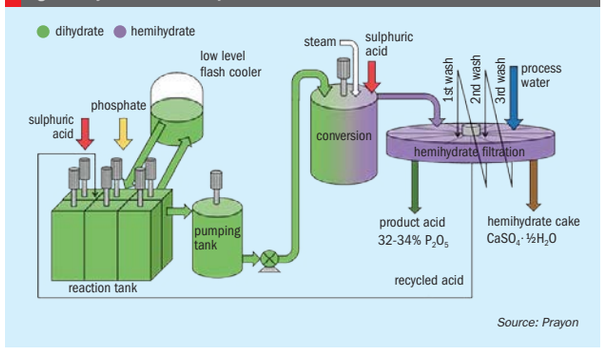
Resource efficient phosphate production

ICL's phosphate recycling unit, Amsterdam. PHOTO: ICL

The phosphate fertilizer industry is turning to production methods that are able to consume low-grade phosphate rock and/or generate pure gypsum as a by-product. Gypsum-free processes, and technologies that capture phosphorus from waste streams, are also on the rise.

Fig. 1: **Prayon's new DA-HF process**



Source: Prayon

Prayon's new DA-HF Process

Most of the world's phosphoric acid is produced via the DH (Di-Hydrate) process route. For some years now, Prayon has been developing an improved phosphoric acid production process known as DA-HF (Dihydrate Attack-Hemihydrate Filtration). The new process (Figure 1) has been thoroughly tested at pilot-scale at Prayon's Engis site in Belgium.

Compared to the standard DH route, Prayon's DA-HF process has the following advantages:

- The weak product acid contains higher P_2O_5 levels of up to 34 percent
- This allows merchant grade acid (MGA, 54% P_2O_5) to be produced using smaller concentration units
- Has a higher process efficiency with P_2O_5 recovery above 97 percent
- Consumes less water during washing of the calcium sulphate cake
- Yields a hemi-hydrate (HH) calcium sulphate by-product that is suitable for cement manufacture.

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Unlike the very high efficiency CPP (Central Prayon Process) operated by Prayon in Engis, Belgium, only one single filtration stage is required in DA-HF. This makes DA-HF simpler and easier to operate compared to CPP. Beneficially, the process also removes undesirable cadmium at the concentration stage.

The DA-HF process has been successfully installed at Grupa Azoty's plant in Police, Poland, as part of a revamp project (*Fertilizer International* 496, p52). This reference plant has demonstrated that DA-HF can be easily implemented at existing DH phosphoric acid plants with only a limited number of modifications. This first-of-its-kind DA-HF plant increased:

- Plant P_2O_5 capacity from 420 t/d to 500 t/d
- Its global efficiency – with total P_2O_5 content in the discharged cake decreasing from 1.2 percent to 0.5 percent
- The P_2O_5 content in the product acid to 32-33 percent
- The quality of the calcium sulphate by-product.

The EcoPhos and GetMoreP processes

Prayon also offers two chemical processes for beneficiating low-grade phosphate rock (*Fertilizer International* 500, p35):

- The EcoPhos process – an innovative acquired technology based on the use of dilute hydrochloric acid
- GetMoreP – a similar in-house technology developed by Prayon based on the use of dilute sulphuric acid.

Both processes generate dicalcium phosphate (DCP). This flexible end-product can be directly marketed as an animal feed additive. Alternatively, it can be used as a high purity intermediate feedstock (39-41% P_2O_5 and 32-34% CaO) for phosphoric acid plants, enabling the manufacture of a range of other phosphate products.

The *EcoPhos* and *GetMoreP* processes have a number of similarities:

- They are both modular
- They generate the same quality DCP product
- Each is capable of consuming low-grade phosphate rock.

Their main differences are:

- The stages at which impurities are removed
- The co-products are not the same due to the use of different acids to digest phosphate rock.

Prayon's approach to phosphorus recovery

The depletion of phosphate resources raises questions about long term security of supply, especially in Europe. However, dependence on external primary resources – in Europe and elsewhere – could be reduced by the large-scale recovery of phosphorus from waste streams. This has dual benefits as it would also cut global phosphate losses.

The following technology options from Prayon are capable of recovering phosphorus commercially from various secondary/waste sources:

- Recovery from phosphate beneficiation wastes (slimes, rejected rock) using the EcoPhos or GetMoreP processes
- Recycling industrial phosphoric acid waste by membrane purification
- Recovering phosphate from sewage sludge fly ash using methods such as ion exchange and nanofiltration.

Recovering phosphorus via sewage sludge incineration is highly challenging (see companion article on page 58) due to the complexity and composition of the iron- and aluminium-rich fly ashes obtained. These typically contain up to nine percent and eight percent iron and aluminium, respectively.

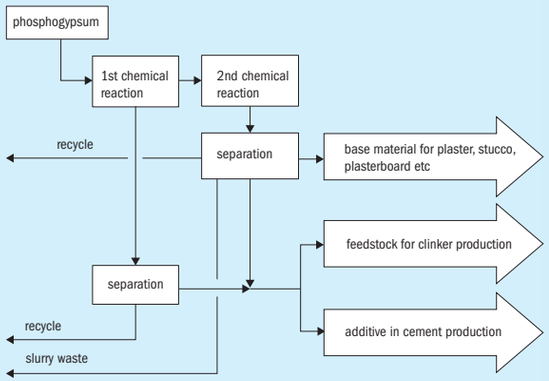
Prayon offers two types of recovery technologies for sewage sludge fly ash. These are selected according to the composition of the fly ash, its location and the required end-product:

- **Technical-grade phosphoric acid production**. This two-stage process firstly involves the digestion of fly ash in phosphoric acid, followed by the purification of the resulting solution by ion exchange and, optionally, nanofiltration. Phosphoric acid is partly recovered as the final product and partly recycled to digest more fly ash. The ion exchange resin is regenerated by hydrochloric acid. Depending on their composition, the solutions arising from regeneration can be valorised as a de-icing product (Ca/Mg Cl solutions) or sent for wastewater treatment (Al/Fe Cl solutions).
- **Fertilizer-grade dicalcium phosphate (DCP) production**. This process is very similar to the methods used to digest low-grade phosphate rock, as described above. The main difference is that, due to their high concentration in filtrates, both aluminium and iron need to be removed by ion exchange to obtain high-quality DCP. The DCP product can be used directly as fertilizer or converted into triple superphosphate (TSP) instead.

tkIS phosphogypsum treatment process

thyssenkrupp Industrial Solutions (tkIS) has been developing a new technology that converts phosphogypsum (PG) into a valuable product for the circular economy. A two-step treatment process for reducing impurity levels in PG has been devised and

Fig. 2: **tkIS phosphogypsum treatment process**



Source: tkIS

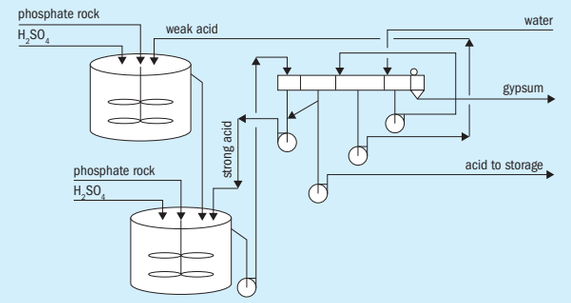
Technip Energies high recovery Diplo process

The two-step Diplo process from Technip Energies combines improved P_2O_5 recovery with the operational advantages of the DH route, such as the flexibility to accept different phosphate rock types. Depending on the phosphate source, this high recovery process can digest around 97.5-98.5 percent of the P_2O_5 present. Its other benefits include:

- Process simplicity
- Ease of operation
- Low maintenance cost
- High plant availability
- Low capex.

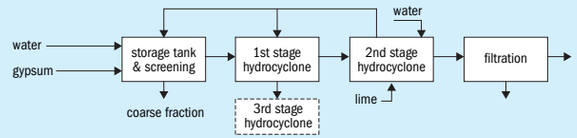
The Diplo process can also be combined with a simple phosphogypsum purification process. This avoids the need to consume costly high-quality phosphate rock feedstock.

Fig. 3: **Simplified flowsheet for Technip Energies' high recovery two-step Diplo phosphoric acid production process**



Source: Technip Energies

Fig. 4: **Multi-stage phosphogypsum treatment process**



Source: Technip Energies

PG recycling and reuse

Currently, most phosphoric acid plants globally operate the DH process due to its advantages over other production routes. DH is also expected to remain the preferred production route for most phosphoric acid producers, at least in the medium-term. This suggests that increasing the recycling and reuse of phosphogypsum in future will require innovations and changes to the existing DH process.

This should favour high P_2O_5 recovery technologies such as the Diplo process – due to their ability to reduce the residual P_2O_5 content of phosphogypsum (PG) and generate higher quality PG suitable for industrial reuse. Industrial cases studies in Senegal and Austria have shown how PG from the Diplo process can be successfully recycled on a large scale for cement, plaster and other commercial applications – while either avoiding or minimising the need for purification prior to reuse (*Fertilizer International* 502, p58).

Two-stage, high yielding process

The two-stage Diplo process was developed by the French company Rhône Poulenc, the technology predecessor to Technip Energies, in the 1980s and 1990s as a new approach to DH production. The aims were two-fold: firstly, to obtain higher P_2O_5 yields and, secondly, to increase the concentration of the dilute acid produced at filtration.

This new approach successfully generated both higher P_2O_5 yields and acid concentration, while keeping the original operational advantages of DH production. This was of particular interest to producers in Europe who were sourcing from the merchant rock market and facing strong economic pressure to reduce their operating costs. Technip Energies has improved and refined the process subsequently.

In the Diplo process, phosphate rock is digested using two reactors in series, with each reactor being fed phosphate rock, sulphuric acid and recycled phosphoric acid in set proportions (Figure 3). This two-stage process is inherently more stable. Incorporating two separate reaction steps also allows the digestion conditions to be varied – including temperature, P_2O_5 concentration, and concentration of free sulphate in the acid.

Around 70-90 percent of the phosphate rock is reacted in the first reactor. This is operated at lower P_2O_5 concentration, higher temperature and with higher excess sulphuric acid. Combined, these conditions tend to reduce co-crystallised P_2O_5 losses in gypsum. The remaining phosphate rock is reacted in the second reactor, increasing the P_2O_5 concentration of the acid. Excess sulphuric acid in the second reactor slurry is closely regulated. This limits unreacted P_2O_5 losses and avoid excess sulphate in the phosphoric acid produced.

Residual contaminants present in the phosphogypsum after filtration can be detrimental to phosphogypsum reuse, particularly for plaster manufacture. These can, however, be removed or reduced using a two- or three-stage PG treatment process (Figure 4).

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tested at laboratory-scale. This has successfully achieved reduction rates of more than 95 percent for both P_2O_5 and fluoride. Promisingly, the radium activity of PG was also reduced by more than 40 percent during initial tests – with higher reduction rates expected in future (*Fertilizer International* 501, p48).

This new PG treatment process from tkIS is based on the original conversion process used successfully at OSW-Krupp plants. It consists of two main steps in sequence. Each step involves a chemical reaction followed by liquid-solid separation (Figure 2).

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

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

Building on these positive lab-scale results, tkIS is carrying out process development work to scale-up capacity and optimise energy consumption. The ability to fully integrate the PG treatment process within existing production plants, through cooperation and partnership with interested phosphate producers, will be another priority (*Fertilizer International* 501, p48).

Novaphos produces high-quality acid

Florida-based Novaphos Inc (formerly JDCPhosphate) has successfully manufactured high-quality super-phosphoric acid (SPA) continuously using its proprietary improved hard process (IHP). This was demonstrated during prolonged operation of the company's IHP demonstration plant in Fort Meade, Florida (*Fertilizer International* 494, p27).

IHP produces phosphoric acid from a low-quality phosphate rock feedstock in a kiln without creating phosphogypsum waste. Instead, the innovative process generates J-Rox, a commercially-useful aggregate, as co-product.

During operations in early 2019, Novaphos was able to continuously manufacture SPA via the IHP route using locally-sourced phosphate mine waste. This phosphate source was combined with clay and petroleum coke to provide feed for the kiln.

A high-grade SPA product was obtained (68 percent P_2O_5) with minimal impurity levels (<2.5 percent). The process eliminated up to 90 percent of cadmium in the phosphate feed. This was captured in the plant's pollution control scrubbing system, leaving levels of around two ppm in the SPA. The process also significantly reduced levels of lead and arsenic.

As a next step, Novaphos plans to commercially deploy IHP technology, after completing process design engineering for a full-scale production process.

> **"Spain's Fertiberia has successfully developed bio-based NPK fertilizers as part of an EU-funded project."**

ICL opens phosphate recycling unit

ICL opened an innovative phosphate recycling unit at its Amsterdam fertilizer production site in 2019. In an industry first, the new unit allows ICL to incorporate recovered phosphate from secondary sources in the industrial-scale production of phosphate-based fertilizers (*Fertilizer International* 494, p27).

The unit, which uses large-scale alternative sources of phosphate such as sewage sludge ashes and bone meal ashes, was formally opened by local Dutch officials in March 2019. ICL says the unit is a "circular innovation" that shows its commitment to sustainability.

There are plans to expand this pathfinder project in future: "Our ambition is to further increase the use of phosphate coming from alternative sources in the coming years, with ICL as one of the international frontrunners in phosphate recycling," the company said.

ICL sells recovered nutrients

In 2018, ICL entered into a long-term sales and distribution agreement with Vancouver-headquartered Ostara Nutrient Recovery Technologies. As part of the new agreement, ICL now markets and sells Ostara's Crystal Green, a struvite-based phosphate fertilizer, into the EU and UK, supplying the turf and lawncare markets (*Fertilizer International* 494, p27).

ICL sells Cystal Green under the name Sierrablen Plus. Its sales and distribution agreement with Ostara was expanded in 2020 to include Australia and New Zealand and the Nordic countries.

Crystal Green is recovered from municipal wastewater at 15 plants worldwide using Ostara's Pearl technology. It is a continuous-release fertilizer incorporating the company's trademarked 'root activated' phosphorus.

Advantageously, Crystal Green contains virtually no cadmium or other heavy metals. It also only releases phosphorus, nitrogen and magnesium in response to the organic acids produced by growing roots. This ensures that phosphorus is available for uptake when required by plants, while at the same time reducing the environmental impact caused by leaching and nutrient run-off.

Fertiberia targets nutrient recovery

Spain's Fertiberia has developed new bio-based NPK fertilizers as part of the EU-funded NewFert project. These were manufactured at pilot scale and successfully incorporated into commercial fertiliser production (*Fertilizer International* 494, p34).

The project validated the following three nutrient recovery processes at pilot plant scale:

- Phosphorus recovery from ashes via the DMphos process.
- Phosphorus and nitrogen recovery from pig slurry. These were extracted and crystallised as struvite using biological acidification.
- Nitrogen recovery and organic matter removal from pig slurry using bio-electrochemical systems (BES).

The DMPhos process extracts phosphorus present in ashes sourced from agriculture, the food industry and wastewater treatment plants and makes this plant-available. The ashes are firstly chemically treated by acid leaching and, after neutralisation, phosphate products (monocalcium phosphate and dicalcium phosphate) are then generated using a thermally-efficient reactor.

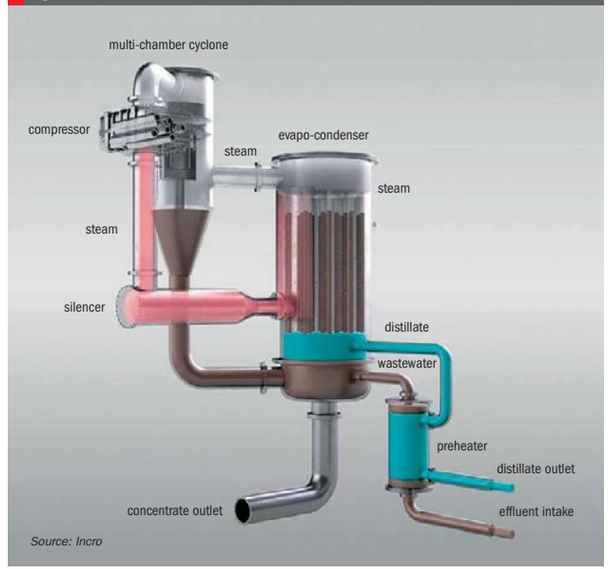
The NewFert project achieved the following results:

- The development of a new family of NPK fertilizers
- 15 percent of the nutrient content of these NPK products was derived from bio-based materials
- 100 percent of their nutrient content is plant-available
- More than 80 percent of their nutrient content is water-soluble
- At least 10 percent of the combined nitrogen (N) and phosphorus (P_2O_5) content is bio-based.

The performance of these partly bio-based formulations was validated using greenhouse trials to determine crop yields.

Building on these positive results, a new project B-Ferst was launched in May 2019. Its main aim is to fully implement NewFert's bio-refining technologies and produce eight new bio-based fertilizers at industrial scale.

Fig. 5: **Incro's MVC wastewater treatment unit**



Source: Incro

From wastewater to liquid fertilizer

Fertiberia's engineering subsidiary, Incro, S.A., has successfully transformed industrial wastewater into a liquid fertilizer (almost 13% P_2O_5 and cadmium-free) as part of the flagship Oleofat project. This pioneering Spanish project also recycles water for farming and industrial purposes (*Fertilizer International* 494, p37).

The liquid fertilizer is manufactured using Incro's proprietary mechanical vapour compression (MVC) technology to obtain a valuable concentrate and a clean distillate from the wastewater (Figure 5). This unit incorporates a highly efficient and low operating cost evaporator. Its dual-use design allows treatment with either sulphuric or nitric acid, depending on acid market prices and/or the end-destination of the concentrate.

The concentrate obtained is suitable for use as a liquid NPK fertilizer, containing 4.0 percent nitrogen (as nitrate), 12.9 percent phosphorus (P_2O_5), 0.7 percent potassium (K_2O) and 17.3 percent organic carbon, while also being free of heavy metals and pathogens. Its nitrate content is derived from the nitric acid used to extract the phosphate from the bio-waste. Incro's MVC unit has the annual capacity to produce 3,000 tonnes of liquid fertilizer from around 10,000 tonnes of wastewater. ■

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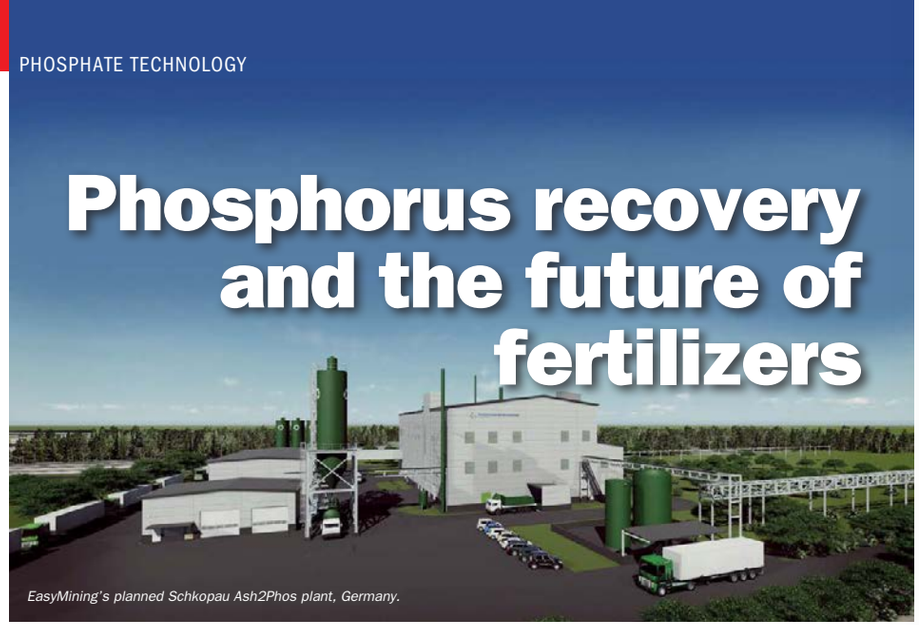
Phosphorus recovery and the future of fertilizers



EasyMining's planned Schkopau Ash2Phos plant, Germany.

PHOTO: EASYMINING

Reclaiming phosphorus from sewage sludge ash holds great potential for the fertilizer industry – by helping to reduce dependency on global supply chains, ensuring resilience and even raising quality. But successful phosphorus recovery largely depends on the process used, as EasyMining's **Anna Lundbom**, **Sara Stiernström** and **Christian Kabbe** explain.

European interest in phosphorus recovery has risen to a whole new level in recent months. The sanctions imposed on Russia following the conflict in Ukraine has highlighted Europe's dependency on imported phosphate rock, and its particular reliance on both Russian and North African sources.

Since the end of February, market prices have started to overheat due to concerns over the supply and availability of Russian fertilizers and raw materials, including high-grade phosphate rock. Unsurprisingly, fertilizer companies and other industrial consumers have been keen to secure sufficient supplies of phosphorus to keep their production running. Fertilizer availability in general is also developing into a global issue, with the potential for a full-blown food security crisis emerging as a major risk.

Recent world events have shone a spotlight on the supply chain weaknesses of the whole fertilizer industry and revealed their vulnerability to disruption. These supply risks will remain, even if the war in Ukraine and Russian sanctions ended tomorrow. That makes establishing a domestic-based circular economy for a nutrient like phosphorus highly attractive – due to its potential to make the fertilizer industry much more self-sufficient, resilient and efficient. But the full potential of nutrient recovery can only be realised if the recovery process is of a high standard and the product generated is of the right quality.

High-quality nutrient recovery from abundant resources

Easy Mining is commercialising the recovery of valuable yet currently discarded resources and implementing this at scale. Our innovative technologies are helping to close nutrient cycles to create new circular material flows that are commercial and efficient.

EasyMining's portfolio of patented processes recovers and extracts the three primary nutrients (nitrogen, phosphorus, and potassium). They include:

- **The Ash2Salt process:** This extracts commercial grade salts, including potassium chloride, out of high-chloride ashes from waste-to-energy plants.
- **Project Nitrogen:** A process for the efficient removal and recovery of ammonium from aqueous flows.
- **CleanMAP:** This technology produces ammonium phosphate from mine tailings or other mineral sources.
- **The Ash2Phos process:** This recovers phosphorus from the ash of incinerated sewage sludge and other phosphorus-rich feedstocks.

Processes like Ash2Phos can play a vital role in securing the critical materials needed for fertilizer production. The commercial recovery of phosphorus generated in the domestic market would obviously reduce dependence on global supply chains. Indeed, high-grade recovered phosphorus – as generated by Ash2Phos – can directly substitute for imported nutrients. Recovering high quality nutrients is important, as these can be easily used as feedstocks for existing value chains, allowing manufacturing processes to become more circular without compromising the environment or affecting production efficiency.

Global agricultural output would suffer without phosphorus. And while sewage from households and industries contains massive amounts of phosphorus, at present, it's mostly seen as a problem rather than an asset.

In fact, a lot of time, effort and cost goes into discarding sewage sludge at wastewater treatment plants, even though it's rich in potentially valuable phosphorus. In our view, this phosphorus can be commercially recovered from sludge in a closed loop to secure an endless supply. With a different approach, therefore, the opportunities are enormous.

PHOTO: EASYMINING

The Ash2Phos process generates a high-quality calcium phosphate end-product.

Ash2Phos can recover more than 90 percent of the phosphorus contained within a mineral-rich feedstock like sewage sludge ash. This three-stage process involves:

- An initial acidic step
- An alkaline step producing intermediate products
- These are then detoxified and processed into the final products.

The main product of the Ash2Phos process is precipitated calcium phosphate (see photo above). Other valuable materials such as coagulants are also recovered, while heavy metals are also extracted and separated to ensure product quality meets or even exceeds current commercial standards.

Yet the effectiveness of phosphorus recovery will always depend on the technology behind it. Other processes like 'ash pimping', for example, just dilute heavy metals or don't fully remove harmful materials. These processes also leave phosphorus still embedded within the waste matrix. This means the quality of the final product remain dependent on the quality of the starting material – the end result being sub-standard products that create sub-standard fertilizers.

In fact, only extraction-based processes like Ash2Phos can guarantee high-quality phosphorus end products, independent of the original input material. The precipitated calcium phosphate generated by Ash2Phos can also be used flexibly in two main ways – either directly as a slow-release fertilizer (see photo below) or as a raw material/feedstock. The quality of this product can exceed that of standard phosphate rock. Ash2Phos therefore has the potential to create better quality products than conventional fertilizers derived from primary phosphate resources, with the added benefit of a more secure supply chain based on a sustainable 'closed loop' process.

Endless supply

In Europe, fertilizers are currently the only available route-to-market for phosphorus reclaimed from sewage. This is because, under current regulations for this nutrient, waste-extracted phosphorus is excluded from use in animal feed or food additives, regardless of its quality.

The EU may repeal these outdated regulations which focus on the origin instead of the quality of products. But, until then, there is a window of opportunity for fertilizer producers, ahead of other industries, to begin integrating reclaimed phosphorus into their value chains.

Are the potential volumes large enough?

At present, mineral fertilizers supply approximately 1.2 million tonnes of phosphorus annually to meet the needs of Europe's farmers. Currently available sewage sludge ash could produce enough phosphorus to meet about four percent of this demand, assuming the same recovery rate as the Ash2Phos process. However, if all the sewage sludge generated in Europe were incinerated, phosphorus recovery could potentially rise to 270,000 tonnes, equivalent to about 20-25 percent of the amount currently supplied through mineral fertilizers.

The availability of large amounts of phosphorus in sewage sludge ash therefore opens up a substantial opportunity for fertilizer producers. Sewage sludge ash is available domestically in large volumes throughout the year without disruption. As long as people eat and sewage systems operate, there's always going to be a consistent supply of sludge available for phosphorus extraction. The price of recovered phosphorus is also expected to remain relatively stable, compared to primary phosphate rock, due to the absence of international transport costs and the lack of competition from other industries.

In our view, extracting, refining and detoxifying phosphorus from renewable resources like sewage sludge ash can contribute to food security by helping create a more resilient and efficient fertilizer industry that generates better quality phosphate products.

The calcium phosphate recovered by Ash2Phos technology is also highly versatile. It's incredibly easy to integrate this recovered material at the early stages of already-established fertilizer production

PHOTO: EASYMINING

Calcium phosphate derived from recovered phosphorus can be directly applied to crops as a slow-release fertilizer.

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processes/value chains – or, alternatively, it can be used as a standalone product.

It is also noteworthy that, as a downstream process, phosphate recovery from ashes is not directly affected by operational issues at wastewater treatment plants. Phosphorus suppliers, using a process like Ash2Phos, can instead collect ashes from many different incinerators. This widespread sourcing provides benefits such as economies of scale and better homogeneity. Importantly, while the process is not that dependent on the quality of the ash, Ash2Phos does guarantee a fixed level of quality for the phosphorus it produces.

Lastly, phosphorus extraction can add new levels of sustainability to fertilizer production by recovering a range of other materials as well as calcium phosphate. Ash2Phos maximises the usage of sewage sludge ash in its entirety, with each material having its own application. These range from commercial-grade coagulants, like ferric chloride and sodium aluminate, to a cleaned sand fraction suitable for use as a construction material or cement replacement in concrete.

The Ash2Phos process also extracts and separates heavy metals and concentrates these in a filter cake. These can be reused (depending on the levels of copper, zinc, nickel, etc. present) provided there is a suitable offtake agreement with a smelter company.

With a process like Ash2Phos, it's therefore possible to achieve an overall recycling rate of 95 percent or more. And, because sewage sludge ash would otherwise be disposed of to landfill, this directly translates into a total waste reduction of 95 percent.

Turning waste into a resource

Sewage sludge, according to the current mindset, is classed as waste. There are good reasons for this, as its composition varies and contaminants may also be present, for example. It also has much less value in an unprocessed state. But these negative connotations are also applied – unfairly – to any materials recovered from sewage sludge. Extracted nutrients are still tarnished by their association with waste, even though harmful substances have been removed and they make an ideal, efficient resource for precision farming.

The problems with the perception and classification of waste-derived nutrients are best illustrated by the previously mentioned EU regulations. Gatekeeping waste legislation was previously enacted by the EU as a precaution – to keep pollutants out of the environment and unsafe materials away from people. Essentially, these regulations prohibit materials on the basis of their origin.

Things are about to change, however, as society transforms from a linear to a circular economy. This change is being driven by increasing demand for resources, due to population growth, as well as the necessity for more efficient resource management. The circular economy is also being enabled by the emergence of new and high quality recycling technologies.

Put simply, we can no longer afford to follow the path of 'take-make-dispose'. Instead, if we are serious about building a sustainable society, we have to start reusing the materials we already have – properly and safely over and over again – with phosphorus being the perfect example. This nutrient, which is already listed by the EU as a critical material, is a potential showstopper if it's unavailable for food production.

In this new paradigm shift, waste is no longer just waste and instead becomes an important source of valuable raw materials in the circular economy. Upcoming regulatory changes in Switzerland and Germany, specific to phosphorus recycling, will be a key part of this economic shift. Both nations will be the first countries on the planet to make phosphorus recovery from sewage sludge mandatory. The new regulations should enter into force in 2026 in Switzerland and 2029 in Germany, with many more countries expected to follow suit. It's also safe to assume that these vanguard regulations will trigger investment in the sector by placing large volumes of recovered phosphorus on the market.

We believe that making wastewater treatment plants the resource factories of tomorrow is well within reach now. Our sewers provide plenty of resources – we just have to start using them properly.

A more level playing field between secondary and primary resources is also starting to be created. While there will still be some discrimination based on origin, the rising recovery of phosphorus from waste, and increased usage by industries like fertilizer production, will normalise secondary nutrients. Consequently, the European Commission and member states will eventually have to change the basis of their regulations from product origin to product quality. Until then, the fertilizer industry can take the lead in the consumption of secondary resources such as recovered phosphorus.

Achieving a critical mass

Generally, three prerequisites are needed for industry-wide adoption of a new material or process: quality, reliability, and volume. All three factors are necessary to guarantee commercial success, even when serious market demand exists. Encouragingly, EasyMining's Ash2Phos process meets two of these preconditions and is close to meeting the third.

Ash2Phos extracts phosphorus from sewage sludge ash at a quality level that is comparable to – and even higher than – existing industry standards for phosphate rock. Additionally, the constant generation of sewage sludge at wastewater treatment plants makes it a reliable resource for phosphorus recovery. All that's left is volume. The amounts of phosphorus received from incinerated sewage sludge is too low for the market at present. But, with the irrevocable shift to a circular economy and legislation being introduced in Switzerland and Germany, that situation will soon change.

In order to achieve a critical mass, phosphorus recovery needs to reach an estimated yearly production level of 10,000 tonnes. EasyMining has already joined forces with German utility Gelsenwasser, due to the country's regulatory framework and the sufficient ash volumes currently available nationally. The two firms formed the joint venture (JV) Phosphorgewinnung Schkopau GmbH in 2021. This JV will construct and operate Germany's first Ash2Phos plant. This is scheduled to become operational in 2025 and is designed to produce 15,000 tonnes per annum of calcium phosphate initially. Production volumes are then expected to ramp up to 150,000 t/a by the end of the decade, fuelled by beneficial regulations mandating phosphorus recovery and the construction of more and bigger plants.

Hopefully, the reliable recovery of high-quality phosphorus in large volumes will create irreversible momentum and be enough to kick start commercial nutrient recovery. There is a definite need for fertilizer producers to incorporate secondary nutrients such as recovered phosphorus, as events since March have shown. The easier it is to integrate these materials into existing value chains, the better. Not just for their own benefit but for everyone else's. ■

Cooling water facilities at phosphoric acid plants

Wet process phosphoric acid plants require reliable cooling water facilities. **Jan Tytgat**, engineering manager, De Smet Agro, shares his insights on the design and operation of cooling water networks, pumps and towers.

PHOTO: DE SMET AGRO

A line of eleven cooling tower cells at a phosphoric acid plant, each cell having its own belt-driven, six-blade fan.

The increasing importance of cooling towers

Cooling water is required at various sections throughout the phosphoric plant (see box). It can be sourced in one of two ways – either being directly taken from nearby open water (such as the sea, a lake or river) or supplied using a dedicated cooling tower.

Hot sea, lake or river water is simply returned to its original source. Hot cooling tower water, in contrast, is sent back to the cooling tower. The temperature of returning hot water is then brought down – thanks to large quantities of air carried by cooling tower fans – enabling it to be pumped back as cold cooling water to the various users in the plant.

In recent times, cooling towers at phosphoric acid plants have become increasingly prevalent, as the popularity of seawater or river water cooling has declined due to their associated negative environmental impacts. This article offers practical guidelines for cooling water use at wet phosphoric acid plant and highlights:

- Cooling water quality
- Cooling water networks
- Cooling water pumps
- Cooling tower design.

Cooling water quality

In phosphoric acid plants, direct contact condensers are widely used for cooling purposes downstream of the reaction flash cooler, the vacuum filter and concentration evaporators (see box). Cooling water in these condensers will partly adsorb the fluorine present in phosphoric acid when this is released as vapour under vacuum. Almost inevitably, cooling water will pick up entrained droplets of P_2O_5 as well.

In many phosphoric acid plants, extra equipment is therefore provided – mainly at the concentration section – to catch the carry-over of P_2O_5 droplets and reduce the fluorine content of the cooling water. For example:

- The installation of a P_2O_5 droplet separator downstream of the evaporator will contribute to a concentration section P_2O_5 efficiency of 99.5-99.9 percent.
- Single or double fluorine absorption towers can recover fluorine as fluosilicic acid (FSA). These are sometimes followed by an extra FSA droplet separator installed upstream of the condenser.

The installation of the above equipment, and proper blow down control, can reduce cooling tower maintenance and operational headaches by keeping cooling water P_2O_5 content and fluorine content as low as possible. Reducing fluorine content lowers fluosilicate deposition on cooling tower piping. This is beneficial as the resulting scaling is very hard and difficult to remove.

Cooling water is typically acidic (pH <2), contains 0.5-1 percent fluorine and 1-2 percent solids, together with traces of P_2O_5 and chloride. This is the reason why phosphoric acid plants have their own dedicated cooling towers – and do not use a common cooling tower with a sulphuric acid plant, for example.

Due to the returning water's acidic nature, cooling via a counter flow forced draft is highly recommended. This uses a fan in a vertical position located at the bottom of the cooling tower. A classic induced draft counter flow or cross flow cooling tower is not recommended. This is because, with the fan in a horizontal position on top of the cooling tower, the fan blades would be subject to an acidic wet air stream and acidic drift loss.

The acidic cooling tower system is completely integrated into the water balance of the phosphoric acid plant. Make-up water (needed to compensate for evaporation loss, blow down and drift loss etc.) can be provided, for example, by re-using the vacuum pump outlet seal water. The blow

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Cooling water requirements

Cooling water is needed throughout the phosphoric acid plant at the following sections:

- **Reaction flash cooler:** Large amounts of heat are generated in reaction tanks by the dilution of sulphuric acid and the exothermic reaction of sulphuric acid and phosphate rock. This is generally removed by either air cooling or evaporative cooling. In the second option, cooling water is used to condense evaporated water in a condenser downstream of a flash cooler.
- **Vacuum filter:** Gypsum generated in the reaction tanks is separated from weak phosphoric acid on a vacuum filter. Cooling water is used by a condenser downstream of the filter to reduce the amount of water vapour entering the vacuum pump.
- **Concentration evaporators:** Filtered acid is typically generated at either 26-29 percent P_2O_5 (Di-Hydrate process) or 40-42 percent P_2O_5 (Hemi-Hydrate process) concentration. This needs to be further concentrated to the required fertilizer-grade or merchant-grade acid (MGA), usually up to 52-54 percent P_2O_5. This is achieved by combining a heat exchanger and an evaporator in a forced circulation loop. Cooling water is used by a condenser downstream of the loop to condense the evaporated water generated.
- **MGA cooling:** In some cases, water-cooled heat exchangers are used to reduce the temperature of the MGA produced from around 85-88°C to about 45°C, prior to load-out onto vessels or road and rail tankers. ■

down – which is required to control and limit the amount of dissolved salts and the presence of fluorine in the cooling water – is not lost. It can re-used in the process as part of the cake washing water, for example.

Cooling water networks

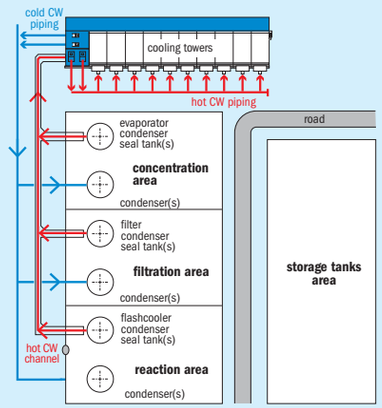
The heat load for a standard DH plant is typically split between one-third for the reaction-filtration section and two-thirds for the concentration section (i.e., for a single-crystal Di-Hydrate process producing 28% P_2O_5 filtered acid and 54% P_2O_5 concentrated acid). The cooling tower is usually installed close to the concentration units to minimise the cooling water network.

Cold water is pumped from the cold cooling water basin, located near the cooling tower, to the various condensers in the plant via an above-ground or underground piping network. Hot cooling water, on the other hand, can be returned to the cooling towers via channels or piping – or a combination of both – depending on the layout constraints.

In a classic scheme, all the plant's hot cooling water is returned to the hot cooling water basin by gravity via a common underground brick lined concrete channel (Figure 1). This arrangement (Case 1) is ideal for smaller phosphoric acid plants (less than 500 t/d P_2O_5) where the reaction, filtration and concentration areas are usually located close together. Pumps are used to move the hot cooling water from the hot water basin to the inlet nozzles of the cooling tower cells.

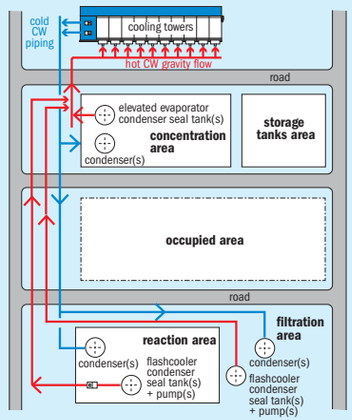
However, in larger phosphoric plants – where the reaction-filtration area is more isolated and located far away from the concentration section – a combination of gravity piping and hot water return piping & pumps can be used (Figure 2). In this arrangement (Case 2), the concentration condensers and seal tanks are elevated well above the top level of the cooling

Fig. 1: **Cassic hot water return scheme via channels (Case 1)**



Source: De Smet Agro

Fig. 2: **Hot water return piping scheme (Case 2)**



Source: De Smet Agro

Table 1: **Three different hot cooling water return arrangements, advantages and disadvantages.**

Scheme	Case 1	Case 2	Case 3
Return	Via underground concrete channels	Via above ground piping	Via a combination of channels and piping
Location Cooling Tower	Close as possible to concentration		
Concentration condenser seal tank position	Ground floor	Elevated above cooling tower inlet level	Ground floor
Underground brick lined concrete hot water basin and pumps?	Required	Not required	Required
Hot cooling water return from Concentration	Via brick lined concrete channel towards hot water basin near cooling tower	Via gravity pipe from seal tank outlet	Via brick lined concrete channel
Hot cooling water return from Reaction and Filtration		Hot water return pumps + piping to common cooling tower inlet by gravity pipe	Hot water return pumps + piping to channel towards hot water basin
Cooling Tower hot water feed	Via pumps from hot water basin	By gravity	Via pumps from hot water basin
Risk of debris or dust in hot cooling water?	Yes, if channels are kept open	No	Yes, if channels are kept open
Specific requirements	Channels can be covered or provided with handrails if open	Hot cooling water return piping on pipe racks	Combination of both
Cold cooling water pump head for concentration	Reference	About 15-20 mLC higher due to elevated condenser	Reference

Source: De Smet Agro

tower. This allows hot cooling water to flow down from these seal tanks under gravity through a large pipe towards the cooling tower inlet nozzles. The hot cooling water from the reaction-filtration area is pumped back to join the flow through the large gravity pipe towards the cooling tower. This arrangement is very valuable if underground channels are not desirable or possible due to lay-out constraints, e.g. where overhead pipe racks are used to avoid crossing roads with channels.

Of course, an arrangement combining channels (Case 1) and return piping (Case 2) is also possible. In this hybrid configuration (Case 3), concentration condenser seal tanks are kept at ground level and use a hot water return channel to link with the hot cooling water basin. Hot cooling water from the remotely located reaction-filtration area, meanwhile, is pumped back via piping to join the hot water return channel from the concentration section.

Each arrangement (Case 1, Case 2 and Case 3) has advantages and disadvantages, as summarised in Table 1.

The Case 2 arrangement has the following drawbacks, leading to extra costs, compared to Case 1 and Case 3:

- The concentration building needs to be elevated by 12-14 metres because the condenser seal tank, and hence the condenser and barometric leg (the down pipe between the condenser outlet and seal tank), needs to be elevated to enable gravity flow from the seal tank towards the cooling tower inlet nozzles.
- The cold cooling water pumps feeding the concentration condensers need a higher head (15 to 20 mLC) and hence larger motors.

On the other hand, depending on the phosphoric acid plant's specific layout constraints, Case 2 could offset these extra costs by avoiding the need for:

- Costly brick lined concrete channels with handrails or covers
- A hot water basin
- Hot water pumps & motors.

Cooling water pumps

The reaction-filtration and concentration areas can both use a common cold water network and common cold water pumps when the condenser seal tanks are all located at the same level. In other plant layouts, dedicated cold cooling water pumps and piping are necessary for each section. For example, a dedicated system for the concentration condensers is recommended where the concentration condenser seal tanks are elevated due to a different head.

In plants with more than two or three parallel concentration lines, it is very convenient to select and match cold cooling water pump capacity to the condenser's cooling water requirements. Then, if one concentration line is placed offline, the corresponding cold cooling water pump can be shut down too.

Arranging hot and cold cooling water pumps in a manifold line-up maximises operational flexibility. If desired, one standby pump can be easily installed via a common header.

Vertical or horizontal centrifugal pumps can be used to distribute cold cooling water and bring hot cooling water back to the cooling tower inlet nozzles. Vertical and horizontal pumps both operate at a similar efficiency of about 78-84 percent.

Vertical pumps, although usually more costly, are simpler to install as no suction piping is required (Figure 3). Horizontal pumps, meanwhile, can be installed on the basin bottom level (Figure 4). This arrangement does need an extra concrete pump pit, although it avoids the dedicated priming system required when pumps are located on the ground floor (Figure 5). Each of these cooling water pump arrangements have their own advantages and drawbacks, as summarised in Table 2.

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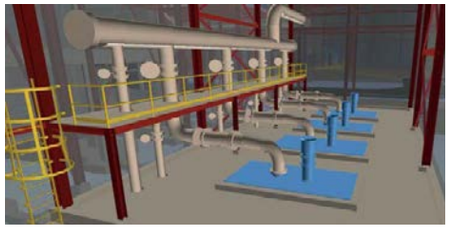
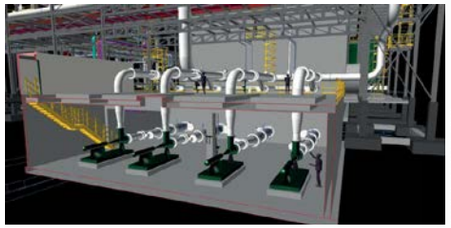


Fig. 3: Vertical cooling water pumps.



IMAGES: DE SMET AGRO

Fig. 4: Horizontal cooling water pumps – installed at basin bottom level.

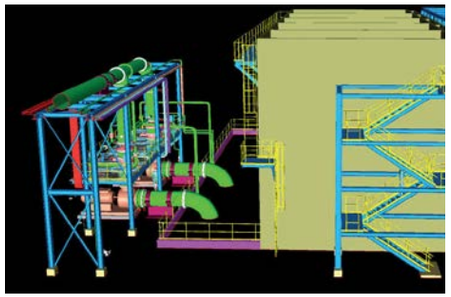


Fig. 5: Cooling water pumps – installed at ground level.

IMAGES: DE SMET AGRO

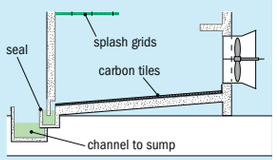
Fig. 6: Forced draft cooling towers cells in a back-to-back layout.

Table 2: **Three different cold cooling water pump arrangements, advantages and disadvantages**

	Vertical pumps	Horizontal pumps: installed at basin bottom level	Horizontal pumps: installed at ground level
Pump Cost	Higher	Reference	Reference
Priming system	Not required	Not required	Required
Suction piping	None	Very short	Longer
Concrete work for pumps installation	Slab on cooling water basin	Pump Pit + concrete pads required	Concrete pads required
Cooling water basin top	Closed, no risk of dust & debris entry	Open	Open

Source: De Smet Agro

Fig. 7: **A seal between the cooling tower cell's cold water outlet and channel to the sump prevents air loss**



Source: De Smet Agro

Cooling tower design

Specific construction materials are used to combat the acidic nature of the cooling water. The cooling tower structure consists of reinforced concrete with anti-acid protection. The anti-acid lining at the bottom of the tower and the base of the walls (a few bricks high) is protected with carbon bricks. A timber, concrete or polyester structure inside the tower support the grids or packing, the distribution channels and the drift eliminators. The grids are usually made of PP and are hung with 904L metallic wire to avoid corrosion. UV resistant PVC wave-type sheets located on top of the cooling tower cells are used for the drift eliminators.

Cooling towers consist of several cells arranged in parallel. Each typically receives a water inlet flow of about 500-1,000 m^3/h, the exact value depending on the cell size selected. The provision of one spare cell is generally recommended.

As already noted for the cold cooling water pumps, for plants with more than two or three parallel concentration lines, it is convenient if the cooling water required for one concentration line is equal to the flow sent to an exact number of cooling tower cells, e.g. 2-4 cells per concentration line. Then, when one concentration line is shut down, the corresponding cooling tower cells can be isolated and their fans stopped.

Cooling tower cells can be placed next to each other in one single line. Alternatively, they can be placed in two back-to-back rows if there are space constraints (Figure 6). In either case, it is very important that enough free area is provided in front of the fan – a minimum distance of double the fan height – and that no tall structures are installed near the cooling tower. Hot saturated air leaving the cooling tower must be able to disperse as freely as possible, as any recirculation to the inlet of the fan stacks would decrease cooling tower performance.

Hot cooling water needs to distributed as equally as possible between cells. To this end, each cell is equipped with a manual valve whose position is set and checked during cooling tower start-up. Internally, water also needs to be distributed equally over the entire cell. There are several ways to do this. A concrete channel can be positioned in front of each cell, for example, as shown in Figure 6. Several perpendicular and parallel FRP (fibre-reinforced plastic) channels bring the water from this channel to spray nozzles located below. Alternatively, closed plastic piping can also be used to feed the spray nozzles. Channels are, however, more maintenance-friendly as visual inspection and cleaning is relatively easy. The fan stacks surrounding the fans blades are fixed to the concrete wall. These are covered with a stainless-steel mesh to prevent injury when the fans are in operation.

The loss of air through the cooling tower's cold water outlet can be prevented by using a seal between the cell and the cold water channel that connects with the sump (Figure 7).

Conclusions

This article highlights the different options for the cooling water facilities at wet process phosphoric acid plants. This includes the type of cooling water network – channels, piping or both? – the configuration of cooling water pumps, as well as cooling tower design. Exactly what these facilities will look like depends mainly on the plant layout and its constraints. For phosphoric acid plant designers and producers, it is also important to understand the design parameters used by cooling tower suppliers when selecting the optimal cooling tower for your plant. ■

Cooling tower design parameters

Although thermal duty is a primary consideration, there are many other parameters that determine the size and design of cooling tower cells. Some important ones are highlighted below:

- **Range:** difference between hot and cold cooling water temperature, e.g., 42°C minus 32°C equals a 10°C range.
- **Dry bulb temperature:** the ambient air temperature taken by the fans.
- **Wet bulb temperature:** the lowest temperature obtained under ambient conditions by water evaporation only. Hotter and more humid regions have higher wet bulb temperature in comparison to colder ones. A larger difference between the dry and wet bulb temperature of the ambient air correlates with lower relative humidity. It is important to select the right coinciding wet and dry bulb temperatures, based on available ASHREA (American Society of Heating, Refrigerating and Air-Conditioning Engineers) weather data. The cooling tower should not be undersized or oversized, yet still be able to perform during the year's hottest and coldest periods.
- **Approach:** this is the difference between cold water temperature and design wet bulb temperature and, as a rule of thumb, needs to 4-5°C minimum.
- **Spraying rate or water loading:** this is the rate of cooling water sprayed per metre squared of cell area. A value of around 14-18 $m^3/h/m^2$ is typical.
- **Type of packing:** this must cope with water containing 1-2 percent solids, with a splash fill or grids used to avoid blockages.
- **Maximum allowable drift loss rate:** this is the percentage of circulating water that is allowed to be entrained by the wet hot air leaving the top of the cooling tower cell. Typical values are 0.0005-0.005 percent. Lower values are better although this does increase the cost of the drift loss eliminators.
- **L/G:** this is the ratio of the mass flow of cooling water (L) to the mass flow of air (G) brought by the fans. Values between 1.3-1.6 are typical.
- **Fan capacity:** this is selected based on the required L/G. Higher air flow per cell requires more fan blades (typically 4-8) and a larger fan diameter – and therefore a higher cooling tower since the fan is positioned vertically. Typically, 8,500-10,000 m^3/h of capacity is required for every square metre of cell area.
- **Fill height:** the fan's pressure drop will rise as fill height increases.
- **Fan driver:** the fan hub is located about two metres above ground level, depending on the fan size. A belt-pulley connecting the fan to the motor is an elegant solution as it maintains the motor on the ground level for easy access. It is possible to regulate fan speed – and hence cooling capacity – using a VFD (variable frequency drive).
- **Pumping head:** this is the pressure of hot cooling water required above the basin curb at the water inlet flange. This is an important parameter for correctly sizing the head of the hot cooling water pump.

> **"Cooling tower design parameters need to be well defined and agreed by both the plant designer and the cooling tower supplier.**

By keeping within set limits for the above parameters, cooling tower suppliers can determine the final sizing of the cooling tower cell, the amount and type of packing required, the best way to distribute hot water inside the cell, fill height and fan capacity etc.

Many of these parameters can affect the rest of the cooling water equipment at the plant. They therefore need to be well defined and agreed by both the plant designer and the cooling tower supplier. ■

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