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Phosphates 2022 conference, Tampa

The year ahead

Optimising phosphate production

Potash market report

Cover: State-of-the-art remote operation station at Mosaic's Integrated Operations Center, Lithia, Florida. The operator is controlling high-pressure water guns in the phosphate mining area miles away. Photo: The Mosaic Company.

The year ahead

Optimising phosphate production

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REGULARS

Editorial

Beirut's aftershocks

Ammonium nitrate (AN) is valued as a nitrogen fertilizer and mining explosive. Consequently, it is also widely traded and distributed globally. Some 20 percent of the 49 million tonnes manufactured annually is shipped around the world and stored in warehouses at various ports and inland destinations.

One such shipment of AN arrived in Beirut in 2013 on a dilapidated cargo ship, the MV Rhosus. En route from Georgia to a mining operation in Mozambique, this was, in fact, an unscheduled stop. But, unable to pay its port fees and reportedly leaking, the Russian-owned vessel had its AN cargo impounded and brought ashore.

That's how, in the summer of 2020, some 2,750 tonnes of mining explosive happened to be stored at Warehouse 12 in the Port of Beirut, Lebanon. Having sat there for six long years, in hot and humid conditions, largely unnoticed and neglected, in the centre of a densely populated city of two million people.

That was until the evening of 4th August when welders working at the warehouse accidentally ignited nearby combustible material. The resulting fire spread for around 14 minutes until it reached the AN pile. Then, at eight minutes past six, something cataclysmic happened.

At that moment, a massive chemical detonation occurred when nearly 3,000 tonnes of AN suddenly ignited, releasing an enormous wave of pressure and heat. The resulting supersonic blast instantaneously killed 220 people and injured more than 6,500, subsequently leaving around 300,000 people homeless.

This huge blast, which was heard in Cyprus 125 miles away, also created a 140-metre-wide crater and a seismic shock measuring magnitude 3.3 on the Richter scale. Nearby warehouses, grain silos and docked ships were instantly demolished, while 50,000 residential houses, 178 schools and nine hospitals were severely damaged. As well as the appalling human cost, the massive economic damage inflicted on Beirut by the blast is likely to exceed $6.7 billion.

So, what created this dreadful sequence of events on that warm Mediterranean evening 18 months ago – and was it avoidable?

After all, most experts agree that the safe production, transport and storage of ammonium nitrate is perfectly possible. Indeed, within the fertilizer industry, continuous improvements are being made to nitrate process safety and sustainability (see p20).

Writing about the tragic lessons of Beirut, fire protection expert Vyto Babrauskas said: "Manufacturers [have] learned to be safety conscious and there have been very few accidents in connection with the actual manufacturing process."

> **"Most experts agree that the safe production, transport and storage of ammonium nitrate is perfectly possible... most accidents occur in storage or in transport due to a single cause: an uncontrolled fire."**

Instead, concludes Babrauskas, almost all AN accidents occur in storage or in transport due to a single cause: an uncontrolled fire.

On 14th December last year, UN/OECD convened a one-day seminar on the 2020 Beirut port explosion and, in its aftermath, how best to manage the risks of AN storage, handling and transport.

Speaking at the event, Kishore Shah, a consultant to Fertilizers Europe, pointed out that: "Many codes and guidance documents for the safe storage of AN… are freely available for all. Their general message is that it is a very stable substance and its hazards are well known and understood. They stipulate similar safety expectations: non-combustible building design; avoidance of contamination; effective segregation from incompatible materials, sources of heat and shock. These requirements are not difficult to understand and implement."

What remains a challenge, though, is the fragmented regulation and division of responsibilities along international supply chains. These can be split between the primary producer, the transport industry, port authorities, local or national governments, fertilizer blenders and the merchant/distributor/farmer etc.

The industry recognises this, as Kishore Shah comments: "Most primary producers recognise that prevention of serious incidents involving fertilizer is vital, and therefore seek to work with highly professional agents, ship owners and port operators."

Governmental, regulatory and compliance failures were clearly key factors in the Beirut explosion. It is therefore unsurprising that the need to strengthen national legal frameworks and regulatory compliance was specifically flagged up in the conclusions of last December's UN/OECD seminar.

It is impossible to legislate for every eventuality. But there are usually steps which could and should have been taken to prevent disaster.

In Beirut, officials had repeatedly tried to warn government of the potential risks. At least 10 times over a six year period, individuals from Lebanon's customs, military, security agencies and judiciary raised the alarm about the large stockpile of explosive chemicals being kept at the port, according to an investigation by the Associated Press.

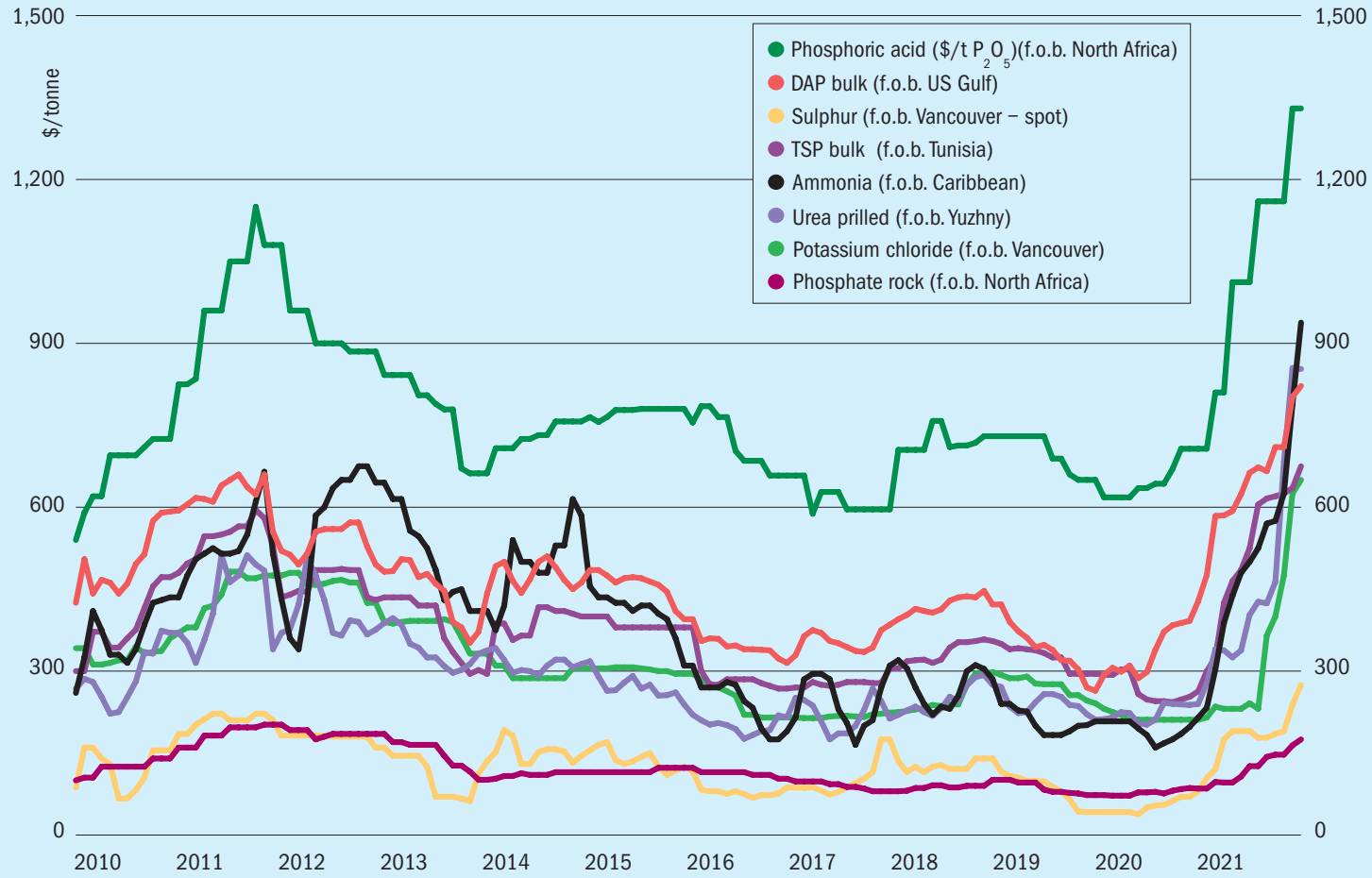
The real tragedy for Beirut and its people is that none of these warnings were ever acted on. ■

S. Inglethorpe

Simon Inglethorpe, Editor

Market Insight

Historical price trends $/tonne



Source: BCInsight

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: Widespread anticipation of a price correction appears to have forced it to become a reality. Consequently, prices crashed in many markets in mid-January. This crash was particularly marked in the US and Brazil. In general, buyers remained on the sidelines, prompting sellers to lower their prices to incite demand.

In Brazil, early January prices were in the low $700s/t cfr, down by $100/t in a week; bids and offers from buyers and sellers tracked downwards together – although trade itself was limited. US prices fell as low as $575/st f.o.b. Nola – equivalent to around $630/t cfr US Gulf – their lowest level since September 2021. Although Asian markets remained generally quiet, prices also fell in this region.

Key market drivers: many producers, from the Baltic through North Africa and the Middle East, are still holding uncommitted volumes for January loading; elevated natural gas prices; several offline nitrogen plants; severe Chinese exports restrictions.

Ammonia: While underlying sentiment remains very firm, with several regions short of product, mid-January trading was relatively calm. Indian buyers have been caught extremely short, however, and are in the market for any delivery date on offer. Middle East and southeast Asia cargoes – which could have met the Indian demand gap – are instead being diverted to Morocco and northwest Europe to take advantage of the huge premium in delivered pricing. Markets west of Suez are stable. Producers here are offering product above last done business. There is also an absence of spot availability from the Black Sea and Trinidad.

In Europe, the average cost of ammonia production in early January was estimated at $1,036/t, down by around $90/t on the week. Gas feedstock prices were trading in the range $22-29/mn Btu before settling around $28.3/mn Btu on the 13th January.

Key market drivers: supply shortages, particularly to Europe, Morocco and India, although some availability is reported in Turkey, Egypt and the Baltic; European energy prices.

Phosphates: India is the only market showing significant activity with buyers concluding sales from Russia, Morocco, Australia, China and Jordan. Another 350,000 tonnes of DAP purchases were confirmed mid-January – on top of 250,000 tonnes bought earlier that month. Further sales are still likely, given that a further 500,000 tonne first-quarter requirement is predicted. Domestic stock levels (around 1.3 million tonnes) are also still low historically. Chinese authorities are continuing to clear more product for export, although approvals are proceeding slowly.

Key market drivers: the slump in Chinese DAP output, with run rates in Hubei province reportedly at below 50 percent due to low domestic demand; the first-quarter phosphoric acid price and the

Market price summary $/tonne – Start January 2022

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	890-1,000	-	f.o.b. E. Europe 360-440	f.o.b. US Gulf	792-820	-	-
f.o.b. Yuzhny	950-1,055	780-890	-	f.o.b. N. Africa	881-950	650-700	1,290-1,400
f.o.b. Middle East	850-1,000	810-910**	-	cfr India	889-950	-	1,330*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	600-700	-	cfr US Gulf	200-275	f.o.b. Vancouver	275-310	-
f.o.b. Middle East	625-700	-	-	-	f.o.b. Arab Gulf	265-310	-
f.o.b. Western Europe	-	760-820	-	-	cfr N. Africa	280-320	-
f.o.b. Baltic	600-690	-	-	-	cfr India	297-340+	-

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.*

anticipated settlement between OCP and its Indian contract partners; downward revisions to the Brazil crop forecast due to adverse weather.

Potash: The market was still seasonally quiet in mid-January, with producers reflecting on the wider impacts of sanctions on Belarusian potash supply. While contracts between producers and India are imminent, there are currently no signs of any negotiations with the Chinese buying consortium.

Key market drivers: Yara – which typically sources 10-15 percent of Belaruskali's total annual potash output – winding down its sourcing from Belarus by 1st April due to sanctions on Belaruskali and BPC; Lithuania ending its railway transport agreement with Belaruskali, potentially signalling a complete cessation of potash exports through the port of Klaipeda from 1st February.

NPKs: NPK buyers are closely watching price movements in raw material markets. While potash and phosphates prices are stable-to-firm, urea prices, in contrast, are slipping with an expectation of a sharp downwards correction on the horizon. This softening has yet to translate to downwards price pressures. Instead, supply remains tight, particularly in Europe where offer prices are continuing to rise. Russian 15-15-15 offers for Europe, for example, are $635/t f.o.b. Baltic and above. In Africa, meanwhile, Kenya's KTDA has closed the pre-qualification stage of its annual tender for 87,000 tonnes of 26-5-5, with the usual suppliers all participating.

Key market drivers: low stocks prompting more Indian demand – RCF has issued the first Indian NPK/NPS buying tender of the year for 100,000 tonnes of 20-20-0+13S and 10-26-26; Belarusian fertilizers being unable to transit through the port of Klaipeda; Yara ceasing to source potash from Belaruskali by 1st April.

Sulphur: New sales to Indonesia, South Africa and Brazil concluded at firmer prices in mid-January. Suppliers have increasingly opted to sell product on a spot basis and have lowered their contract allocations this quarter. This stance is due to reduced export availability in some cases. It also offers the chance to benefit from current firm spot pricing. A recent spot sales tender from Qatar (35,000 tonnes for February lifting) is expected to attract a good level of interest. Kazakh sulphur export losses, due to the recent violent clashes between protesters and the military, are expected to be around seven days of production at a minimum.

Key market drivers: firmer cfr based sales, Kazakh supply resuming, and Turkmen product being sold on ex-works basis at a higher level.

OUTLOOK

Urea: Prices are likely to continue adjusting downwards in the near term. India is now out of the market until March or April, while Brazilian buying has slowed, and the US market remains volatile. Although there are plenty of offers in Europe, the hope of lower prices is causing buyers to wait. Gas prices in the region should, however, provide support while temperatures are low.

Ammonia: The market at the start of 2022 looks very different to 12 months ago. Early January Pivdenny prices, for example, are $875 higher (midpoint basis) than at the start of 2021. Import appetite in Europe, the US, Morocco, Latin America and India is keeping the market in deficit, with supply options remaining limited. The sale of an Indonesian cargo to a European customer earlier in January highlights just how tight the market is.

Phosphates: Demand is largely located in India. There is an expectation that prices will start softening in February-March, after the lunar new year, although this is dependent on the export clearances situation in China.

Potash: MOP prices have hit an affordability ceiling in Brazil, Europe and southeast Asia. SOP and NOP prices, in contrast, still have some upside in those regions where feedstock MOP prices are continuing to rise. Belarusian supply difficulties, including Yara's announcement that it will cease sourcing from the country and Lithuania's move to stop exporting Belarusian product through Klaipeda, are providing some upside to prices.

NPKs: More price clarity is required on the impact of diverging price directions in raw material markets. Yet NPK prices are likely to be flat-to-firm while demand continues to outweigh supply.

Sulphur: Firmer conclusions continue to be made week-on-week in the spot market, as the first-quarter continues to see constrained supply and robust demand. Metals buyers are seeing healthy margins, and the phosphate market also remains firm despite some slowing to liquidity. While contract supply concluded to date has been at the low end of product pricing, we expect the first-quarter of 2022 to see firmer pricing.

NORWAY

First commercial contract to sell fossil-free fertilizers

Yara and Lantmännen have signed an agreement to bring fossil-free mineral fertilizers to market.

This first-of-its-kind commercial deal will provide a market for green fertilizers Yara will produce using renewable energy. This should help decarbonise the food chain while offering consumers more sustainable food choices.

Yara began testing the commercial viability of green fertilizers with Lantmännen, northern Europe's leading 'farm-to-fork' agricultural cooperative, in 2019. The overall aim was to deliver the world's first fossil-free food chain. This collaboration has now resulted in a commercial contract for green fertilizers. These will be produced by Yara and marketed by Lantmännen in Sweden starting in 2023.

The green fertilizers will incorporate ammonia manufactured using renewable energy sourced from within Europe, such as Norwegian hydropower, for example. The result will be fertilizers with an 80-90 percent lower carbon footprint. Yara should be well-positioned to supply green ammonia in future from its portfolio of underdevelopment projects in Norway, the Netherlands and Australia. The company is also actively expanding its clean ammonia business.

"We have to transform the food system to deliver on the Paris Agreement, and this will require collaboration across the entire food chain instead of working in silos," said Svein Tore Holsether, Yara's president and CEO. "The Yara-Lantmännen partnership is a concrete example of how this can be done."

"With green fertilizers from Yara in place, we enable Swedish farmers to continue to be at the forefront, offering our customers sustainability performance according to global climate targets, as well as bringing sustainable food to consumers," said Per Olof Nyman, Lantmännen's president & CEO. "With this partnership, we can continue to meet an increased market demand for sustainable products."

Yara and Lantmännen are also collaborating on other projects to reduce the carbon footprint of farming. These are focused on crop nutrition, innovative farming practices and the use of digital tools.

PHOTO: MARTEN SVENSSON

Hans Larsson, Yara Sweden's commercial director, and Torbjörn Wahlström, market manager for arable inputs at Lantmännen, shake hands on the new fossil-free fertilizer deal.

By 2023, Yara says it will be able to provide the market with nitrate-based fertilizers with an 80-90 percent lower carbon footprint thanks to the use of renewable energy. These carbon savings will be validated by DNV, an independent assessor, using an established and reliable product carbon footprint (PCF) method.

Lantmännen – through its *Farming of the Future* programme – has already reduced the climate footprint of wheat cultivation by as much as 30 percent since 2015. Including green fertilizers within this programme should reduce the climate impacts of cereal growing by a further 20 percentage points. The sustainable grains already sold by Lantmännen include flour from Kungsörnen and oats from Axa. ■

Enova bankrolls Porsgrunn decarbonisation

Yara has been awarded NOK 283.25 million by the Norwegian state-owned investment company Enova. Yara will use the finance to begin the full decarbonisation of its Herøya ammonia plant in Porsgrunn, Norway.

Yara's Herøya fertilizer complex, which emits 800,000 tonnes of CO_2 annually, is one of Norway's largest industrial carbon emitters outside the oil and gas sector. However, Yara is implementing an ambitious project to manufacture emissions-free 'green' ammonia at Porsgrunn. This involves electrification of the site and switching to hydrogen generation using renewable energy.

"Norway has the unique opportunity to take a leading position in the green transition, but the window of opportunity is limited – that is why this decision is so important," said Svein Tore Holsether, Yara's president and CEO. "Emission free ammonia is the key to reducing emissions from world food production and long-distance shipping."

Commenting on the new award from Enova, Magnus Ankarstrand, the director of Yara Clean Ammonia, said: "We move from good intentions to actions. The investment decision has been made and the project begins now."

Yara's board made the decision to invest in a green ammonia demonstration plant at Porsgrunn in December 2020 (*Fertilizer International* 500, p10). The project is one of the world's largest.

At the heart of the Porsgrunn project is a new 24MW capacity electrolyser unit. This will produce enough hydrogen from renewable electricity to generate 20,500 tonnes of green ammonia annually. This, in turn, will be enough to manufacture around 60,000-80,000 tonnes of fossil-free fertilizer each year. The first green ammonia from the project, which is scheduled to enter the market as early as mid-2023, will be used for both green fertilizer production as well as a shipping fuel.

Holsether underlined how important the shift to green ammonia production is to Yara's own emissions reduction plans:

"Yara has already cut its own emissions by about 45 percent since 2005 and will continue to reduce its own emissions and emissions from power production by an additional 30 percent within 2030," he said. "We are very pleased that the authorities support the investment and has granted us the necessary permits and the financial support from Enova."

Yara restarts 'most' European ammonia production

Most of Yara's ammonia production in Europe is back on stream, the company confirmed in mid-December.

Record high natural gas prices led Yara to curtail ammonia production at a number of its European plants at the end of the third-quarter last year. Consequently, the company's European ammonia production had been operating at approximately 30per-cent (c. 370,000 tonnes) below capacity from September to November 2021.

Yara, like many European producers, was forced to cut ammonia production in response to record high natural gas prices in early October. Ammonia production costs became unsustainable for most market players and, consequently, units across the region ceased production and were idled (*Fertilizer International* 505, p8).

However, the impact on this curtailment on Yara's finished fertilizer production is said to have been limited. This was due to the company's ability to replace lost European production by sourcing ammonia from Yara plants outside Europe, via its global ammonia shipping network.

Nevertheless, Yara says it is continuing to monitor the gas price situation in Europe, with the aim of keeping customers supplied but curtailing production where necessary.

UNITED STATES

US sanctions target Belarusian Potash Company (BPC)

The US government has imposed targeted sanctions on the Belarusian Potash Company (BPC), the international marketing and export arm of the country's potash producer Belaruskali.

The sanctions, announced in early December, were in reaction to the escalating migration crisis on the EU-Belarus border.

State-owned potash producer Belaruskali was already the subject of previously imposed sanctions – with US companies being given until the 8th December to end their business dealings with BPC's parent company.

The new, additional sanctions now require US businesses to end their dealings with BPC as well. They will come not force from the start of April 2022 and also apply to BPC subsidiary Agrorozkvit and any firms in which BPC or Agrorozkvit hold a controlling stake (more than 50 percent). The sanctions will also have a wider effect by limiting access of the named firms to the US dollar-based financial system.

Belarusian muriate of potash (MOP) exports to the US – already fraught with difficulty due to the 8th December measures previously imposed on Belaruskali – now look certain to end.

Belarus has typically supplied about one-third of offshore MOP imports into the US in recent years. The likely loss of these volumes has been a key driver of bullish potash market sentiment, according to Argus, with a strong fall application season expected to boost demand for winter tonnages.

Despite this, demand destruction from escalating potash prices could act to offset the loss of export supply from Belarus. "Higher MOP values continue to fuel concerns for springtime consumption losses, potentially dampening the effect of lost BPC shipments," Argus commented in December.

US announces preliminary UAN import duties

The US has set provisional duties on urea ammonium nitrate (UAN) imports from Trinidad and Tobago and Russia.

The US Department of Commerce announced preliminary countervailing duties (CVD) at the end of November. The following rates were announced as anti-dumping measures:

- A preliminary 1.83 percent rate on Methanol Holdings Trinidad Limited (MHTL) and all other Trinidad suppliers
- Preliminary rates of 9.66 percent and 9.84 percent on Russian producers Acron and EuroChem, respectively
- A preliminary 9.72 percent rate on all other Russian suppliers.

The US Department of Commerce began investigating imports of UAN from Russia and Trinidad in July last year. This was in response to a petition from US producer CF Industries alleging unfair dumping and subsidy levels.

"Commerce's preliminary determinations are an important step towards levelling the playing field for the US UAN industry and its workers," said Tony Will, the president and CEO of CF Industries. "We appreciate the hard work of the Commerce professionals who are handling these investigations, and look forward to participating in the post-preliminary phase."

The conclusions of the US government's antidumping investigations into UAN, together with its preliminary rulings, are expected on 26th January. Under US law, the Department of Commerce and the US International Trade Commission must both make final determinations before a final antidumping/CVD order can be made. Their final decision-making is now expected in mid-2022 and could remain in place for five years or more.

Private equity firms buy DuPont clean technologies

DuPont has sold its clean technologies business to an international private equity consortium.

The sell-off created Elessent Clean Technologies, a new, independent company, at the start of January.

The private equity consortium completed the clean tech purchase from DuPont at the end of last year. The international group of buyers were named as BroadPeak Global LP, Asia Green Fund and The Saudi Arabian Industrial Investments Company (Dussur).

As a global leader in process technologies, newly-formed Elessent will be well-positioned to drive sustainability and carbon neutrality in the metal, fertilizer, chemical and oil refining industries. Elessent retains exclusive rights to the technologies, expertise, products, and services formerly offered via DuPont Clean Technologies. These include: *MECS*® sulphuric acid and environmental technologies, *BELCO*® scrubbing technologies, *STRATCO*® alkylation technology and *Isotherming*® hydroprocessing technology.

"We are excited about what the future holds for us as a standalone company," said Elessent CEO, Eli Ben-Shoshan, "The strong global expertise of the Group will accelerate our mission to deliver the technology and tailored solutions our customers need to more efficiently produce cleaner products for the world."

Elessent will continue to offer critical process equipment, technologies and services to a range of industries – most notably phosphate fertilizers, non-ferrous metals, oil refining, petrochemicals and basic chemicals. These are designed to minimise environmental impacts while optimising productivity.

INDIA

Smartchem fertilizer complex starts construction

Construction has begun on Smartchem Technologies Limited's new fertilizer complex. A ground-breaking ceremony with the laying of a foundation stone took place at

Gopalpur Industrial Park, Odisha, on 9th December 2021, Casale has announced.

Smartchem Technologies Limited's (STL) is a wholly-owned subsidiary of the major Indian fertilizer producer Deepak Fertilisers and Petrochemicals Corporation Limited (DFPCL). The complex will feature three of Casale's best-in-class technologies:

- A nitric acid plant (900 t/d) based on Casale's proprietary *NA2000* dual pressure process
- An ammonium nitrate solution plant (1,143 t/d) incorporating Casale's *AN2000* pipe reactor technology
- A prilling unit (1,000 t/d) for either high density ammonium nitrate (HDAN) or low density ammonium nitrate (LDAN), based on the newly acquired technology from ORICA.

For all three units, Casale will also supply:

- Licenses and know-how
- A revalidation of the original basic design
- Proprietary items
- Follow up design engineering
- Site assistance.

Additionally, the plant will be equipped with advanced NOx/N_2O abatement technologies to minimise emissions and discharges.

"This testifies to Casale's commitment to the development of technologies that favour not only the plant's performance, but also the reduction of emissions," said Federico Zardi, Casale's CEO. "Our final goal is always to contribute to the reduction of pollution and therefore to the general improvement of the climatic conditions of our planet."

Piling work at the Gopalpur site will begin this January with construction expected to be completed by August 2024. Around 50 percent of the project's engineering work is already complete.

BRAZIL

EuroChem gains controlling share in Fertilizantes Heringer

Swiss-headquartered EuroChem Group has bought a 51.48 percent share in the major Brazilian fertilizer distributor Fertilizantes Heringer.

The part-purchase will substantially strengthen EuroChem's production and distribution reach in one of the world's largest crop nutrient markets.

Fertilizantes Heringer is Brazil's fourth-largest fertilizer distributor on a capacity basis. The company has the ability to distribute more than four million product tonnes annually via a total of 14 storage, blending and distribution units in Brazil's southeast, midwest, south and northeast regions.

The controlling share in Fertilizantes Heringer forms part of EuroChem's wider growth strategy for the Brazilian market. It follows an agreement to purchase the Serra do Salitre phosphates project from Yara in August last year (*Fertilizer International* 504, p9), as well as the complete buy-out of distributor Fertilizantes Tocantins in 2020.

"This acquisition… will enable EuroChem to better serve the total market of Brazil – from north to south – even more reliably, while providing more outlets for our full product line of standard and premium fertilizers," said Charles Bendaña, EuroChem Group's global head of sales and distribution.

He added: "It will also help us achieve higher efficiency in our shipping and logistics programs in order to provide reduced costs to our customers in Brazil, as well as increased netbacks to our global production facilities. Taken with our recent full acquisition of Fertilizantes Tocantins and the ongoing purchase of the Serra do Salitre phosphates project, this move will help anchor the Group as a leader both locally and abroad."

Lieven Cooreman, the CEO of EuroChem Fertilizantes Tocantins, and the head of EuroChem's South American commercial division, said: "With Heringer joining a South America distribution base that already includes EuroChem Fertilizantes Tocantins in Brazil and EuroChem Emerger Fertilizantes in Argentina, this deal, once approved, will cement our reputation as the crop nutrient supplier of choice across great swathes of the continent. This naturally gives our customers added confidence in our ability to cater to any crop anywhere, in a timely manner."

The acquisition – which is valued at nearly BRL 555 million – will require the approval of CADE, Brazil's antitrust authority.

Heringer reported 12-month fertilizer sales of 1.5 million tonnes last year (October 2020 to September 2021).

AUSTRALIA

IPL announces Queensland fertilizer plant closure

Incitec Pivot (IPL) is planning to shut its Gibson Island fertilizer plant in December this year when its current gas supply contract expires.

IPL took the decision to close the Brisbane, Queensland, site – which has a 50-year history of fertilizer manufacturing – after failing to secure an economically viable long-term gas supply agreement for the plant. The Australian fertilizer and chemicals producer is, however, still looking at the feasibility of converting the existing plant to green ammonia production instead.

IPL signed its existing nine million t/a gas supply agreement for Gibson Island plant with Australia Pacific LNG (APLNG) in June 2019. IPL had previously announced plans to supply gas to the plant beyond the end of 2022 by restarting the Queensland's Range gas project with its partner company Central Petroleum.

But in a memo to shareholders, Jeanne Johns, IPL's managing director and CEO, said: "We were unable to enter into a proper commercial gas supply contract with our people in the Australian manufacturing industry. It's a shame for me."

Around 80 percent of the gas produced in eastern Australia is either shipped as liquid natural gas (LNG), according to Argus, or used to fuel three LNG-powered electricity generating plants at the port of Gladstone in Queensland.

IPL plans to replace the lost domestic production from Gibson Island by sourcing ammonia, urea, ammonium sulphate and other products with imports from its existing international supply chains.

SAUDI ARABIA

Contract for green hydrogen mega project

thyssenkrupp Uhde Chlorine Engineers is to supply the electrolysis plant for one of the world's largest green hydrogen projects at NEOM in Saudi Arabia.

thyssenkrupp secured the contract for the project from Air Products in mid-December. Under its terms, the German engineering giant will engineer, procure and fabricate a massive electrolysis plant with more than two-gigawatts capacity for the project's three partners – NEOM, ACWA Power and Air Products. These partners will then operate the facility

PHOTO: THYSSENKRUPP

thyssenkrupp signs a contract with Air Products to supply a massive electrolysis plant of more than two-gigawatt capacity.

as the NEOM Green Hydrogen Company.

The giant project will use thyssenkrupp's large-scale 20-megawatt alkaline water electrolysis module to generate hydrogen for use in green ammonia synthesis. Air Products will have exclusive rights to export the resulting carbon-free ammonia to global markets. Project engineering and procurement have already started, with first production scheduled for 2026.

"As a world market leader in electrolysis we bring in two decisive factors to realize such gigawatt projects: With our large-scale standard module size and gigawatt cell manufacturing capacity per year – together with our Joint Venture partner De Nora – we are able to deliver large capacity projects today", said Denis Krude, CEO of thyssenkrupp Uhde Chlorine Engineers. "With this gigawatt project, we are committed to invest into ramping up our manufacturing capacities further. We also aim for a strong local setup which is key to delivering customized service solutions throughout the entire plant life-cycle and enables our strategic partner in their vision to become a global decarbonization pioneer."

Samir J Serhan, chief operating officer at Air Products, said: "This project milestone with thyssenkrupp furthers our strong progress at NEOM to deliver carbon-free hydrogen on a massive scale in the Kingdom and for the world. The development and execution of this innovative megaproject is one of many required to drive a successful energy transition, and we look forward to continuing to develop, build, own and operate facilities that help address the world's significant energy and environmental challenges."

MALAWI

Ma'aden opens fertilizer terminal

Saudi Arabian mining company Ma'aden, through its African subsidiary Meridian Group, has opened a new world-class fertilizer terminal in Liwonde, Malawi.

The terminal was officially inaugurated on 22nd November in an opening ceremony attended by the president of Malawi and other dignitaries, including Malawi's finance and agriculture ministers and members of parliament. The ceremony was also attended by Hassan Al-Ali, the senior vice president of Ma'aden's phosphate business unit.

The Liwonde terminal is strategically located on the rail line connecting Malawi to the deep-sea port of Nacala in Zambia – a location that will allow Ma'aden to distribute its fertilizer products across central and southern Africa.

The state-of-the-art terminal has a roof area of 15,000 m^2 and combines 40,000 tonnes of storage capacity with 2,400 t/d of blending capacity. Its annual production output equates to 360,000 tonnes in total.

The terminal operates using a modern cloud-based logistics and supply chain management system, and has an advanced on-site laboratory for rapid and accurate fertilizer testing. It is also powered by renewable energy to minimise CO_2 emissions.

The Liwonde terminal will provide more than five million smallholder farmers in Malawi and Zambia with access to a steady supply of high-quality fertilizers for the first time. Ma'aden expects the resulting growth in its exports to Africa to improve food security for the whole continent.

The terminal's opening cements Ma'aden's position in one of the world's fastest growing agricultural regions. It follows other strategic investments by the company in Africa, such as the acquisition of Meridian Group in 2019.

People

Ken Seitz has been named as Nutrien's interim CEO following the resignation of the former CEO and president **Mayo Schmidt** on the 4th of January. Schmidt had only been in post for eight months, having taken over from Chuck Magro in April 2021. Mr Seitz was the company's executive vice president and CEO of potash prior to the announcement. His appointment is a transitional arrangement.

Russ Girling, the chair of Nutrien, said: "Nutrien has a talented and deep executive team, and we are confident that Ken Seitz and this team will continue to build on the organisation's record financial and operating performance. The Nutrien board of directors will work with an executive search firm to begin a global search to select a long-term leader that will take the company into its next phase, which will consider internal and external candidates."

Ken Seitz replied: "I look forward to working with the executive leadership team, our tremendous employees and the board of directors to execute on our plan, continue this exciting progression across our business to serve our stakeholders, and deliver on our commitment to advance sustainable solutions to feed a growing world."

Mr Seitz joined Nutrien in 2019, bringing with him 25 years of global management experience. Notably, he was formerly president and CEO of Canpotex, one of the world's largest potash suppliers. He holds a BSc in agriculture, a BEng and an MBA from the University of Saskatchewan, together with a certificate in management from New York's Stern School of Business.

Yijun "Jenny" Wang has joined The Mosaic Company's senior leadership team. She was appointed senior vice president for global strategic marketing, and head of China and India, with effect from the 1st of January.

Jenny foined Mosaic in 2011 and was previously the company's vice president for global strategic marketing. In this role, she led on Mosaic's pricing strategy, global product placement, strategic market analysis, brand marketing, new product commercialisation, and Mosaic's distribution businesses in China and India. Ms Wang has also served as a board director at Canpotex for two years.

"Jenny's expertise in the global agriculture market has played a key role in Mosaic's strategy for the past 10 years," said Joc O'Rourke, Mosaic's president and CEO. "Her leadership will be critical to Mosaic's global positioning as the industry continues to evolve and we expand our distribution business in China and India."

Prior to joining Mosaic, Wang held various leadership roles at Syngenta for 16 years, working out of China, Vietnam and its global headquarters in Switzerland. Her roles and responsibilities included sales, marketing, strategy and business development, global product management and a stint as country managing director.

Jenny is a graduate of the advanced management program at Harvard Business School. She also holds a biology MSc from South China Agriculture University and a biology BSc from Sun Yat-sen University.

Kai Bartram is TOMRA Mining's new global sales director. He was appointed to the company's management team at the start of November and will be based at TOMRA's offices in Wedel, Germany. In his new role, Kai will be responsible for managing and coordinating the company's mining sales teams globally.

Kai Bartram, TOMRA Mining.

Albert du Preez, senior vice president and head of TOMRA Mining, said: "I am delighted that Kai is returning to TOMRA and joining our management team. He started his career with us as a graduate engineer, and over the past two decades he has acquired vast knowledge in the mining industry. With his experience, he will strengthen our sales team and help shape our approach to market."

Commenting on his appointment, Kai Bartram said: "I am excited about returning to TOMRA and looking forward to working with our global sales teams to further grow our sensor-based sorting market in the mining sector."

Mr Bartram worked for TOMRA from 2000 to 2010, firstly in R&D and applications and then in sales, where he was tasked with introducing sensor-based sorting to the mining sector. He holds a master's degree in electronics from Hamburg University of Applied Sciences.

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.

MARCH

7-9

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

21-23

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

28-30

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

28-31

IFA, Global Sustainability Conference,
Virtual event
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

MAY

12-13

IFS Technical Conference,
AMSTERDAM, The Netherlands
Contact: Steve Hallam
Tel: +44 (0)1206 851819
Email: secretary@fertiliser-society.org

30 MAY – 1 JUNE

IFA 2022 Annual Conference,
VIENNA, Austria
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

The year ahead: affordability and availability concerns

We look ahead at fertilizer industry prospects for the next 12 months, including the key economic and agricultural drivers likely to shape the market during 2022.

IMAGE: LIGHTSPRING / SHUTTERSTOCK.COM

Export restrictions, alongside elevated prices and plant shutdowns, are affecting fertilizer availability and affordability.

Economic backdrop

The world is continuing to recover from the exceptional contraction in economic activity triggered by the onset of the Covid-19 pandemic in 2020 (*Fertilizer International* 500, p13)

Global growth is currently projected to increase by 5.9 percent in 2021, according to the latest International Monetary Fund (IMF) forecast. Growth is expected to continue to rebound strongly this year, rising by 4.9 percent overall in 2022. Yet the extent and speed of this recovery, for individual countries and from region-to-region, remains unpredictable.

Strong fundamentals and policy measures in advanced economies such as the US and the European Union are expected to support solid economic growth this year. In emerging markets, while some commodity-exporting countries (e.g., Russia, Brazil

What drives fertilizer demand?

Fertilizer demand is influenced by the complex interplay of many factors – some of which are harder to predict than others. In the short-term, the main drivers of demand include:

- Farm economics and the macroeconomic outlook
- Crop prices and fertilizer-to-crop price ratios
- Crop mix, growing areas and crop yields
- Soil nutrient levels and nutrient replenishment
- Policy, regulation and fertilizer subsidies
- Sustainability, nutrient management and recycling

The importance of these factors varies from country-to-country and region-to-region. Adding to the complexity, these primary drivers are in turn influenced by a host of secondary considerations.

Macroeconomic conditions, by triggering slowdowns or expansions in global, regional and national growth, control overall economic demand and affect the health of agricultural markets. **Farm economics** and attendant issues such as credit availability and barter ratios have a more direct impact on the ability of farmers to purchase fertilizers.

Crop prices and fertilizer-to-crop price ratios act as key controls on crop nutrient demand as they play a critical role in determining farm buying power and fertilizer affordability. Crop prices in turn are driven by the **harvest size** annually, **stock levels** and **demand** for agricultural commodities. Fertilizer industry analysts pay particularly close attention to the prices of cereals, oilseeds, cotton, sugar and palm oil, the main fertilizer-consuming crop types globally.

The **biofuels market** is also an important driver of fertilizer demand due to large-scale cultivation of maize and sugarcane for ethanol and oilseed rape (canola) for biodiesel (*Fertilizer International* 474, p22). Crop failures due to extreme weather events such as the **El Niño** (*Fertilizer International* 475, p38) and **La Niña** can also affect fertilizer demand in the short-term.

and Mexico) are recovering swiftly, recovery elsewhere will be strongly linked to vaccine access. China's resilient powerhouse economy is expected to show robust growth during 2022, despite concerns over the stability of its property and financial sectors[1].

Natural gas prices have surged in recent months – driven upwards by a combination of resurgent demand and stagnant supply – with European and Asian spot prices reaching record highs. In Europe, the resulting energy crunch has triggered a chaotic collapse in ammonia production (*Fertilizer International* 505, p8).

Disruptions to shipping and global supply chains inflicted by the Covid-19 pandemic are continuing – leading to longer transit times and higher international freight costs. As a consequence, commodity markets are expected to be affected by elevated shipping costs into 2022[1].

Some major fertilizer-producing countries have reacted to supply chain disruptions and inflationary pressures by restricting exports in 2021's last quarter (*Fertilizer International* 505, p4). Most notably:

- China acted to freeze fertilizer exports in October
- Turkey set export restrictions on diammonium phosphate (DAP) and NPK fertilizers, while Vietnam placed a six percent import duty on DAP
- In November 2021, Russia introduced a six-month export quota on nitrogen and phosphate fertilizers
- Similarly, Egypt halted any nitrogen exports not specifically cleared by the country's ministry of agriculture.

In combination, these government measures are having negative impacts on fertilizer availability and trade flows globally[1].

Food prices reach 10-year high

The FAO Food Price Index (FFPI) reached its highest level in a decade as 2021 ended, averaging 133.7 points in December, some 23 percent higher than a year ago. In real terms, this has boosted food prices to levels last seen in the mid-1970s.

The FFPI averaged 125.7 points for 2021 as whole, almost one-third higher (28 percent) than the previous year's average, with prices of cereals, vegetable oils, and sugar all sharply up on 2020.

The cereal price index averaged 131.2 points in 2021, the highest annual average since 2012 and up by 27 percent on 2020. Maize and wheat prices rose on strong demand and tighter supplies. Rice, meanwhile, was the sole major cereal to register a price decline last year, reflecting ample export availability.

The vegetable oil price index rocketed to an all-time high in 2021, averaging 164.8 points, an increase of 66 percent on 2020. As the year closed, world soy and rapeseed oil prices maintained their strength, being underpinned by firm import demand (primarily from India) and protracted global supply tightness, respectively.

The 2021 sugar price index – averaging 109.3 points, up 38 percent on 2020 – reached its highest level since 2016. Price increases throughout the year were supported by concerns over falling Brazilian output at a time of stronger global demand.

Waxing and waning global demand

Fertilizer demand has been on a rollercoaster ride in recent years, with periods of both contraction and expansion. Going back to 2019, Canadian fertilizer giant Nutrien infamously described the spring that year as "the worst US planting season in history" after record rainfall prevented crop planting across 10 million acres – a new US record. This followed and compounded a poor US fall application season for fertilizers in 2018 (*Fertilizer International* 500, p13).

These unfavourable North American market conditions tipped world fertilizer demand into reverse in 2018/19. Global fertilizer consumption did, however, subsequently recover by 1.9 percent in 2019/20 to reach 189.8 million nutrient tonnes, according to the International Fertilizer Association (IFA), reversing the contraction of the previous year (Table 1, Figure 1). The global recovery in fertilizer use seen in 2019/20 was led by India, which enjoyed abundant monsoon rains, and the US, which, at long last, benefitted from favourable weather conditions (*Fertilizer International* 500, p13).

Then Covid-19 happened. With the pandemic's arrival in March 2020 further large-scale disruption to the fertilizer market looked almost inevitable, given the unprecedented damage inflicted on other parts of the world economy. As late as May 2020, IFA was forecasting a three percent year-on-year decline in global fertilizer demand in 2020. This would have been the largest contraction in the fertilizer market since the eight percent drop that occurred during the global financial crisis more than a decade ago (*Fertilizer International* 500, p13).

However, contrary to initial forebodings, the fertilizer market proved to be remarkably resilient as 2020 progressed, bucking the general economic trend and confounding the original downbeat expectations. The fertilizer sector instead overcame the widespread economic paralysis from Covid-19 lockdowns to rebound strongly during 2020. Indeed, IFA currently expects world fertilizer demand to grow by more than six percent in 2020/21 to reach 203.8 million nutrient tonnes (Table 1). This 12 million tonne increase is the largest annual expansion in fertilizer use since 2009/10[1].

A number of factors sustained fertilizer demand during the pandemic. In particular, national governments moved quickly to prioritise food supplies – introducing mitigation measures that supported and protected the fertilizer industry and the wider agricultural sector. Demand was also bolstered by attractive fertilizer-to-crop price ratios in 2020 and favourable weather conditions in key end-markets. Weakening of domestic currencies, versus the US dollar, also boosted profits in key agricultural-exporting countries (*Fertilizer International* 500, p13).

Agricultural commodities: grim prospects after a stellar year

Demand for agricultural commodities has been stellar over the last 12 months, comments Rabobank in its latest annual outlook. Not always due to consumption either. The precautionary buying of 'just in case' stocks, the bank suggests, is putting pressure on supply chains that are already stressed on a number of fronts.

Rabobank predicts that food prices are unlikely to return to five- or ten-year averages in 2022. This is due to a range of inflationary pressures, including high shipping costs (astronomical for containers), escalating energy and fertilizer prices, as well as labour shortages in many countries.

Adverse weather has continued to take its toll on global agriculture as well. For example:

Table 1: **Global fertilizer demand forecast, million nutrient tonnes***

Nutrient	2022/23f	2021/22f	2020/21e (million tonnes)	2019/20 (million tonnes)	2018/19 (million tonnes)
N	114.0 (+2.4%)	111.3 (-2.1%)	113.7 (+5.0%)	108.2 (2.5%)	105.6
P_2O_5	49.5 (+3.1)	48.0 (-3.3%)	49.7 (+6.8%)	46.5 (+2.2%)	45.5
K_2O	40.3 (+3.8%)	38.9 (-3.9%)	40.4 (+9.1%)	37.0 (-0.3%)	37.1
Total	203.9 (+2.9%)	198.2 (-2.7%)	203.8 (+6.3)	191.8 (+1.9%)	188.2 (-0.9%)

** Year-on-year percentage increase in parentheses. e = estimate. f = forecast.* *Source: IFA (November 2021)*

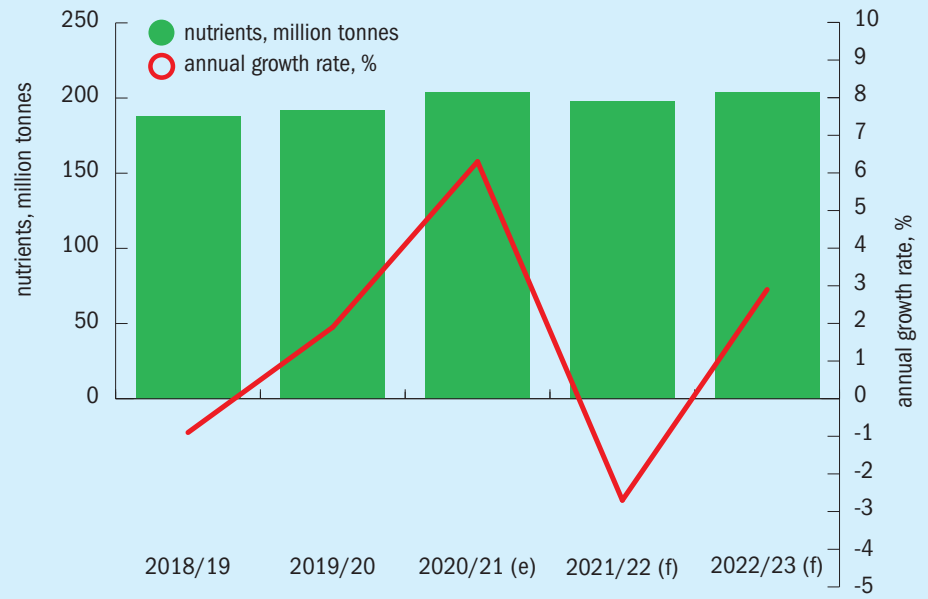
- Brazil, on top of an extended drought, experienced its worst frost in over two decades in July last year
- The major North American drought, that first started in the west of the country in late 2020, extended north in mid-2021, and is likely to expand into Kansas in the coming months
- Europe was affected by strong rainfall and flash floods last summer
- Europe and Canada also broke maximum temperature records in the summer of 2021
- Finally, current La Niña conditions are likely to persist into 2022's second-quarter.

In summary, If 2021 was a stellar year for ag commodities, Rabobank's outlook for 2022 is more grim – with warnings of potential social discontent due to food price inflation:

"Higher farm input costs, expensive shipping and good demand provide for a grim combination. We should see these inflationary pressures move upstream along the supply chain to reach consumers in 2022, with uncertain social consequences.

"The proportional increase in prices on supermarket shelves will of course be much smaller, as commodity prices are usually only a relatively small proportion of the prices of final goods. But social discontent is already being felt in a few countries and more is likely to come in 2022."

Fig. 1: **World fertilizer consumption (nutrient tonnes) and annual growth rate: 2018/19-2022/23**



Note: 2019/20 = Estimated. 2020/21 & 2021/22 = Forecast. *Source IFA (November 2021).*

Fertilizer demand

Continuing the seesaw in consumption (see box), the International Fertilizer Association (IFA) expects fertilizer demand to have slipped into reverse last year – driven downwards by negative changes to affordability. The association is currently forecasting a contraction of three percent in global demand in 2021/22 – equivalent to a drop of 5.5 million tonnes to 198.2 million nutrient tonnes, with all three nutrients being negatively affected (Table 1, Figure 1).

The international prices of the main commodity fertilizers all rose sharply over the course of 2021 to outpace crop prices. In particular, the affordability of urea and diammonium phosphate (DAP) declined relative to grains, while that of muriate of potash (MOP) fell relative to soybeans. The continued growth in palm oil prices did, however, maintain the affordability of MOP in this market.

Looking ahead, the demand outlook for this year is clouded and uncertain – due to emerging availability as well as affordability concerns – with IFA commenting[1]:

"Most correspondents highlighted the difficulty in forecasting 2022/23 fertilizer demand given the current uncertainty regarding crop prices, fertilizer affordability and fertilizer availability. Fears of nitrogen shortages in the second half of 2021 were driven by production cuts at some plants, related to soaring gas prices, and other factors disrupting fertilizer supply."

Nevertheless, demand fundamentals are expected to improve this year and into next, with IFA forecasting a three percent recovery in global fertilizer demand in 2022/23, rebounding from the three percent fall seen in 2021/22[1].

Fertilizer production and trade

World production and trade in urea and finished phosphates are estimated to have fallen last year – the victim of the supply disruptions that have emerged across the major fertilizer markets. As a result, fertilizer availability, not just affordability, has become a source of growing concern, with multiplying disruptions prompting a rapid increase in fertilizer prices over the course of 2021 and into this year.

Fertilizer supply has been affected in a variety of locations and across all major product categories. The consequent disruptions

can be split into three main categories – physical, economic, and geopolitical – as follows[1]:

- **Physical disruptions** to US nitrogen and phosphates production due to weather-related events
- **Economic disruptions** to European nitrogen production due to the tight energy market and soaring gas prices
- Looming **geopolitical disruption** due to incoming sanctions affecting potash exports from Belarus, and three major producing countries (China, Russia and Turkey) limiting their exports to protect domestic fertilizer supply.

Urea: Nitrogen availability in 2021 was hampered by both high energy prices and export restrictions. Consequently, supply disruptions are now expected to result in year-on-year (y-o-y) decreases in world ammonia and urea production in 2021, pushing these to below 2019 levels in both cases. Urea production last year is thought to have contracted to 176.8 million tonnes.

Similarly, global urea trade is estimated to have fallen by almost 1.5 million tonnes y-o-y in 2021. Lower urea imports into India, Mexico and Turkey reflected lower export levels from Ukraine, West Asia, Algeria and China.

World urea capacity is projected to increase by 14.3 million tonnes in 2021 and 2022. IFA is forecasting the commissioning of 18 nitrogen projects over this two-year period – a highly significant volume of new capacity following a quiet year for plant start-ups in 2020[1].

Phosphates: Global production of finished phosphates in 2021 is thought to have remained flat, the IFA suggests. Nevertheless, an increase in monoammonium phosphate (MAP) trade for the year is predicted. Rising Brazilian import demand during 2021 was satisfied by higher MAP exports from China and Russia, more than offsetting the decline in US exports to the country.

Global diammonium phosphate (DAP) trade, meanwhile, is thought to have contracted in 2021 linked to lower Indian import levels. Declining exports from West Asia, North Africa and the US were also to blame, eclipsing higher 2021 exports from China.

Globally, finished phosphates capacity is forecast to increase by 3.8 million product tonnes in 2022. largely due to the commissioning of three new projects in Russia, Morocco and Tunisia[1].

Potash: While urea output most likely fell last year, and finished phosphates production flatlined, buoyant potash output bucked the general market trend. Indeed, strong year-on-year growth in world muriate of potash (MOP) production and trade is now predicted for 2021 in response to record levels of demand. Looking ahead, however, the imposition of draconian sanctions on Belarus remains a significant potash market risk.

World potash capacity is forecast to rise by 3.1 million tonnes (K_2O) during 2021 and 2022, with 1.6 million tonnes of this additional capacity likely to be commissioned this year. Expansion projects over this two-year period look set to increase global potash capacity to just under 66 million nutrient tonnes. Growth in 2021 was driven by new capacity in Belarus, Russia, Laos and China, while the expansions forecast for this year centre on Russia supplemented by smaller expansions in Canada and Jordan[1].

Reference

1. IFA, 2021. Short-Term Fertilizer Outlook 2021-2022. Public Summary. *IFA Strategic Forum*, Dubai, 15-17 November 2021. International Fertilizer Association (IFA).

PHOTO: IDO MEIROVICH / SHUTTERSTOCK.COM

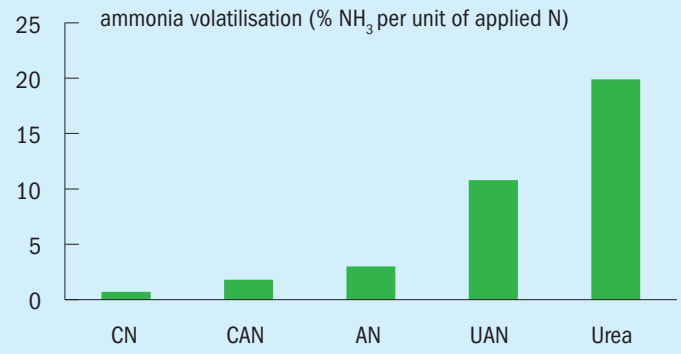
Safer and sustainable nitrates production

State-of-the art technologies offered by thyssenkrupp, Casale and Stamicarbon are helping make nitrates production more secure and sustainable.

Worldwide, ammonium nitrate (AN) is the second most important nitrogen fertilizer after urea (*Fertilizer International* 503, p29). Advantageously, it supplies nitrogen in two different forms: nitrate (NO_3^-) and ammonium (NH_4^+). While crops can take up nitrate directly, ammonium acts more slowly as it needs to be converted into nitrate by soil bacteria prior to take-up. Using AN as a fertilizer therefore helps ensure that nitrogen is available to crops both immediately and over the longer term.

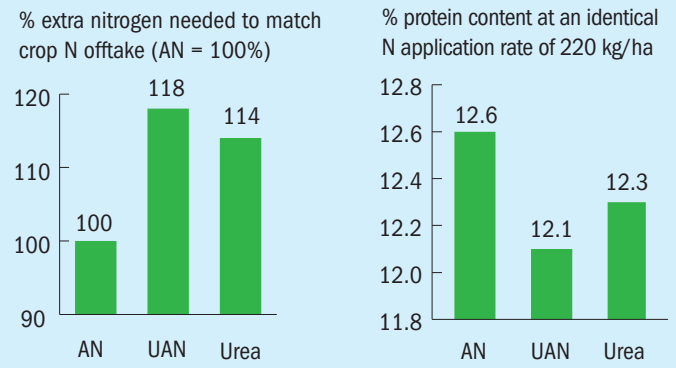
AN can also improve crop yields by avoiding the ammonia volatilisation associated with urea and urea ammonium nitrate (UAN). The resulting nitrogen losses contribute to pollution, affect air quality and waste resources. Indeed, ammonia volatilisation from AN and calcium ammonium nitrate (CAN) is several times lower than from urea or UAN (Figure 1). In UK wheat trials, the application of AN also achieved the best yield response (crop N offtake) and crop quality (protein content) compared to other nitrogen fertilizers (Figure 2).

Fig. 1: **Percentage ammonia volatilisation of different nitrogen fertilizers**



Source: EMEP/EEA air pollutant emission inventory guidebook

Fig. 2: **UK wheat trial results for different nitrogen fertilizers extra nitrogen needed (L), % protein content achieved (R)**



Source: DEFRA, 2006

THYSSENKRUPP

Green and safe ammonium nitrate

Green technologies

By using renewable energy, thyssenkrupp Uhde (a business unit of thyssenkrupp Industrial Solutions) can design and offer a completely integrated and green fertilizer production line based on its own technologies (*Nitrogen+Syngas* 371, p44). These include:

- Green hydrogen production by the water-electrolysis process.
- The conversion of hydrogen to green ammonia
- Nitric acid production with the proven and most effective N_2O and NOx reduction technology (*EnviNOx*®)
- Ammonium nitrate production to supply granulation, prilling or urea ammonium nitrate (UAN) plants.

Green hydrogen production is based on alkaline water electrolysis technology offered by thyssenkrupp Uhde Chlorine Engineers (tk-UCE), a joint venture with Industrie De Nora. This can be converted to green ammonia and methanol or used to supply other hydrogen-based production processes such as synthetic natural gas and Fischer-Tropsch synthesis.

The subsequent use of green ammonia in nitric acid production results in a much smaller carbon footprint. Also, by partly replacing or supplementing process air with oxygen – an otherwise unused by-product of water electrolysis – the efficiency and/or capacity of the nitric acid plant can be significantly increased.

Make your plant fit for the future

100 Years Uhde

100 years ago, Friedrich Uhde saw a huge demand for ammonia to ensure food supplies. That was the birth of Uhde in 1921. Today, thyssenkrupp Uhde is your partner for new plants and for upgrading your grey ammonia plant to blue and/ or green ammonia. We do this by taking our vast experience in the uhde® ammonia process and adapting it with our uhde® alkaline water electrolysis for green ammonia or with our uhde® CO2 sequestration unit for blue solutions. But the story does not end here because thyssenkrupp Uhde also offers you best-in-class solutions in nitric acid and ammonium nitrate technologies for green fertilizers to shape you up for the future.

www.thyssenkrupp-industrial-solutions.com

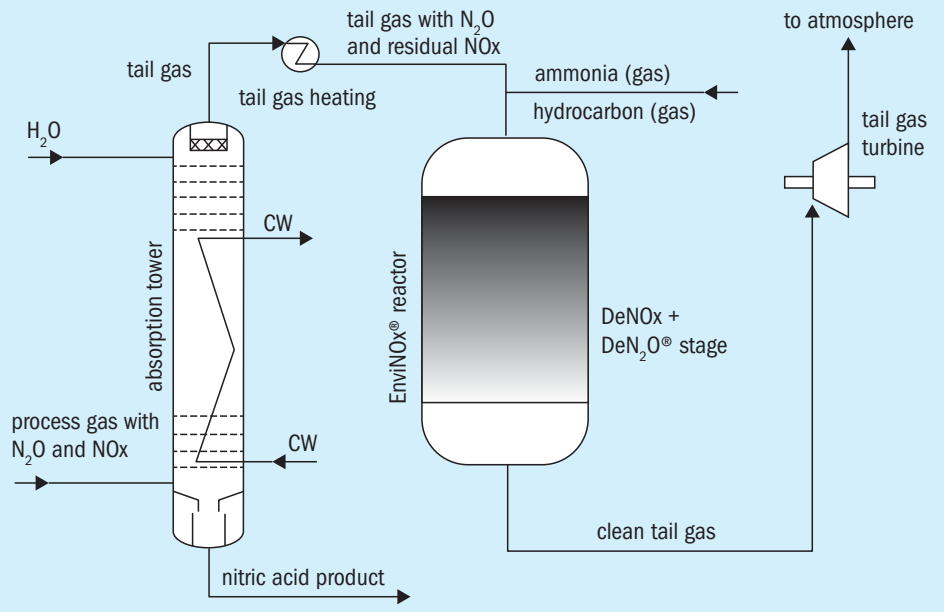
engineering.tomorrow.together.

thyssenkrupp

The *EnviNOx*® abatement system

The *EnviNOx*® abatement system from thyssenkrupp Uhde is effective at reducing both NOx and N_2O emissions from nitric acid plants (*Nitrogen+Syngas* 373, p32). This end-of-pipe technology, being installed in the plant's waste gas stream, avoids any risk of product contamination, production losses or the fouling of equipment (Figure 3). Multiple installations in nitric acid plants worldwide have demonstrated N_2O removal rates of 99 percent or more, and come close to eliminating NOx at almost zero ppm. *EnviNOx*® is also a highly practical abatement method as both pollutants are dealt with in a single reactor vessel. Advantageously for operators, the installation of an *EnviNOx*® system will also qualify as a greenhouse gas emissions reduction project under any emission trading scheme.

Fig. 3: **Typical *EnviNOx*® abatement system for nitric acid plants**



Source: thyssenkrupp Uhde

The ammonium nitrate process

For AN to remain widely used as a fertilizer, what are the essential elements of safe production – and what can manufacturers do to minimise the likelihood of an accident, within their own scope of responsibility? Below, we consider some basic rules for the design and operation of AN plants.

In general, AN plant design always has a focus on safety (see box). Nonetheless, other aspects of plant operations are also important. These include:

- Flexibility in plant load
- The export of very pure process condensate
- General ease of operation, i.e. no wear and tear parts in static equipment.

How are safety considerations best combined in an AN neutralisation plant? Well, an Uhde® AN vacuum neutralisation and concentration unit (Figure 4) allows plant operators to perform the exothermic reaction between nitric acid and ammonia at a low temperature (only 145°C) well within critical on-set limits.

The precise control of both pressure and temperature possible with this unit also enables producers to generate AN solution at a constant concentration (e.g. 92 wt-%) in the neutralisation step (Figure 4, item 1). This high AN grade is achieved by flash evaporation alone without external steam supply. The vapours generated are also thoroughly cleaned

Plant safety by design

Temperature and pressure

AN decomposes via several temperature-dependent chemical reactions. Reactions that start at elevated temperatures (>180°C) are particularly problematic. These generate huge amounts of heat – and are therefore self-sustaining – and the gaseous reaction products released can cause ruptures or explosions when confined. The resulting increase in pressure, if reaction gases are contained instead of being vented, also accelerates decomposition.

The following design rules are required for production plants due to the risk of AN decomposition, its reaction chemistry and the undesirable physical consequences:

- Manufacture needs to take place at low operating pressure
- Low process temperature must be maintained
- The release of gases/vapours must always be possible
- All possible heat inputs into the system must be detected and limited.

Feedstock composition

AN is formed by neutralising nitric acid with ammonia in equal molar ratio. Yet compositional purity is very important when it comes to safety. That's because the presence of low-level constituents such as chlorides, organic carbon and metal ions (e.g. Cu, Zn, Cr etc.) can reduce the onset temperature of AN decomposition reactions with negative consequences. Increasing concentrations of these impurities, by lowering the onset temperature, can make decomposition reactions more likely to happen and develop more quickly. Carbon, in particular, has the potential to liberate large amounts of heat when reacting with AN.

Even the presence of nitric acid itself can be undesirable if present in excess. It can also become available through the slow decomposition of AN into nitric acid even at ambient temperature. This causes the pH of AN solutions to drop and generates gaseous ammonia that needs to be vented from the system. (AN producers will all be familiar with the faint smell of ammonia close to storage vessels if these are not properly vented.)

As a result, AN plant design needs to meet the following challenges:

- Precise feedstock control
- Process monitoring
- Provisions to compensate for the natural acidification of AN solutions
- All accompanied by strict quality management of the feedstocks. ■

and completely condensed, eliminating any possibility of nitrogen passing into the atmosphere (Figure 4, item 4). Importantly, this high nitrogen yield is delivered without permitting the system pressure to increase. Temperature, pressure and critical flows are all continuously monitored using an ESD system, while a sophisticated control system ensures that the best operating conditions are maintained.

The Uhde® AN vacuum neutralisation system also runs at slightly acidic conditions as well as at low temperatures. This is the key factor for ensuring the safe control of process parameters and the lowest nitrogen slippage via process vapours. However, for intermediate storage, pH needs to be kept within an alkaline range – and is therefore adjusted downstream of the vapour separation stage under atmospheric conditions (Figure 4, item 8).

Special features

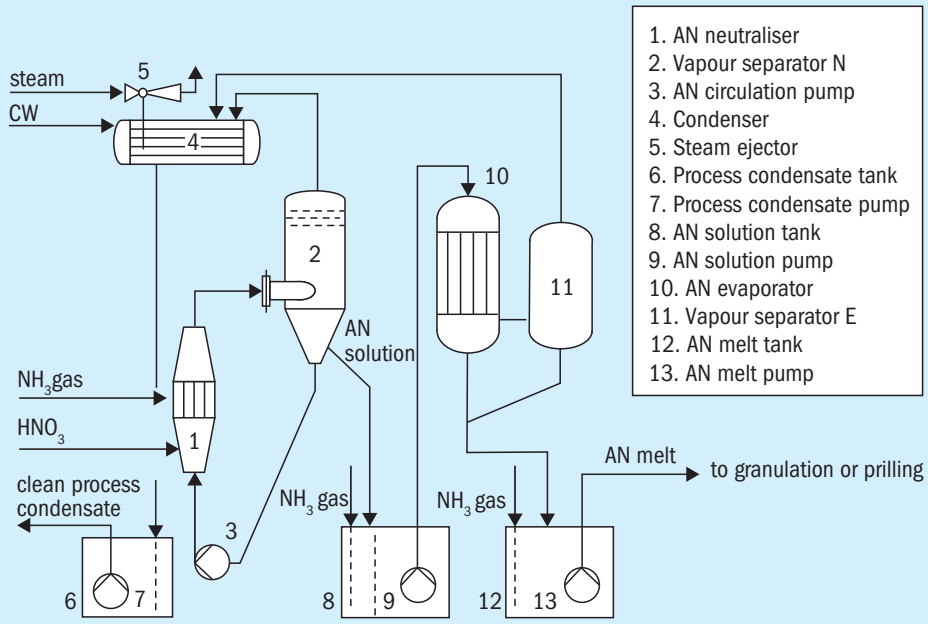
The ability to measure pH values throughout systems containing solutions of AN is an important guarantor of both safety and product quality. Uhde therefore provides a suitable and proven **pH measurement and sampling system**. During sample preparation, the lifetime of the pH probe is prolonged by diluting the AN solution with water to reduce the risk of crystallisation. Saturated steam is also available for flushing purposes.

The plant's control system will automatically stop production if the pH falls below the optimal level for process control for a prolonged period. However, the plant does not need to be drained even during a shutdown as, after stopping the feedstocks, the circulation pump remains in operation allowing for a very quick restart.

Maintaining an **ideal mix of the reactants**, ammonia and nitric acid, inside the reactor is key to reducing ammonia losses (a critical environmental factor) and minimising spots of high nitric acid concentration (a critical safety factor). Simulations have demonstrated that the Uhde® reactor is able to keep an almost perfect flow pattern.

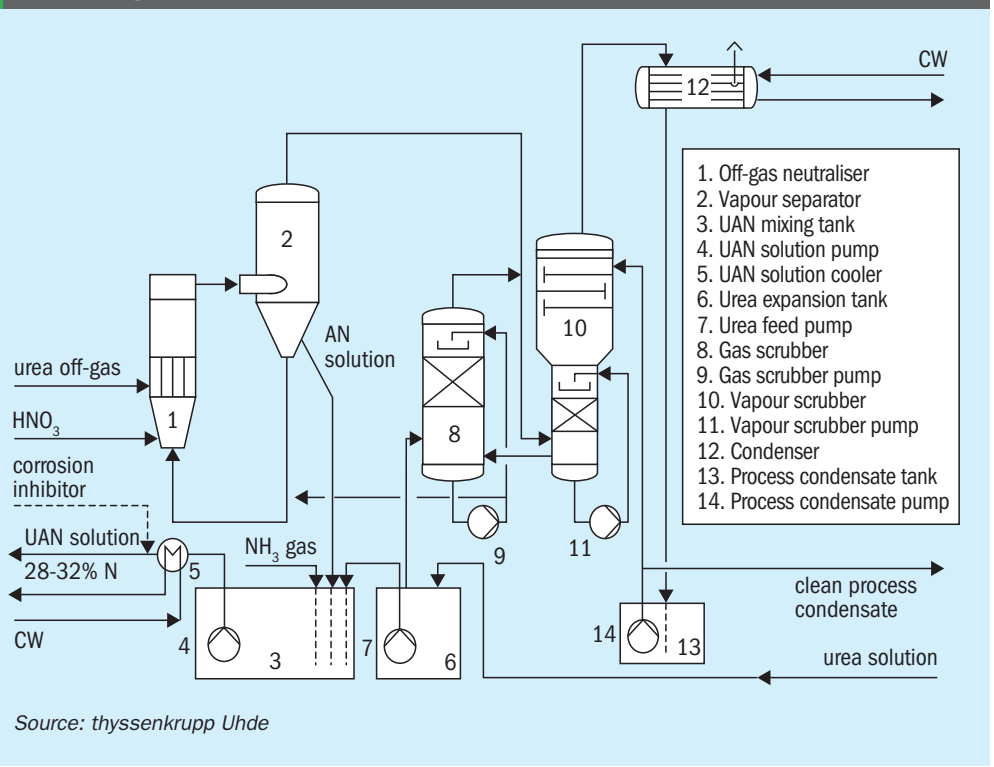
Valuably, in an Uhde plant both the neutralisation reaction and the concentration of the final AN melt can be performed under **low sub-atmospheric pressure conditions**. This means plant managers do not have to think about raising operating temperatures, so avoiding the formation and subsequent abatement of AN aerosols in the separated vapour stream. Uhde's AN vacuum neutralisation and concentration plants are in fact free of aerosols and have clean vents – as their comparatively low operating temperature and the absence of air-swept concentrators avoids the formation of AN aerosols from the very beginning. Only leakage air from the vacuum systems (containing inert gas) is released to atmosphere.

Fig. 4: **Uhde combined neutralisation and concentration system for ammonium nitrate: simplified flowsheet**



Source: thyssenkrupp Uhde

Fig. 5: **Uhde off-gas neutralisation system for urea ammonium nitrate (UAN): simplified flowsheet**



Source: thyssenkrupp Uhde

Latest developments

Combined neutralisation and concentration: In the newest development in AN technology (patent pending), thyssenkrupp has combined two vacuum units for neutralisation and concentration to form one single vapour and condensate system (Figure 4, items 4 to 7). In this system, the concentration and temperature of the final

AN melt determines the overall pressure of the entire vacuum network. Vapours from the concentration and neutralisation units – although cleaned separately, under their respective ideal conditions – are subsequently merged and condensed together. This avoids the need for a dedicated condenser for the concentration unit with both stages having one common process condensate tank instead.

Urea ammonium nitrate (UAN) production: it can be commercially beneficial to feed the low-pressure, ammonia-rich off-gas from the urea plant directly to the AN neutraliser (Figure 5). However, in this configuration, the system pressure in the AN neutraliser must be lowered to cope with the pressure of the urea off-gas. This can be achieved by employing natural draft circulation instead of the forced circulation that is typical of most plants. By incorporating additional dedicated scrubbers (Figure 5, items 8 and 10), AN can be produced within environmental limits from these low pressure off-gases.

Pressure neutralisation: thyssenkrupp also offers 'pressure neutralisation' AN plants to customers. These operate at atmospheric pressure (in the vapour separator) or at elevated pressure, depending on project-specific requirements such as plant availability and the cost of utilities. Special attention must be paid to the system operating temperature when designing these types of AN plants. This is because of the absolute necessity to avoid reaching the on-set conditions for decomposition reactions. The proper selection of construction materials is also mandatory for these plants as the corrosion rate will increase at elevated temperatures. Pressure neutralisation is the right choice if the focus is on safety and on utility consumption (steam and cooling water), rather than investment cost, as process heat can be captured for concentrating the AN solution using reboilers.

Conclusions

The design of safe and reliable AN plants must:

- Consider lessons learned
- Follow strict internal and external standards based on experience and best practice
- While at the same time focus on the individual needs of clients.

This can be achieved by using the 'pre-configured plant concept' (PCPC) engineering approach. This method divides up the complete plant into functional modules. It covers all the main engineering documents for the design of a standardised plant and summarises all safety and operability information.

PCPC ensures that all design proposals are treated holistically and on a quality-assured basis. It includes key engineering information covering the plant's process, layout, piping, static equipment and machinery. The system is both stringent – as it guarantees quality and safety – and flexible enough to allow the plant's design to be tailor-made to match client requirements.

Although AN is a potentially hazardous substance that requires a high level of attention to safety, equally, it is a state-of-the-art fertilizer that can contribute to global efforts to reduce greenhouse gas emissions.

It is perfectly possible to produce AN under carefully selected and closely monitored conditions at plants that are designed with experience and care. In this way, significant steps towards safely manufacturing AN have been taken. ■

CASALE

Sustainable ammonium nitrate production

Green technologies

For several years now, Casale has been devising and bringing to market new green technologies for ammonia production. Its wide-ranging capabilities cover the design and delivery of complete green ammonia production plants including the converter and synthesis loop. Casale can also supply engineering components for other sections of the green ammonia plant, including hydrogen generation and storage. Additionally, the company has relevant complementary engineering expertise and know-how in areas such as:

- Plant digitalisation and optimisation
- End markets and uses for green ammonia
- Cracking ammonia to obtain hydrogen
- Conversion of green ammonia into nitrogen fertilizers

The Casale ammonium nitrate process

Casale's know-how in designing ammonium nitrate plants dates back to the start-up of the first ammonium nitrate plant by Grande Paroisse in France in the early 1980s. Since then, Casale has designed more than 45 ammonium nitrate units with capacities ranging from 250 t/d to 2,000 t/d.

These plants produce ammonium nitrate solution (ANS) via the strongly exothermic reaction between ammonia and nitric acid:

$$HNO_3 + NH_3 \rightarrow NH_4NO_3$$

The main manufacturing goal is to optimise the process by making the best use of the energy released and obtain the highest ANS concentration possible. This is the key concept underpinning the *AN2000*™ pipe reactor (Figure 1), Casale's distinctive technology for ANS. Neutralisation takes place at nearly atmospheric pressure inside this reactor – which is designed to capture and maximise the use of the heat generated to achieve a high ANS concentration.

The pipe reactor is at the heart of the overall production process (Figure 2) and the place where raw materials are efficiently mixed and reacted to produce ANS. Preheated ammonia and nitric acid feeds are mixed and fed to a specially designed tubular reactor at a pressure of 7-8 bar. Ammonium nitrate forms almost instantaneously releasing a significant amount of heat. Hot ANS flashes from the end of the pipe reactor into a separator vessel. The liquid ANS product is collected at the bottom of this separator and sent to storage, while vaporised water is released as process steam.

Design improvements

The *AN2000*™ pipe reactor design has undergone a series of design modifications to satisfy a range of operational and customer requirements. These improvements have maintained the reactor's existing advantages, such as simplicity and easy maintenance, while offering the following benefits:

- **Safety:** this is of paramount importance in ammonium nitrate solution production. In a pipe reactor, raw materials

are mixed in an extremely small space, eliminating the need for large reaction volumes which would exacerbate the consequences of an uncontrolled decomposition. Using the pipe reactor, the reaction volume required by a 2,000 t/d ANS plant is 0.2 m^3, for example, versus 20 m^3 for a conventional neutraliser process.

- **Low capex:** the process only requires a few items of equipment and occupies a limited footprint due to its extreme simplicity. In addition, capital cost is also minimised because the process operates at atmospheric pressure.
- **Start-up and shutdown:** the plant can be started up from scratch to reach full capacity in less than 30 minutes, all thanks to its limited reaction zone volume. Shutdown occurs almost immediately once the raw material feed valves are closed.

Condensate purification

The *AN2000*™ pipe reactor process – which already has a low contaminated liquid stream due to its intrinsic design – can be easily upgraded to eliminate the discharge of waste effluent. The treatment is relatively simple: a venturi scrubber and a cyclonic column are used to remove traces of ammonia, nitric acid, and ammonium nitrate from steam released by the pipe reactor.

Casale's *Purifier Exchanger* can be used for further purification without the need for an external energy source. This specially designed shell-and-tube heat exchanger is used to partly vaporise concentrated process condensates from the ammonia and nitric acid heaters. Within the heat exchanger, excess process steam flowing within the tubes is used to vaporise condensates fed to the shell side (Figure 3).

The clean vapour generated via vaporisation of the condensate contains less than 30 mg/kg of ammonium nitrate and it is eventually re-condensed in a water cooler. The remaining concentrated condensate can be recycled as make-up water to the initial scrubbing system and the nitric acid absorption towers. The clean condensate, meanwhile, can be reused elsewhere in the plant as clean water or discharged. It can also be partly used to dilute the ammonium nitrate content of the concentrated condensate recycled to the nitric acid plant.

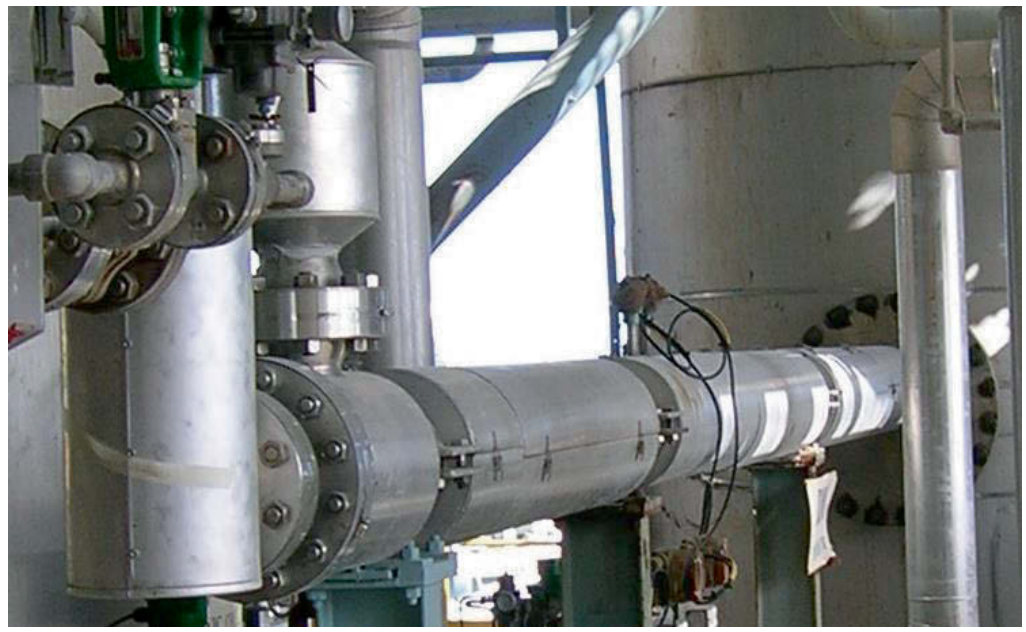
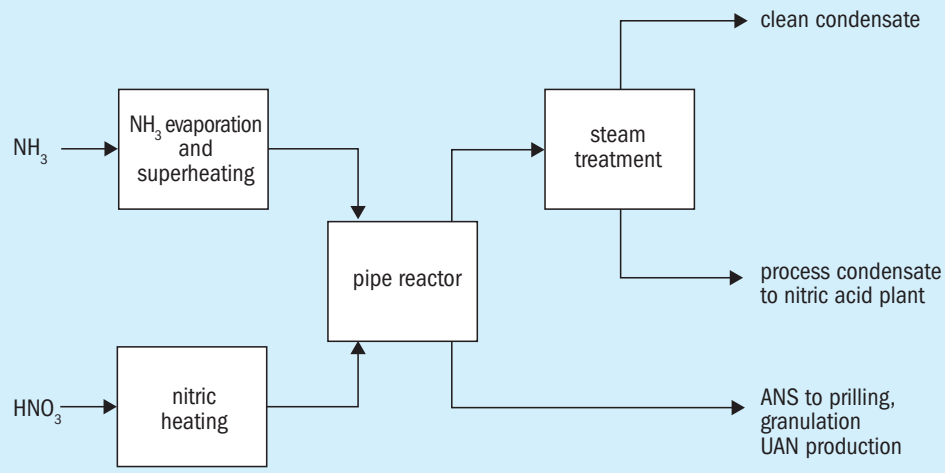


PHOTO: CASALE

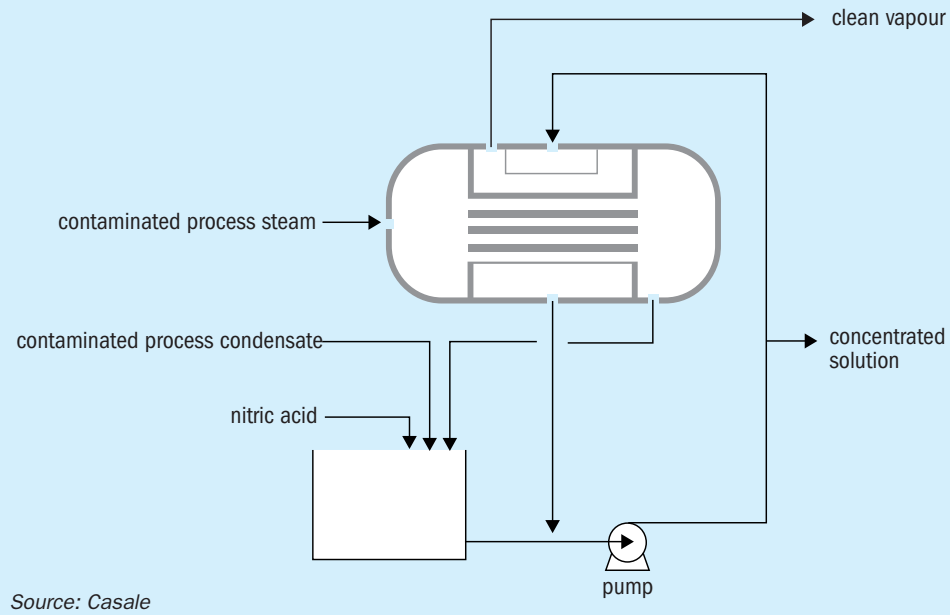
Fig. 1: Casale's *AN2000*™ pipe reactor

Fig. 2: **Flowsheet for Casale's ANS process**



Source: Casale

Fig. 3: **Casale's *Purifier Exchanger* is used to treat concentrated process condensate**



Source: Casale

CASE STUDY: JSC Navoiyazot nitric acid plant

Casale is able to provide a complete production line for nitric acid and ammonium nitrate solution (ANS) that fully complies with the most stringent emissions and liquid waste regulations.

The following Uzbek case study illustrates how emissions reduction programmes are now being rolled out and applied – even in countries which do not impose limits on N_2O emissions currently.

In 2020, Casale completed an engineering, procurement and construction (EPC) project for a new nitric acid plant for JSC Navoiyazot in Uzbekistan (see photo). Casale's scope of work for this dual-pressure technology unit – based on the company's *NA2000*™ process – extended beyond nitric acid production to encompass all the other utilities required at the site. This included the start-up boiler, nitric acid storage tanks, cooling water facilities, demi water unit and the water treatment plant.

Casale also provided JSC Navoiyazot with an effective emissions abatement system for the new 1,500 t/d capacity nitric acid plant. This was designed to reduce emissions in line with limits specified by the client:

- NOx <50 ppmv
- NH_3<5 ppmv
- N_2O <50 ppmv.

These emissions limits go beyond Uzbekistan's statutory requirements. Furthermore, the actual reductions achieved on completion of the project far exceeded the client's original expectations – as the installed abatement system actually reduced N_2O and NOx emissions to below 10 ppmv and 25 ppmv, respectively.

New JSC Navoiyazot nitric acid plant, Uzbekistan.

The catalytic system installed at the new JSC Navoiyazot nitric acid plant combines integrated secondary and tertiary abatement. The design of the burner basket used for secondary abatement ensures enough secondary catalyst (*deN20*) is available to deliver substantial N_2O abatement underneath the gauzes. The Casale tertiary catalyst (*GPRN20*), meanwhile, was installed directly upstream of the tail gas expander. It operates at 430°C to ensure the decomposition of both residual N_2O from the secondary catalyst and NOx residue from the absorber. The pressure drop of the entire tertiary abatement system was limited to less than 120 mbar. Its optimised design also guarantees a proper gas distribution across the catalyst.

Special operating procedures and control loops were implemented at the Uzbek plant to achieve the emissions targets. These avoid overdosing ammonia to the tertiary catalyst and minimise ammonia slip (<2 ppmv).

Minimising ammonia slippage prevents unsafe operations by ensuring that no ammonium nitrate is formed during start-up. Additionally, NOx concentration in the tail gas is kept below the limit of stack plume visibility during both normal operation and start-up.

The proven *GPRN20* tertiary catalyst used with this system has been successfully applied in similar applications worldwide – with a track record of long and trouble-free performance. Feedback after several years of continuous operation at another nitric acid plant commissioned by Casale has been extremely positive. This abatement system has recorded almost 98.5 percent N_2O conversion and NOx emissions lower than 10 ppmv.

Thanks to its remarkably high N_2O conversion, Casale's tail gas treatment system should provide JSC Navoiyazot with a shorter return of investment due to the higher payback from carbon trading.

Casale long experience in the design of catalytic reactors for ammonia synthesis has also contributed to their successful performance in nitric acid applications, including:

- Maximum abatement efficiencies with low emissions levels
- Optimal gas distribution within the catalyst bed to ensure longer service life
- Reduced pressure drops over the reactor and minimised compressor energy loss. ■

The *Purifier Exchanger* typically generates clean and concentrated condensates at a mass ratio of 2:1, respectively. By substantially reducing the volume of liquid waste, this allows liquid effluents to be managed economically at ANS plants.

In some cases, the recycling of concentrated condensate may not be a viable option at the client's complex, e.g., when the nitric acid plant at the site is not available, or the nitric acid produced has a dual use as raw material for both fertilizers and chemicals. These issues can be overcome by installing two *Purifier Exchangers* in series to double purification capacity and boost clean steam generation.

A reverse osmosis package can also be added to treat the concentrated condensate stream. These treatment options, by reducing the amount of concentrate condensate to a suitable level, allows their internal reuse in the venturi scrubber and cyclonic column. The end result is an ANS plant that produces virtually no liquid effluents.

Due to its intrinsic design, the *AN2000*™ pipe reactor process does not release any gaseous emissions, as the steam generated is fully condensed, either as heating steam for the raw materials, or in the Casale purifier and cooling water condenser. As a consequence, virtually no vapour streams are released to the atmosphere. ■

STAMICARBON

The world's first renewable-powered nitrate fertilizer plant

Stamicarbon is developing the world's first commercial-scale, renewable-powered nitrate fertilizer plant in Kenya. This will have the capacity to produce 550 t/d of calcium ammonium nitrate (CAN) or NPK fertilizers. This innovative plant (see photo) is being built by three Maire Tecnimont subsidiary companies – MET Development, Stamicarbon and NextChem – at the Oserian Two lakes Industrial Park, near Lake Naivasha, 100 kilometres north of the capital Nairobi (*Fertilizer International* 503, p9; *Nitrogen+Syngas* 374, p30).

The renewable power-to-fertilizer plant incorporates new Stami Green Ammonia technology (*Fertilizer International* 504, p20) and the company's existing nitric acid technology. Front end engineering design (FEED) is scheduled to start later this year with construction due to follow in 2023. The new plant is expected to start operating commercially in 2025.

Efficient, reliable, compact and modular

At the heart of Stamicarbon's novel green ammonia technology is a high-pressure ammonia synthesis loop (synloop) operating at approximately 300 bar (Figure 1). This has been customised to deliver the most efficient small-scale plant design. The synloop's innovative design allows ammonia to condense with the cooling water, eliminating the need for a refrigerating compressor. As a result, the plant operates using just one proven and reliable electric-driven reciprocating multiservice compressor.

Stami Green Ammonia technology also offers the following key features:

- Capex efficiency
- Lean, compact, modular design
- High plant reliability with a proven track record and strong reference base
- Full compliance with environmental standards.

The minimal amount of equipment needed to operate the plant delivers a substantial capex saving – generally an important consideration for small-scale projects. Four plants are currently operating with this innovative, small-scale technology, in addition to the Kenyan project announced last year.

Source: Stamicarbon

3D model of a Stami Green Ammonia plant.

Overall, this technology package offers a viable and competitive option for the local and small-scale production of green ammonia. When used in combination with Stamicarbon's existing urea and mono-pressure nitric acid technologies, it can produce ammonia-based fertilizers such as green ammonium nitrate and greener urea (using recycled or recovered CO_2). By applying this same technology to blue ammonia and urea production, Stamicarbon also plans to help other industries such as steelmaking become more sustainable.

Kenyan power-to fertilizer plant project

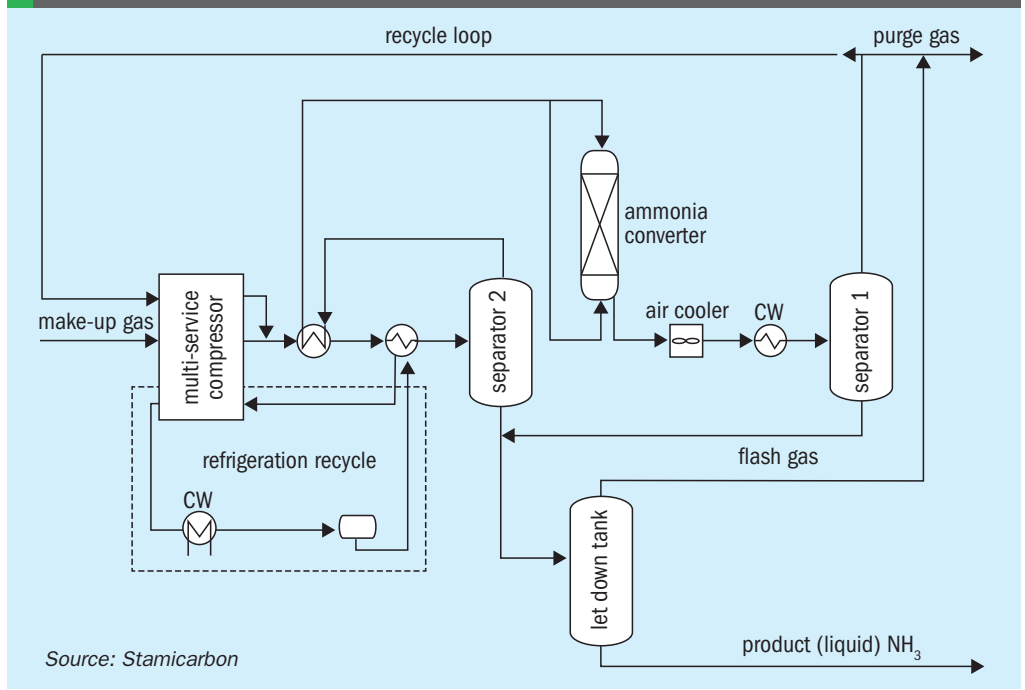
The Lake Naivasha plant, which is located next to Kenya's largest geothermal energy basin, will require around 70 MW of renewable power. It will also be partly powered by on-site solar electricity generation. Switching to production based on renewable energy is expected to cut carbon emissions by 100,000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

This first-of-its-kind green fertilizer plant will help secure the availability of domestically-produced fertilizers in Kenya throughout the country's agricultural season. On completion, the plant's production output should reduce Kenya's import dependency for nitrogen fertilizers by around 25 percent, as well as improving domestic fertilizer affordability and availability.

Conclusions

In summary, Stami Green Ammonia technology provides a 'futureproof' gateway to carbon-free ammonia production and, importantly, delivers a sustainable and renewable feedstock for the production of nitrogen fertilizers. By demonstrating the viability of the renewable power-to-fertilizer concept today, this Kenyan pathfinder project is expected to pave the way for future projects and growth in green fertilizer production. ■

Fig. 1: **Stami Green Ammonia technology**



Source: Stamicarbon

January-February 2022

phosphates & potash INSIGHT

ERIC STATZER / WIKIMEDIA COMMONS

CRU Phosphates welcomes you to Tampa!

CRU Events will convene the 2022 Phosphates International Conference & Exhibition in Florida at the Tampa Marriott Water Street, 7-9 March.

CRU Phosphates returns to Florida, the epicentre of US Phosphate production, in March 2022. It's three years since the global phosphate industry last gathered in person for the event due to the ongoing Covid-19 pandemic.

Providing a focal point, this timely conference will spur discussions on key issues such as sustainability, trade, supply chain challenges and technical advances – all of which are occurring against a backdrop of record fertilizer prices.

In-person or virtual attendance? – the choice is yours

Building on the success of 2021's fully virtual event (*Fertilizer International* 502, p42), this year's live, in-person event in Tampa will be bolstered by an international audience tuning in via CRU's virtual conference platform. This dual option of in-person or virtual attendance will enable the global industry to join together, network and access crucial market, policy and technical updates, irrespective of current travel restrictions.

What to expect – the 2022 agenda

Uniquely, CRU Phosphates combines a commercial agenda with a technical agenda in one single event. This enables the conference to cover the entire value chain of the phosphate industry – including the fertilizer, feed and industrial segments – from both an operational and market perspective.

CRU's fertilizer team will be in attendance to offer delegates the very latest insights on the state of the phosphate market (see box). Senior analyst Glen Kurokawa will provide a top-level global outlook in the opening keynote presentation, while a specialised take on the Indian market is expected from Koyel Choudhury, CRU's India-based fertilizer analyst. Dr Peter Harrisson will also be on hand to offer an in-depth view of the sulphur market – a key raw material which is also experiencing record price highs.

Additionally, industry perspectives will be covered by senior representatives from the major phosphates producers, including Mosaic, ICL, Nutrien, Yara and Kingenta.

Catering to the global nature of the industry and its audience, the conference agenda will provide updates and outlooks from key supply and demand markets, including North America, China, India, Brazil and Africa. Global market forces will also be covered and discussed – including supply chain and logistics challenges, trade policy, specialty markets and demand destruction.

Sustainability continues to be a driving force throughout the fertilizer industry. This will be explored extensively as part of both the commercial and technical agendas – with in-depth discussions about the why and the how. Several major technology licensors will demonstrate how advances in emissions reduction and energy efficiency are supporting sustainability goals at plant production level. New innovations in phosphorous recovery technologies will also be highlighted.

The event's strong technical programme will also explore efficiency advancements in phosphoric acid production, and new developments in beneficiation, fertilizer coatings, finishing and granulation.

The full agenda for CRU Phosphates 2022 is online now. Register today for your place in Tampa or online. For more information visit www.phosphatesconference.com. ■

PHOSPHATE MARKET OVERVIEW

Glen Kurokawa, senior analyst, phosphates, sets the scene for the event with this personal take on the state of market:

"Phosphate prices were generally declining over 2011-2020 due to overcapacity, hitting a nadir around late 2019. OCP, Ma'aden, and others commissioned significant new capacity around this time, and unfavourable planting weather reduced demand in key markets. Chinese producers, Mosaic, OCP, and others announced production cuts throughout 2019.

"Amidst low prices, Morocco and Russia significantly increased phosphate fertilizer exports to the US. However, due to the imposition of countervailing duties, a US trade investigation into US phosphate fertilizer imports from Morocco and Russia in mid-2020 ended in substantially altered global phosphate trade. Covid-19, meanwhile, resulted in several production disruptions, reducing supply.

"Prices first began to recover in 2020, and then accelerated upwards in 2021. High crop prices, concomitant strong fertilizer demand, lower-than-expected supply, low inventories, high raw material prices, and a world emerging from lockdowns have all had an effect. Indeed, it is these factors which have helped drive current phosphate fertilizer prices to their highest levels since the financial crisis.

"While phosphate fertilizers are still affordable in some countries, Indian phosphate importers and producers have required steep subsidies, and China is diverting phosphate exports to supply its own farmers to ease domestic price pressures. These and other measures have further contributed to heated prices." ■

Technical programme highlights

A selection of Phosphates 2022 abstracts from the conference's technical and operational programme.

Phosphate beneficiation using sensor-based sorting

Harold Cline, TOMRA Sorting

The use of sensor-based sorting is a proven pre-concentration technique capable of reducing energy, water and reagent consumption. In particular, the use of X-ray transmission sorting to reject coarse silicate waste from phosphate run-of-mine ore has demonstrated dramatic environmental dividends and social license to operate improvements. Operational phosphate projects that have implemented sensor-based sorting will be discussed, together with the downstream benefits this provides.

Phosphate flotation: the use of new synthetic reagents

Gabriela Budemberg, BASF

The flotation process involves collectors or surfactants – from both natural and/or synthetic sources – and regulators, frothers and depressant agents. These are selected based on their ability to concentrate a specific phosphate ore coming from a certain deposit. The global depletion of easily accessible deposits demands new approaches to beneficiation technology. Previously untapped deposits present numerous additional challenges for mining operations. Typically, the profitable processing of such deposits is not feasible with conventional flotation reagents. At the same time, the desire for more sustainable product formulations (e.g., those that can biodegrade) is starting to limit the use of common flotation chemicals.

Prayon reinvents phosphoric acid production using DCP

Hadrien Leruth, Prayon

Phosphoric acid producers must find the right balance between raw material quality and cost. Integrated producers feed their reactor with a local phosphate rock, while non-integrated producers rely on imports for their supply. If phosphate rock quality decreases or prices rise, then profitability is affected. Shifting to the use of dicalcium phosphate (DCP) to feed the plant can, in contrast, lead to big rewards. Technologies developed and acquired by Prayon deliver a high-purity DCP product. Additionally, the gypsum crystals generated show significantly improved filterability and a corresponding reduction in residence time. Consequently, the capacity of the phosphoric acid plant can be effectively doubled. By adopting this configuration, any producer can become a potential pioneer in phosphogypsum recycling for cement or plaster applications.

Phosphoric acid: exploiting more with an integrated approach

Svetoslav Valkov, Desmet Ballestra

The paper highlights the importance of process integration at phosphoric acid plants (PAPs). The improper design and integration of the sulphuric acid plant (SAP), the energy producer, with the PAP, the energy consumer, often jeopardises or reduces the performance of the entire complex and increases opex. Conversely, designing the SAP alongside the PAP can deliver robustness and energy savings. Proper control of operating parameters in both units results in enhanced P_2O_5 recovery and better reliability, without affecting capex and opex. Furthermore, the PAP's fluosilicic acid waste stream potentially offers a valuable source of additional income. Finally, a new process to purify phosphogypsum and convert it into saleable products is presented.

A coating solution for difficult fertilizer blends

Lucas Moore, Arkema-ArrMaz

Fertilizer substrates are generally very hygroscopic, meaning they will absorb water from the air. To maintain the structural integrity of monoammonium phosphate (MAP), potash, and urea blends, Arkema-ArrMaz has developed a series of coatings that slow the rate of moisture absorption. This presentation will discuss the phenomenon of deliquescence and the role coatings can play in reducing moisture absorption in complex fertilizer blends. Performance data for coatings specially developed for this purpose will be presented.

Improved efficiency of phosphorus fertilizers in corn production

Aaron Waltz, Phospholutions

Society has become heavily dependent on inorganic phosphorus (P) fertilizers. This dependency is inefficient and costly, given the rapid sorption of P by soils and poor plant uptake efficiency. It is also depleting finite global phosphate reserves. Recently, *RhizoSorb*® has received increased attention due to its potential contribution to sustainable agricultural production. By buffering P concentrations in the soil solution, based on a crop's needs, this product reduces phosphate fertilizer requirements. This has been demonstrated by the results of 2021 field study at Farmer City, Illinois. As well as delivering yield advantages, *RhizoSorb*®-treated corn displayed higher phosphorus use efficiencies compared to untreated controls.

Granulation plant revamps: drivers, methodology and case studies

David Ivell, JESA Technologies

Granulation plants often continue to operate for 50 or 60 years. During that time, many operators will need to improve the performance of their plant by implementing a revamp project. The drivers for these projects include capacity increase, product quality improvement, new products, reduction in emissions, energy savings – or a combination of these elements. In this paper, we will describe the typical methodology used to develop flowsheet changes to achieve each of these aims. Finally, we will review a couple of examples of revamp projects that we have executed which resulted in significant improvements for our clients.

Preparing for energy transformation in the sulphuric acid industry

Hannes Storch, Metso Outotec

Within industry, the threat of climate change is prompting a fundamental re-think of energy infrastructure and its planning. The fundamental aim is to be neutral in greenhouse gas (GHG) emissions by the middle of this century. Achieving this goal is mostly based on the shift from fossil fuel dominated energy infrastructure to renewable energy systems (solar, wind, biomass, etc.). It is important to review the potential impacts of this energy transformation on the sulphuric acid industry. We may, for instance, see a shift in sulphur feedstock availability, potentially requiring the revision of acid plant technology and new developments. In this presentation, we review sulphuric acid production – based on the use of various sulphur derivatives – and ongoing sustainability initiatives. We also highlight potential new production technologies that could turn sulphuric acid into a more sustainable commodity as part of this energy transformation. ■

Optimising phosphate production

FEECO granulation plant.

PHOTO: FEECO

Phosphate manufacturing is being enhanced thanks to process integration, digitalisation and other advances.

JESA TECHNOLOGIES, WORLEY

Integrating beneficiation and phosphoric acid plant designs

James Byrd, director of fertilizer technology, and Gary Fowler, beneficiation technology manager

As the world population grows, so does the need to produce more food. Phosphate and other fertilizers help feed the world by making farms more productive by boosting per hectare crop yields. As a consequence, fertilizer demand continues to rise driven upwards by population growth.

While production plants can typically operate decades beyond their original end-of-life, there will always be an ongoing need for new phosphate plants to satisfy current and future fertilizer demand. This applies to both brownfield projects – which improve the efficiency and output of existing production plants – and greenfield projects able to benefit from modern techniques and technologies.

All projects are subject to economic pressures. And, in a mature industry, even small improvements to plant design can deliver large results and economic dividends. This is especially true of modern, large-scale, world-class plants.

When it comes to investment costs, merging the design of both the beneficiation and phosphoric acid plants into one project – with a single design firm taking responsibility for both – presents a major opportunity. As we discuss here, this allows designers to work together in synergy, pool efforts and use a feedback loop to optimise project economics.

Taking account of variability

What often makes phosphate production so interesting for those within the industry is the simple fact that phosphate ore bodies around the world are vastly different. This means that individual phosphate rock types behave very differently in beneficiation and phosphoric acid plants. Out of necessity, different plant designs are therefore required to accommodate these wide ranging ore characteristics.

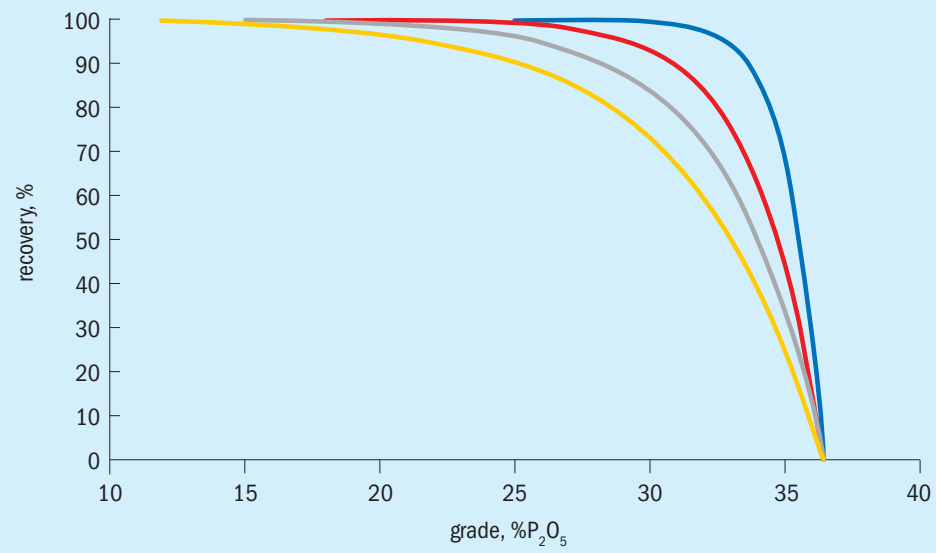
Also, there is always some inherent variability within a single phosphate ore body. The degree of variability can also differ between projects, making the installation of additional unit operations necessary in some cases. Consequently, a generic design, unless it is able to adapt to the specific ore and the local constraints encountered, will be doomed to fail on project economics for a variety of reasons. Furthermore, the fallback option (debottlenecking) can take years of trial and error, if carried out in the field after mechanical completion. Ensuring that the correct approach to phosphate plant design is taken at the outset is therefore critical for meeting the owner's goals.

Phosphate rock concentrates

The design of a phosphate production plant requires a dual test programme – for the beneficiation plant and phosphoric acid plant, respectively. Typically, the phosphate rock is analysed and bench-scale beneficiation tests are carried out. The results obtained are then used to develop a pilot plant flow sheet to validate the original bench tests. Following on from this, phosphate rock concentrate from the beneficiation pilot plant is used as feed for the phosphoric acid pilot plant. Results of these pilot tests are then used to design the phosphoric acid plant.

This is a high-level view of what in practice is a detailed process. Nevertheless, the main point here is that the dual test programmes complement each other. Normally, these tests are done individually

Fig. 1: **Generic grade-recovery curves typical of a beneficiation process**



Source: JT/Worley

to meet set goals provided by the owner. Yet, if done jointly, these goals may be iterated to help optimise the whole project – not just one area of the plant. In other words, what if the concentrate generated by the beneficiation plant was a variable for the designers rather than being a fixed point?

Beneficiation plant design

Many factors will influence flowsheet development for a phosphate beneficiation plant. Of overriding importance are both the owner's objectives and local site-specific constraints – as these form the basis of the design. Yet it is the – seemingly endless! – equipment combinations that will ultimately define the flowsheet. Configuring the equipment correctly is an essential consideration due to differences in the ore bodies encountered. Especially as the techniques used to cater to respective ores around the world differ too.

In beneficiation plant design, owners will set four primary objectives:

- Throughput
- Grade
- Recovery
- Cost.

These potential variables are routinely shared with the phosphoric acid plant designer for feedback. Yet the room for manoeuvre is limited, given that the owner will normally specify the grade and/or recovery. These two variables are not mutually exclusive either. Instead, there is typically a trade-off between grade and recovery, as shown generically by the family of curves in Figure 1.

Many factors can affect the shape of these grade-recovery curves, e.g., ore grade, mineralogy and particle size, to name a few. The shape of the curve for a particular ore is initially determined from bench testing and later confirmed by pilot testing. After the completion of the beneficiation tests and design work, there is normally an evaluation of the trade-off between grade and recovery versus capex and opex.

The preliminary flowsheet for bench-scale beneficiation is then drawn up based on this information, alongside site information and knowledge of similar ores. Adjustments are made to this flowsheet as test data becomes available and unit operations are defined. Targeted techniques for the removal of gangue minerals are largely identified based on the chemistry of the rock. The grade-recovery curve is then established by combining all the test data obtained from the process flowsheet.

Because the concentrate grade is normally specified by the owner, recovery is the main output of bench- and pilot-scale beneficiation tests. The design of the beneficiation pilot plant is modular and can therefore be arranged according to the original bench-scale flowsheet. In this way, the pilot plant can test and confirm the hypotheses generated during bench-scale testing.

For the designer, one advantage of doing testwork is that it allows modifications to be made during the pilot plant run, i.e., the pilot plant is not necessarily fixed. Since the plant is modular, modifications can be made during the test if a parameter is not being met, allowing additional data points to be evaluated. This eliminates the necessity for additional test runs that would occur in a lab operating without designers making real time assessments.

Making grade a variable

The concentrations of phosphate minerals and gangue minerals are a function of concentrate grade, as shown in the generic chart in Figure 2. This chart illustrates the opportunity that exists for an integrated approach to optimising beneficiation and phosphoric acid plant design. This can be achieved by evaluating the impacts of accepting greater concentrations of gangue mineral in the rock concentrate feed to the phosphoric acid reactor – i.e., by making grade a variable.

The impacts of varying concentrate grade can be evaluated through integrated beneficiation and phosphoric acid testing and design. If the designers are working in the same testing facility, they can communicate directly with one another in real time, instead of via intermediaries, so avoiding the risk of miscommunication and the loss of intentions and subtleties.

Phosphoric acid plant design

The key drivers for a phosphoric acid plant project are client objectives, local constraints and ultimately economics. Client objectives include:

- **Throughput:** Production capacity is the obvious and foremost design point – being the basis for which equipment is sized and arranged.
- **Yield:** This is a function of the rock but can be influenced by the design of the plant, especially when considering global recovery.
- **Flexibility vs operability:** These tend to be at odds due to the relative merits of a simpler design versus a more complicated design. While the latter requires operations to be more precise, it does allow more opportunities to make changes without loss of production.
- **Environmental concerns:** These are becoming more and more of a design driver.
- **Robustness of the design:** This relies on materials of construction, a sparing philosophy, and other means of ensuring the plant has a high operating factor.

- **Synergies:** There are potential synergies in a production complex. The phosphoric acid reactor, in particular, is often seen as a place where everything can be recycled, although there is an equal need to ensure the chemistry of the process is not altered and compromised.
- **Capex/opex:** Both are highly visible drivers.

All of the above points need to be discussed and then cleared for compatibility with the owner's direction to the design team. Local site-specific constraints include:

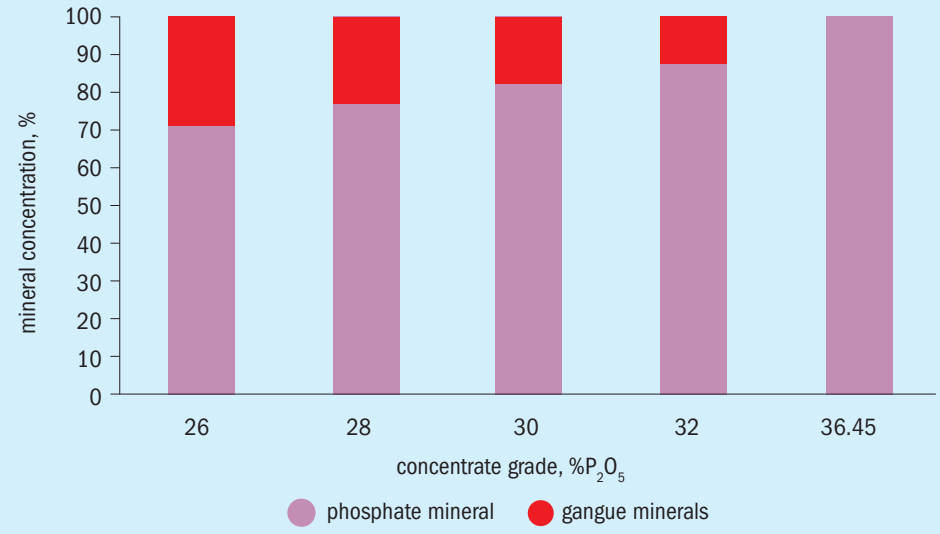
- **Water:** This is arguably the single most important constraint as it defines recycles, potential discharges and plant efficiencies.
- **Plot plan**: This should not be underestimated and can cost the owner considerable capital if not defined by an experienced engineer. A well laid out plot plan can enhance operations and maintenance activities as well as saving capex and opex.
- **Environment**: Is winterisation needed, is it a zero-discharge design, will the water balance be positive or negative?
- **Process route:** Different process routes for phosphoric acid deserve consideration as each one has a place. What is the goal for production, is the facility vertically integrated or will merchant-grade acid be the product?
- **Product quality and rock feed:** Last but not least, the concentrate feed will define a large part of the process. While the concentrate feed from the beneficiation plant is normally a given, the key point of this article is that treating it as a variable instead can lead to the betterment of the whole project.

The importance of concentrate feed

The concentrate is fed into the phosphoric acid pilot plant (see photo) to determine equipment sizing parameters such as:

- Reactor volume
- Filter size
- Specific gravities
- Viscosities
- Vapour pressures
- Consumptions
- Chemical splits
- Gypsum properties
- Particle size distributions
- Specific heat
- Bulk density.

Fig. 2: **Phosphate and gangue content as a function of concentrate grade**



Source: JT/Worley

Size distribution also affects the crystal habit in the reactor. Our main premise is that – if the feed is allowed to be variable – these parameters can be adjusted to the benefit of the project.

An experienced designer will be aware of how the following changes in the chemical content can affect the process:

- Aluminium deficiency can result in low filtration rates
- High iron affects global recovery
- Magnesium affects scale rates
- Calcium affects sulphuric acid consumption.

Other minor impurities can also play a major role, as the chemistry throughout the process is quite complex. Again, our point here is that the phosphoric acid plant designer is well equipped to 'negotiate' these impurity levels – if allowed to go back and liaise with the beneficiation plant designer.

Synergies and integrated working

By making the phosphate rock concentrate a variable, and enabling beneficiation and phosphoric acid plant designers to work together closely, a valuable feedback loop between the design teams is created. Although it might may take a few iterations, real savings could well be realised, in our view, if the concentrate were able to be adjusted as a matter of course.

For example, if the phosphoric acid plant can meet its performance goals with a lower grade concentrate than the target set in beneficiation, then the capex on the

PHOTO: JT/WORLEY

Phosphoric acid pilot plant, JESA Technologies laboratories, Lakeland, Florida.

beneficiation plant is probably excessive. Conversely, if the phosphoric acid plant is experiencing severe problems due to the presence of an impurity, then higher capex on the beneficiation plant may well have been justified to lower the capex on the phosphoric acid plant.

Put simply, the investment cost required in the beneficiation plant rises as the investment cost of the phosphoric acid plant decreases, and vice versa. Finding the lowest overall capex should therefore be the overall project goal. This can be achieved through pilot-scale iterations to discover the inflection point between the respective plant investment costs.

There are some obvious opportunities for synergies. The particle size fed to the phosphoric acid reactor is one notable

area. Milling is almost always required in the beneficiation plant. So, sizing their milling operations to accommodate milling requirements of the phosphoric acid plant could either eliminate the downstream need for milling or greatly reduce the loading. Increasing the grade of the concentrate, meanwhile, or taking advantage of the ore's reactivity, could reduce the reaction volume required in phosphoric acid production. Also, if an ore does not filter well, there are beneficiation techniques available to improve these rates – enabling the active filtration area to be reduced.

Additionally, reducing calcium in the phosphoric acid plant feed will lower sulphuric acid consumption, as well as the heat load in the system. This is advantageous as it results in smaller equipment and lower water flows. Heavy metal removal, by reducing viscosity, also aids filtration as well as clarification. Benefits would almost certainly accrue if the beneficiation and phosphoric acid plants both shared a water balance. While the two plants do not necessarily need to be proximate for synergies to take place, more opportunities will exist if this is the case.

Certainly, when it comes to synergies, chemistry is at the crux of the matter. Additionally, there are many other site-specific constraints that could be targeted depending on the circumstance.

Conclusions

In our view, by having both plant design teams working together under the same roof, the above points can be addressed routinely and without interruption. This can also save time during project schedules that rarely allow the synergies between the beneficiation and phosphoric acid plants to be examined in the way described here.

The design philosophy set out in this article offers real opportunities, in our view, especially in a mature market where minor improvements can result in large returns. These opportunities are, however, not always obvious. Only test work is likely to reveal them, making it difficult to quantify or predict the synergies at the outset of a project. Despite this, synergies can be pursued as part of a value-added exercise during projects.

Indeed, an experienced and adept design team will always look to add value for the owner. In fact, this concept is at the core of how Jesa Technologies (JT) executes projects. With pilot plant facilities for both beneficiation and phosphoric acid – and licensed technology for each of these plants – JT offers exactly the unified approach needed. Our integrated project approach allows us to delve deep into value-added opportunities across these plants. Furthermore, since phosphate fertilizer plants will typically be operating for 20-50 years or more, getting the design right, up front, will deliver benefits to the owner for years to come. ■

PRAYON TECHNOLOGIES

Improving phosphogypsum quality using a soft sensor

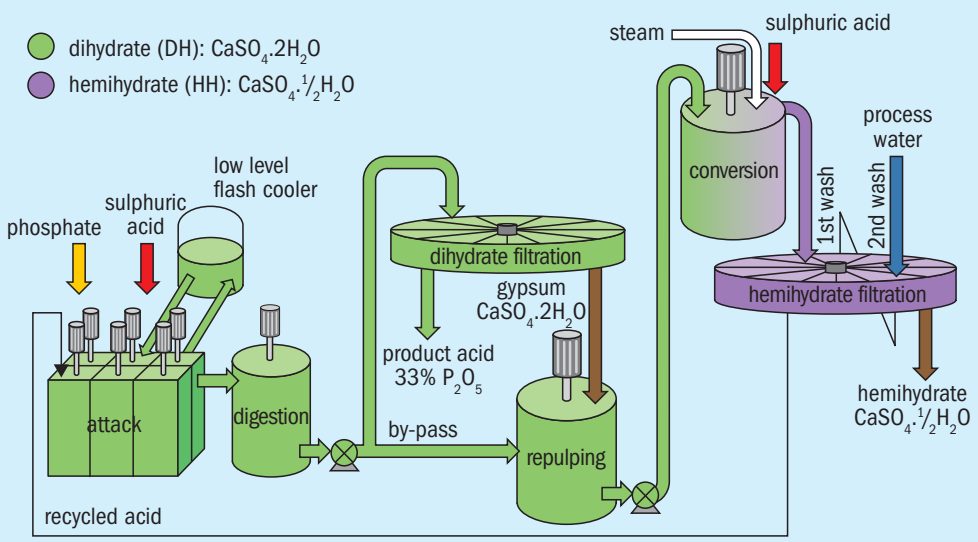
Sébastien Havelange, process engineer, and Nicolas Van Lierde, process manager

The Prayon case study

Data generated by any phosphoric acid plant will contain worthwhile and actionable information. Indeed, by managing and analysing such data, a decision support system can be established by introducing new variables know as 'soft sensors'. These can provide real-time information on the performance of the phosphoric acid plant, its maintenance status, and even the quality of the products generated.

Prayon has implemented a specific programme on data management to get the best from one of its own phosphoric acid production plants. The overall objective was to develop a new decision support tool. This was based on the collection and analysis of data and the identification of links between this information.

Fig. 1: **The Central-Prayon Process (CPP) operated by Prayon at its Engis phosphoric acid plant in Belgium**



Source: Prayon

The Central Prayon Process and calcium sulphate quality

Prayon's phosphoric acid plant in Engis, Belgium, operates using the highly efficient Central-Prayon Process (CPP, Figure 1). This combines a double crystallisation process with a double filtration step to produce phosphoric acid at high P_2O_5 recovery as well as a pure calcium sulphate co-product.

The main advantages of CPP, versus other phosphoric acid technologies available on the market, are as follows:

- It offers the highest level of P_2O_5 recovery (> 98%) from the phosphate rock raw material
- It generates phosphogypsum with the lowest P_2O_5 content
- This phosphogypsum is self-drying – achieving a final moisture content as low as 10 percent, without the use of a dryer.

Due to environmental legislation, the stacking space for gypsum at Engis is both limited and strictly regulated. To comply with these constraints, and due to its high purity, most of the phosphogypsum produced at Prayon's Engis plant is turned into a valuable co-product ('valorised') and re-used for applications such as plaster, cement and agriculture.

The quality and purity characteristics of phosphogypsum needs to be maintained at a high level if it is to be valorised in the plaster or cement industry. In particular, the P_2O_5 content in the calcium sulphate hemihydrate cake needs to be continuously monitored and kept below 0.6 percent. Additionally, while the on-specification ('green') gypsum can be transferred to the plaster company, off-specification ('red') phosphogypsum must be diverted before being conveyed to the gypsum stack.

Operators flying blind

Prior to the implementation of the data management programme, it was not possible to monitor the quality (% P_2O_5) of the hemihydrate cake generated by the CPP process in real time. This was due to the interval between gypsum sampling and the added delay in receiving results from the analytical laboratory.

At Engis, gypsum samples are generally collected and sent for analysis every two hours, with the results from the laboratory then available one hour after sampling. Because of this time lapse, operators are effectively 'flying blind' for much of the time and, due to this lack of data, are unable to correct the process for hours. This can lead to a shortfall in process performance, potentially resulting in the production of off-spec gypsum (>0.6% P_2O_5) for around three hours (see Figure 2).

The answer – a 'soft sensor'

The answer to this problem was to identify and create a 'soft sensor' The aim was to predict the P_2O_5 content in the cake from a set of data in real time (see methodology in Figure 3). This would then allow the plant operator to take corrective action earlier, based on the soft sensor prediction, instead of waiting for the laboratory results.

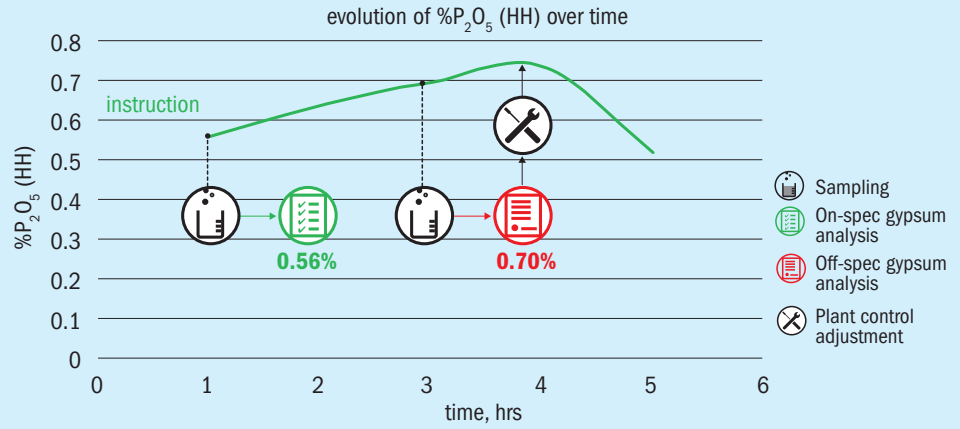
In developing the soft sensor, the first step was to identify – based on Prayon's expertise – all the process parameters that needed to be selected for inclusion in the model of the system. These process parameters are determined from both in-line sensors (for flow, temperature, pressure and density) and the analysis of samples collected at defined plant locations.

The second step involved acquiring all of the necessary data in a reliable and continuous manner. This step was particularly critical as the analytical modelling results would completely depend on the quality of the input data.

It is no secret that every phosphoric acid plant faces issues such as scaling, corrosion, erosion and plugging – due to the nature of the raw materials and products handled. That makes obtaining reliable in-line data from these plants a challenge. Critical sensors were therefore identified and upgraded to ensure that subsequent data analysis and processing would be successful.

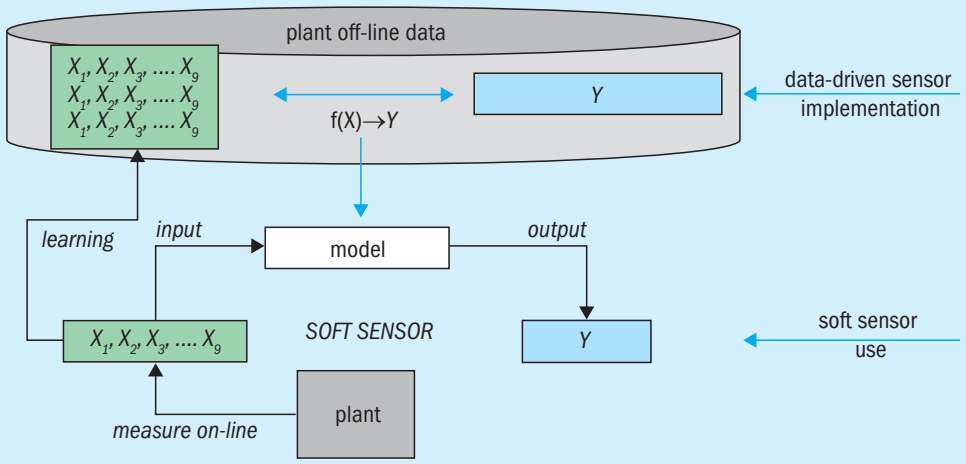
At the same time, data from two sources, laboratory analysis and the distributed control system (DCS), were collected and centralised in a common storage space – called a datalake – and aligned on a common time basis. This collection-centralisation routine was then automated to ensure reliable and continu-

Fig. 2: **Delays in process control due to the interval between sampling and time taken for subsequent laboratory analysis (% P_2O_5) of hemihydrate cake quality**



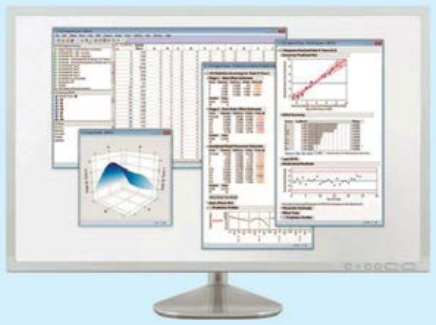
Source: Prayon

Fig. 3: **Illustration of the principle behind a 'soft sensor'**



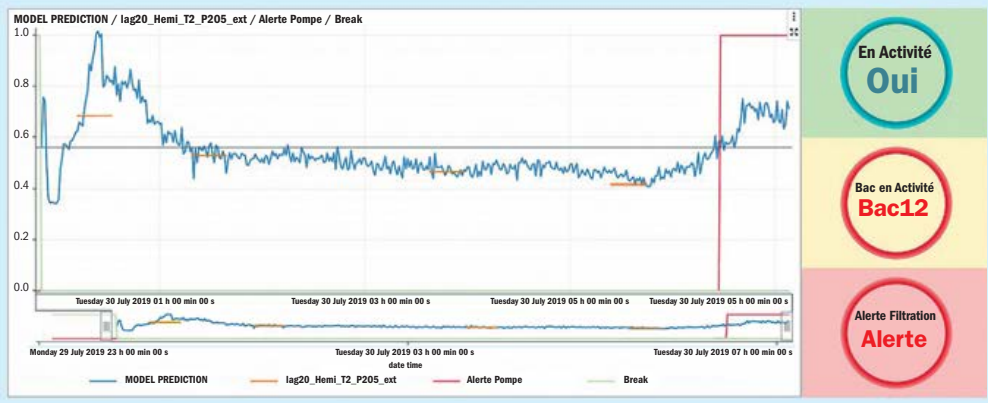
Source: Prayon

Fig. 4: **Data analysis**



Source: Prayon

Fig. 5: **Output from the soft sensor is displayed as a dashboard in the Engis plant's control room**



Source: Prayon

ous analysis of the data.

Finally, once this was achieved, data scientists were able to work on the analysis itself, using an algorithm platform that adapts to the type of data collected (Figure 4). Several analytical tools (windowed distribution, decision tree, violin plot, PCA) are used to process the data and to highlight correlations between these.

In this way, data analysis enabled a soft sensor to be created. This provides a real-time estimate of the P_2O content in the hemihydrate cake, by combining continuous measurements from real sensor measurements with quick sample analyses (i.e. pump speed, filtrate density). The soft sensor is displayed in the control room of the Engis plant as a dashboard next to the DCS screen (Figure 5).

A success story

Prayon was able to successfully develop a soft sensor for its Engis phosphoric plant. This predicts the P_2O_5 content of gypsum cake more quickly than was possible using the previous sampling and laboratory analysis approach. As a result, the plant's operators are now able to react faster to correct deviations in process performance and, as a consequence, have reduced the quantity of off-spec gypsum (that cannot be sold) by 25 percent. This represents a huge saving for Prayon in terms of gypsum disposal and simultaneously improves valorisation.

Development of the soft sensor firstly required enhancements to the DCS and laboratory data gathering (collection and concatenation) and then the use of data analytics. This concept can be adapted to the specific needs of any phosphoric acid producer.

Based on the experience gained from the successful implementation of a soft sensor at its Engis phosphoric acid plant, Prayon Technologies has decided to offer this service to the industry as part of its long-term collaboration with clients. ■

FEECO INTERNATIONAL

Tips for optimising phosphate fertilizer granulation

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

As many plant managers and fertilizer producers know, small inefficiencies – although they may seem inconsequential – can quickly add up, especially when working with the large tonnage throughputs typical of the fertilizer industry.

The production of phosphate fertilizers such as diammonium phosphate (DAP) and monoammonium phosphate (MAP) is certainly no exception.

Fortunately, there are a number of opportunities for plant managers to optimise their process for both maximum efficiency and product quality. These are highlighted here.

Select equipment suited for duty

Process optimisation should start well before the installation of the production line: it actually needs to begin during the equipment design process. From the outset, choosing the right equipment able to meet the demands of phosphate processing is crucial, as selecting inferior and inadequate equipment will inevitably result in frequent shutdowns and repairs.

Phosphate-based materials are hard on equipment. That makes the selection of proper construction materials, the reinforcement of high-wear areas, and appropriate fabrication techniques essential. This not only ensures equipment longevity, but will also avoid frequent process upsets and repairs.

Save energy with a pipe reactor

For MAP production, producers should evaluate whether to incorporate a pipe reactor into their granulator (Figure 1). Pipe reactors – although not necessarily an appropriate fit in all settings – do have the potential to recover significant value where installation is appropriate.

Incorporating a pipe reactor into the process enables the beneficial capture of reaction energy. By using this captured heat to dry product in the granulator, signif-

icant energy savings can be garnered later on by reducing the burden on the rotary dryer. The tanks previously used for pre-neutralisation can also be repurposed to feed the operation.

Conduct a process audit

When plant managers are confronted by unexplained production inefficiencies, or products of inferior quality are being generated, then calling in the OEM (original equipment manufacturer) or an external consultant to conduct a process audit usually offers the best pathway for expediting matters and resolving these issues.

Process audits – while they can differ depending on the provider and the issue at hand – generally focus on revealing discrepancies between the original design parameters and current operating conditions. Audits can also offer valuable insights into the inner workings of a process and provide benchmark data.

Process audits are not just for troubleshooting headline issues either: they also offer an excellent way of identifying underlying inefficiencies that might not be readily apparent. Plant managers can typically expect one or more of the following benefits from a process audit:

- Reduced energy costs
- Improved product quality
- Increased production
- Minimised downtime
- Better equipment longevity
- Lower maintenance costs
- Greater operator understanding and performance.

Keep equipment maintained

It might sound obvious, but poorly maintained equipment is one of the quickest – and most common – ways that plant inefficiencies and costs can start stacking up.

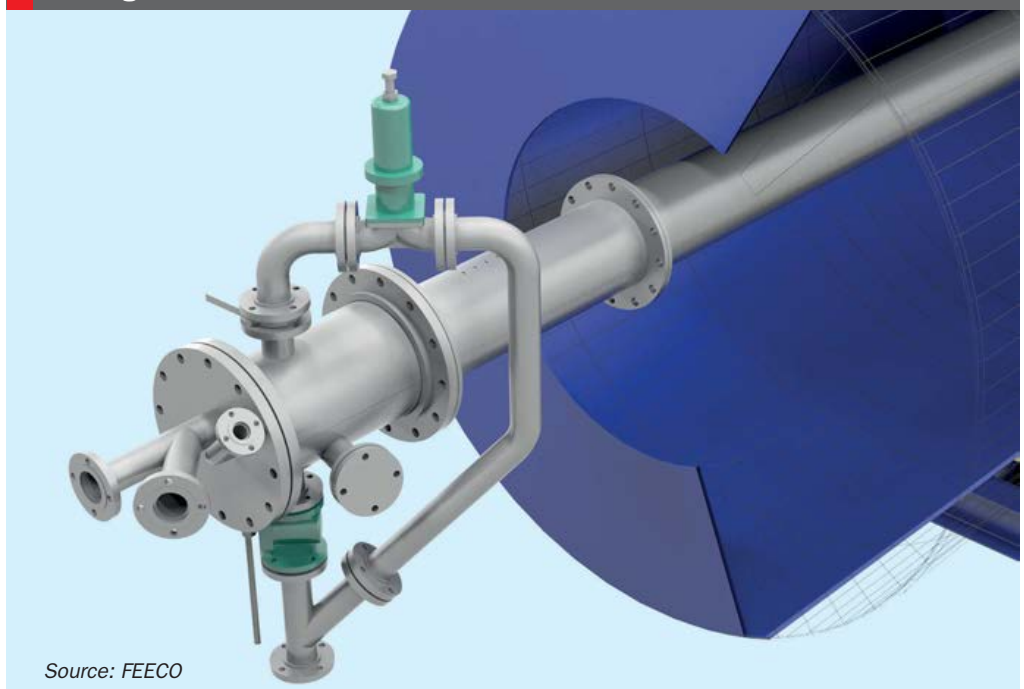
Poorly maintained equipment cause a host of problems. These include lost product, inflated energy costs, increased wear on equipment and, eventually, premature equipment failure.

Housekeeping is also an important part of maintenance efforts, as fugitive dust and improperly managed materials can degrade equipment and cause mechanical problems.

Maintain a consistent feedstock

Ensuring feedstock consistency is important at every step in the granulation process. As a rule, the more consistent the feedstock entering the equipment is, the more consistent the product that emerges will be.

Fig. 1: **3D illustration of a pipe reactor incorporated into the end of a granulation drum**



Source: FEECO

Look for inefficiencies in the drying step

Drying – being the most energy-intensive step in the fertilizer granulation process – also offers the most opportunity for maximising efficiency. Several aspects of the rotary dryer can be assessed and modified to improve efficiency. In examining a dryer, plant managers should:

Check for air in-leakage: Inadequate dryer seals are a common culprit responsible for inconsistent product quality and high energy costs. Seals should therefore be carefully selected and properly maintained. Sub-par, worn, or damaged seals allow ambient air to leak into the dryer causing a reduction in operating temperature. This, in turn, can reduce capacity, increase fuel costs, and result in inconsistent product quality. Leakage through seals at the discharge end, by adding extra air volume, can also reduce the efficiency of the exhaust gas handling system, potentially causing it to become non-compliant in emissions.

Assess flight design/pattern: The design and pattern of flights can also have a significant influence on the operating efficiency of rotary dryers, with ramifications for both energy efficiency and product quality. The standardised flight design implemented by many rotary dryer manufacturers will not necessarily match up with the characteristics of individual materials. Consequently, to enable the dryer to function with maximum heat transfer and efficiency, its flight design and pattern should always take the unique characteristics of the material being processed into account.

Use a combustion chamber: While not every dryer incorporates a combustion chamber, these can offer a number of process improvements to the drying step. Such chambers, by housing the combustion reaction and keeping the flame away from the product, allow producers to maintain product integrity and minimise potential attrition. The use of a combustion chamber also provides more control of the temperature of process gas as it enters the dryer. This allows operators to optimise drying temperature and promotes more uniform heating. Another advantage of combustion chambers is that they provide plant managers with an effective option to utilise recovered waste heat by incorporating it as dilution air. This boosts efficiency by improving fuel combustion and reducing the overall energy demand of the process.

Proper operator training

Ensuring operators receive proper training on the granulation process is vital. A well-trained operator, for example, can

SOURCE: FEECO

Rotary dryer with combustion chamber.

often identify potential issues before they escalate, as well as identify and rectify any inefficiencies. Equipment controlled and maintained by properly trained operators will also experience greater longevity.

Minimise build-up

Phosphate-based materials can cause build-up due to their tendency to clump together. Build-up is a concern in any process, as it will result in inefficiencies such as under-dried product, clogged equipment and inaccurate feeding. Build-up is especially problematic during the granulation of phosphate fertilizers because of their corrosive nature. Consequently, the accumulation of materials in crevices and other areas needs to be avoided as it will promote faster and more corrosive wear.

Such build-up can be minimised, whenever possible, through regular equipment cleaning and by employing 'knockers' on granulators and rotary dryers to dislodge material. Additionally, the use of belt cleaners at the head and tail pulleys on belt conveyors can reduce undesirable build-up by preventing the migration of material left stuck on the belt onto idlers and other components.

Test changes externally

Producers are under increasing pressure to increase capacity, improve their product, or change their formulation. Particularly as – with specialty fertilizers becoming the norm and fertilizer demand continuing to rise – there is a growing need to develop new formulations and exploit new phosphorus sources. Accommodating these new demands, while continuing to meet existing production schedules, can be a challenge.

Fortunately, producers can take advantage of test facilities such as the FEECO Innovation Center. By simulating commercial-scale conditions, experts at the Center can independently test different formulations and evaluate changes in the production line, without affecting the 'live' production environment.

Take advantage of automation

Automation and control systems offer operators tremendous benefits. Although once a luxury, these systems are becoming a necessity, especially as the industrial internet of things (IIoT) starts to become the norm.

As well as being valuable during start-up and shutdown, automation and control systems can take day-to-day operations to a new level through data collection, analysis of trends, predictive maintenance, and even proactive alerts. They can also enable operators to monitor process data and plant performance remotely from any location using a tablet or other mobile device.

Systems can even be programmed to alert operators if key parameters start to fall out of specification. This has the advantage of allowing the process to be adjusted before a problem occurs. To provide everyone with the data they need to make decisions, scheduled reports can also be sent out to the appropriate individuals at pre-set intervals.

"In an age where inefficiency has become public enemy number one, a range of options is available to help phosphate fertilizer producers improve their operations.

Concluding remarks

In an age where inefficiency has become public enemy number one, a range of options is available to help phosphate fertilizer producers improve their operations. Efficiency improvements start by selecting robust equipment designed to withstand the rigours of phosphate production, and end with the advantages and new capabilities offered by automation and control technology. Along the way, producers can optimise their process via a process audit, by keeping equipment properly maintained, and considering the use of a pipe reactor. ■

P&K flotation reagents

Newly developed flotation reagents are improving the selectivity and grade/recovery of phosphate and potash concentrates.

NOURYON

Diverse and sustainable potash mining reagents

Dr Krzysztof Kolman, scientist, Jan-Olof Gustafsson, senior scientist, and Dr Odair Lima, global strategic marketing manager

PHOTO: NOURYON

Typical sylvite flotation test in Nouryon's application lab.

Potash mining and processing are important initial steps in the value chain that produces fertilizers and ultimately food. Nouryon offers products that can assist at nearly every step in the production of high-quality potash concentrate from potash ore. These boost process performance and help reduce adverse environmental impacts along the way.

Introduction

Potash is a water-soluble mineral salt valued for its potassium content that is almost always accompanied by sodium and magnesium chloride[1]. Potassium is a crucial crop nutrient in agriculture. It can be applied directly as 'straight' potassium chloride (KCl, known as sylvite or muriate of potash, MOP) or potassium sulphate (K_2SO_4, commonly known as sulphate of potash, SOP). It is also incorporated and applied alongside other primary nutrients in NPK blends and complex NPK fertilizers.

MOP is the most widely consumed potash fertilizer – with demand from around the world exceeding 55 million tonnes annually[2]. This type of potash is primarily applied to broad acre crops and chloride-loving vegetables such as sugar beet and corn. It also helps to build disease resistance in plants[2].

SOP, meanwhile, has the advantage of combining two key plant nutrients: potassium and sulphur. This premium quality product can be extracted from mineral deposits (primary SOP) as well as manufactured chemically (secondary SOP). SOP is ideal for chloride-sensitive crops, improving both quality and yields, while also making plants more resilient to drought, frost, insects, and disease. In addition, SOP is known to enhance the appearance and taste of vegetables and boost crop uptake of other essential nutrients such as phosphorus and iron. For these reasons, SOP is commonly used on high-value crops such as fruits, vegetables, nuts, tea, coffee and tobacco[2].

Potash production is dominated by the underground mining and surface processing of MOP. This predominant type of potash is also converted to SOP via the chemical Mannheim process. This synthesis method involves reacting MOP with sulphuric acid in a muffle furnace and heating to above 600°C. Alternatively, SOP can be manufactured by reacting potassium chloride with various sulphate compounds. These form a double salt from which it is possible to make SOP plus sod ium chloride[2].

Enhancing potash recovery

As a global leader in specialty chemicals, Nouryon possesses more than 50 years of expertise in mineral processing functions, such as flotation collectors, depressants, and processing aids, with solutions to enhance the recovery of a variety of ore types – including calcite, phosphate, iron, silicate, graphite, sulphide, and potash.

"We partner with our customers to deliver essential solutions for a sustainable future," says Brad Pearson, global marketing director at Nouryon.

Table 1: **Nouryon's mining product range for potash ores**

Ore type	Ore characteristics	Product name	Function
Sylvinite (direct flotation)	Mixture of halite and sylvite	*Armeen® HT*	Fatty amine collector for wintertime (cold brines)
		Armeen® M	Fatty amine collectors for summertime (warm brines)
		Lilaflot® FAB53	
	Various clay/slime content	*Ethomeen® HT/40*	Slime collectors
		Berol® range	
		Phospholan® PE65	Anionic clay/slime collector
		Celect® SD	Clay/slime depressants and blinding agents
		Finnfix® 300	
Carnallite (reverse flotation)	Mixture of carnallite and halite (potassium, magnesium and sodium chlorides)	*Armoflote® 619* (reverse flotation)	Selective and unique halite collector
Schoenite (reverse or direct flotation)	Mixture of schoenite and halite (potassium/magnesium sulphate and sodium chloride)	*Lilaflot® D817M* (direct flotation)	Cationic schoenite collector
Potash concentrate		*Armeen® O*	Anticaking
		Armeen® HT	
		Armeen® T	
		Armeen® M	
		Armoflo® AC-59P	

Source: Nouryon

The froth flotation challenge

Processing potash ore by separating off its different components can be a challenge as many of these are water-soluble. However, this processing challenge can be met and overcome by selecting the right froth flotation technique – as this enables improved separation performance in a cost efficient way.

Nouryon, for example, offers innovative and individually customised flotation agents for unique ores including potash. These deliver superior performance combined with a strong focus on sustainability. These capabilities are possible thanks to decades of mineral processing expertise and the company's track record of customer collaboration.

For Nouryon, environmental stewardship – and the creation of more value for its customers – starts with the sustainable sourcing of bio-based raw materials. Nouryon has a broad portfolio of flotation agents for the potash industry. The company's main potash processing products are listed in Table 1 together with their respective functions.

The use of selective collectors that efficiently make mineral surfaces hydrophobic – and therefore susceptible to separation – is critical for successful flotation. To this end, Nouryon has designed and developed several collectors suitable for diverse potassium-bearing minerals and conditions. Many of these are based on fatty amine technology, one of Nouryon's core areas of expertise.

> **Nouryon's individually customised flotation agents for potash deliver superior performance combined with a strong focus on sustainability.**

"Our collectors can efficiently balance recovery and selectivity during the flotation of sylvite from sylvinite in MOP production across a variety of ore types, brine compositions, and process temperatures," says Henrik Nordberg, global section manager for mining at Nouryon.

Figure 1 illustrates the performance of amine blends used in potash flotation, while a typical sylvite flotation test is shown in the article's main photo.

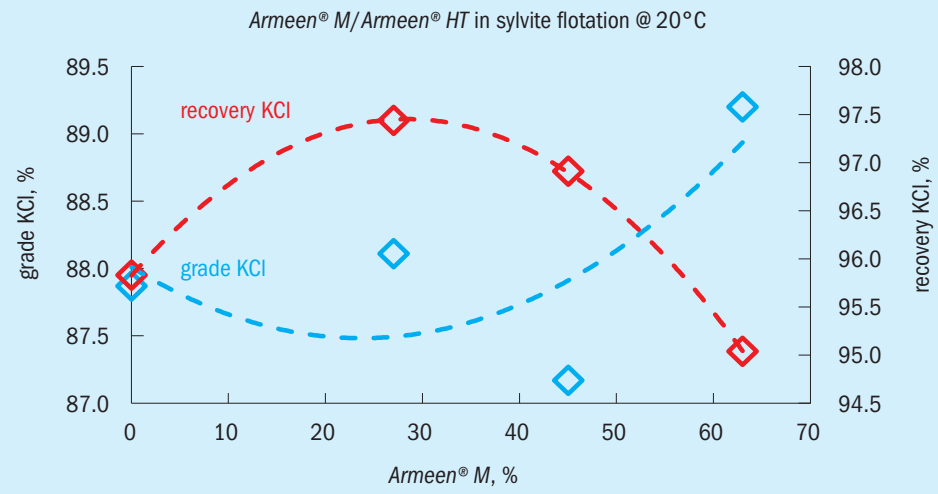
Reverse flotation for halite removal

Nouryon's *Armoflote® 619* collector is unique, as it enables the successful reverse flotation of halite (sodium chloride) from carnallite (a potassium chloride and magnesium chloride mixture) and other double salts such as schoenite (a mixture of potassium and magnesium sulphates). In reverse flotation, the unwanted gangue mineral is floated while the valuable mineral remains as the bottom product. When used as collector in carnallite flotation, *Armoflote 619* exhibits an impressive ability to remove halite from the valuable potash-bearing mineral (Figure 2).

Removal of slimes

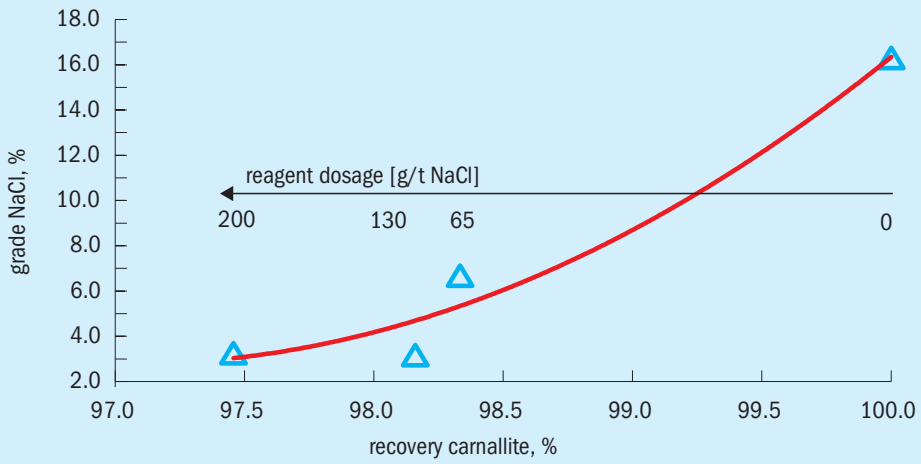
Certain potash ores contain clay minerals in addition to the salt minerals that typically occur. These fine clay particles – also known as slimes – negatively impact potash flotation due to their high charge and high surface area. This prevents separation by depleting collector concentration. Solutions to this problem include:

Fig. 1: **Performance of Nouryon's *Armeen® M/Armeen® HT* collector blend in sylvite flotation: typical grade-recovery curves**



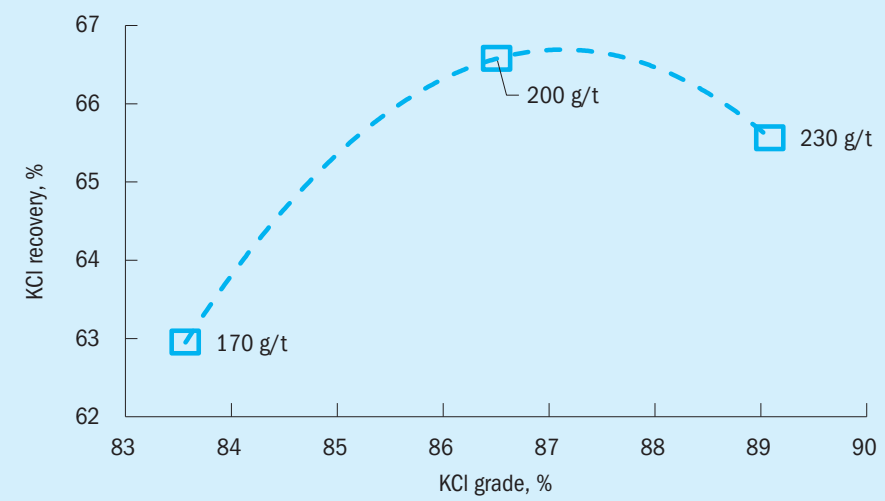
Source: Nouryon

Fig. 2: **Separation of carnallite from halite by reverse flotation using Nouryon's *Armoflote® 619* collector**



Source: Nouryon

Fig. 3: **Use of *Celect®* CMC depressants to optimise sylvite recovery**



Source: Nouryon

- Mechanical desliming using hydro separators and cyclones
- Physico-chemical separation via slime flotation or the use of a depressant that blocks slime surfaces from interfering with sylvite flotation.

Of these two options, physico-chemical separation via flotation is usually preferred, since mechanical desliming causes the loss of fine potash particles, while total potash recovery can also be improved through selective reverse flotation of the slimes. A range of products demonstrates Nouryon's proficiency with slime collectors. These include *Ethomeen® HT/40* and *Berol®* non-ionic collectors as well as the *Phospholan® PE65* anionic collector.

Nouryon is also a leading global manufacturer of carboxymethylcellulose (CMC) depressants (*Celect®* and *Finnfix®*) for mining applications. This enables the company to maximise recovery grade profiles for its customers by offering holistic and individually tailored flotation options. CMC, a bio-based anionic polymer, functions as an efficient depressant in the flotation of a wide variety of minerals, including potash. CMC optimises sylvite recovery (Figure 3) by ensuring that flotation collectors are fully adsorbed on the surface of the target mineral by 'blinding out' the active surface area of clays.

Potash coating

Once successfully separated via froth flotation, the high quality potash concentrates obtained need to be prepared for storage and transportation. This is usually achieved by applying a mineral coating, typically an anticaking agent, to prevent potash adsorbing water and becoming lumpy and sticky. Nouryon offers a range of anticaking agents (*Armeen® HT*, *Armeen® T*, *Armeen® O*, *Armeen® M*, and *Armoflo® AC-59P*) which use fatty amine technology to preserve potash concentrates in their desired form until they reach their ultimate destination. ■

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2. Pistilli, M., 2021. *Potash Fertilizers: What's the Difference Between SOP and MOP?* Agricultural Investing News. 22 June 2021. Accessed: 4/1/2021.

BASF MINING SOLUTIONS

Phosphate flotation reagents

Dr Jan Bennewitz, lab leader, flotation, and Gabriela Budemberg, global developer, non-sulphide flotation

Sustainable, high-performance products

The mining industry is shifting towards improving environmental sustainability. Individual companies are pursuing this objective by optimising ore recovery in a sustainable manner as well as by managing tailings more effectively. Sustainable ore recovery is being achieved by replacing or reducing the use of toxic and non-biodegradable materials, for example, and by lowering the consumption of reagents.

BASF mining solutions provides the mining industry with sustainable solutions which increase productivity, recovery and flexibility. Our expertise and capabilities cover every type of hydrometallurgical process, including leaching, solvent extraction, flotation, solid/liquid separation and tailings management. The company provides mining operators worldwide with innovative products and industry leading technical expertise backed up by global field support.

BASF supports its mining customers on their journey towards sustainability with products that meet the highest regulatory standards. These improve the sustainability of mineral extraction processes by offering innovative chemistry in combination with operational support and digital solutions.

Table 1: **BASF's portfolio of collectors for phosphate flotation**

Product	Application
Lupromin® FP A 369	Fatty acid formulation specific for weathered ores with presence of fine particles; biodegradable and APEO free.
Lupromin® FP A 712	Anionic collector recommended for apatite flotation where CaO/P_2O_5 ratio is high; APEO free.
Lupromin® FP A 1341BW	Non-ionic modifier for direct flotation of both oxidised and un-oxidised igneous phosphate ores; biodegradable and APEO free.
Lupromin® FP A 1095B	Special carbonate selective collector for direct flotation; APEO free.
Lupromin® FP A 1210 Base	Special synthetic formulation for direct flotation of igneous silicate-contained phosphates and for reverse flotation of carbonates in sedimentary phosphates; biodegradable and APEO free.

Source: BASF Mining Solutions

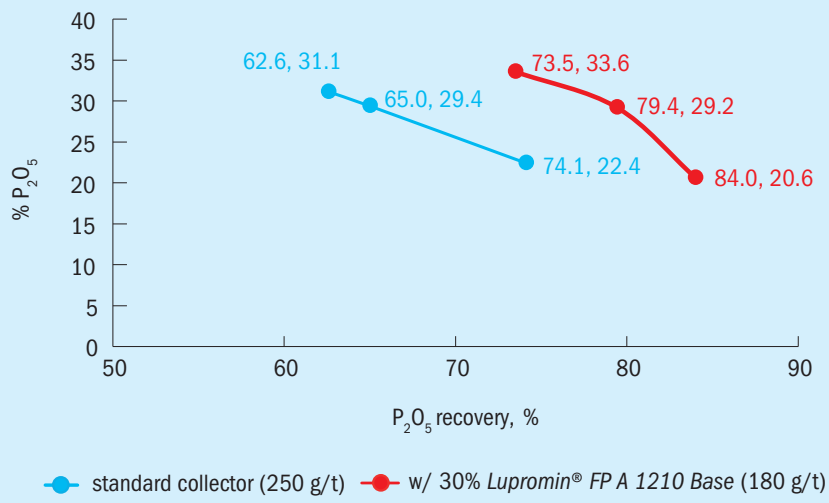
In keeping with this approach, the mining solutions team at BASF continues to work intensively to develop new flotation collectors for phosphate ores. Tailored to customer needs, these reagents are designed and optimised for both direct flotation of apatite and/or reverse flotation of carbonate gangue (Table 1).

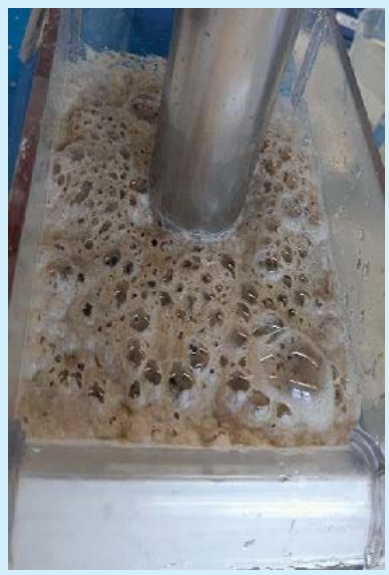
With high-grade ores diminishing, the demand for chemicals offering improved selectivity and higher recovery is correspondingly rising. Indeed, the need to continuously improve the product formulations applied in low grade and complex ore deposits is making sustainable mining solutions essential.

BASF's *Lupromin®* portfolio (Table 1) offers an innovative and sustainable range of collectors, co-collectors, frothers, modifiers and flocculants. These are suitable for phosphate operations as well as the beneficiation of other ore types.

Beyond its standard portfolio, BASF also develops tailor-made formulations in close collaboration with its customers and partners. This includes support for laboratory, pilot plant and industrial test work. These customised formulations achieve

Fig. 1: **Effects of BASF's *Lupromin® FP A 1210 Base* co-collector on grade and recovery: lab scale tests on a weathered igneous phosphate ore from South America**





Source: BASF Mining Solutions

superior flotation performance due to their defined froth characteristics. They are capable of delivering yield increases of up to 10 percent at reduced dosage rates and costs – fulfilling the classic sustainability mantra of 'doing more with less'. On top of this, BASF also provides reliable data and tools to quantify the contribution flotation reagents make to sustainability.

Enhanced flotation with co-collectors

Lupromin® FP A 1210 Base – one of BASF's latest product developments – has been successfully applied on igneous weathered phosphate ore from a mine in South America. This co-collector product was used to boost the performance of a standard flotation reagent (NaOH-neutralized soy oil fatty acid) applied in the direct flotation of the mine's silicate-bearing phosphate ore (4.5% P_2O_5 and 32.0% SiO_2).

Initial lab-scale flotation tests with *Lupromin® FP A 1210 Base* demonstrated significant grade and recovery improvements (Figure 1). These beneficial results were achieved due to the synergistic effect between the co-collector and the fatty acid collector. In recent test work on this mined ore, *Lupromin® FP A 1210 Base* delivered the following advantages:

- P_2O_5 grade remained at around 32 percent while recovery increased by six percent
- The addition of a co-collector at a dose of 10 percent allowed a 30 percent reduction in the fatty acid collector dosage
- Operational CO_2 emissions were reduced by six percent (per tonne of phosphate production) and accompanied by additional savings in energy consumption
- Tailings disposal was also lowered.

"Customised formulations are capable of delivering yield increases of up to 10 percent at reduced dosage rates and costs – fulfilling the classic sustainability mantra of 'doing more with less'.

Performance gains with other collectors

In addition, BASF recently performed further flotation tests on the following two phosphate ores:

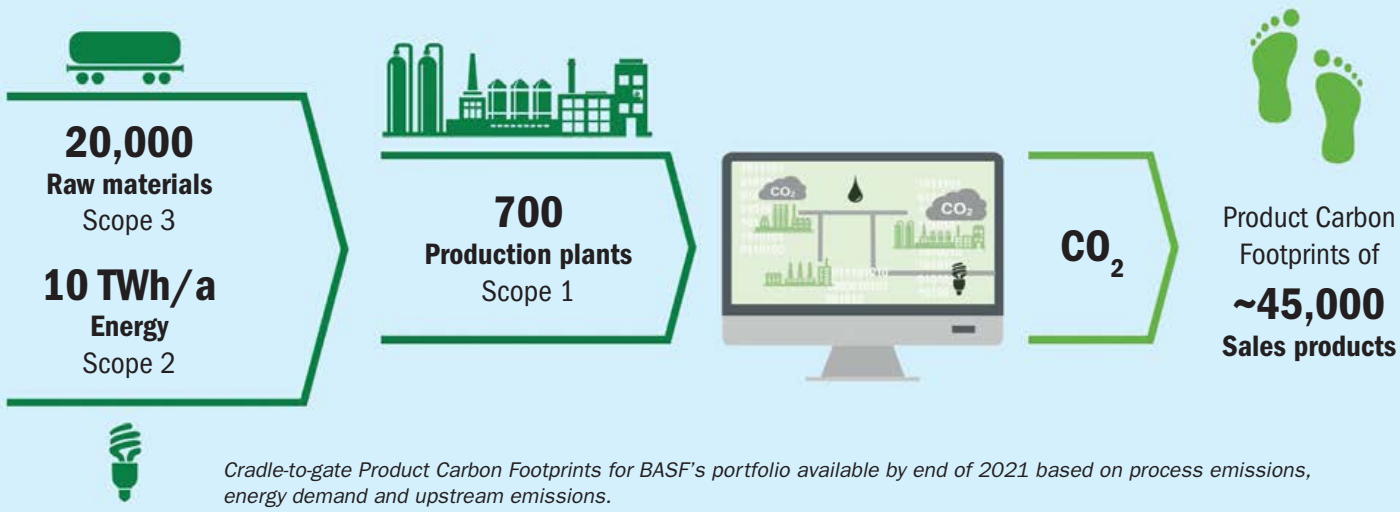
- **North European igneous phosphate ore**: direct flotation with *Lupromin® FP A 1341BW*, a non-ionic modifier resistant to temperature variations, achieved a 2.5 percent increase in recovery at a 40 percent lower dose rate, compared to the previously applied product. CO_2 emissions were also reduced by 2.5 percent (per tonne of phosphate production).
- **South American igneous phosphate ore**: direct flotation with *Lupromin® FP A 712*, a highly selective collector, increased recovery by 18 percent. This product, being a replacement for APEOs, also improved health and safety during material handling. CO_2 emissions were reduced by as much as 11 percent too, depending on the exact customer site. ■

References

1. BASF, 2020. *BASF Report 2020. Economic, environmental and social performance*. p43.

Product Carbon Footprints create transparency for customers

Digital application to calculate greenhouse gas emissions of 45,000 sales products



Cradle-to-gate Product Carbon Footprints for BASF's portfolio available by end of 2021 based on process emissions, energy demand and upstream emissions.

Source: BASF Mining Solutions

Calculating product carbon footprints (PCFs)

As part of its commitment to sustainability, BASF plans to make available individual carbon footprints for its entire portfolio of around 45,000 sales products by the end of 2021[1]. This is being achieved with the help of a new digital calculator that was developed in-house for measuring product carbon footprints (PCFs). PCFs cover all of BASF's product-related greenhouse gas emissions that occur during manufacturing up until the point the product leaves the factory gate for the customer: from the purchased raw material to the use of energy in production processes (Scope 1-3 emissions). Calculating PCFs creates transparency for our customers and partners, enabling us to develop plans to collectively reduce CO_2 emissions along the value chain up to the end-product. ■

Phosphogypsum recycling: good for the environment *and* the economy

Mosaic's Riverview phosphogypsum stack, Florida.

Sarah Fedorchuk, Mosaic's vice president, government and public affairs, North America, explains how recycling phosphogypsum from Florida can help America compete globally.

Creating a sustainable economy is going to require us to recycle more than just trash. How? By turning industrial by-products into new products, and so reduce the need to extract new raw materials from the earth. That's sustainability – and, as explained here, it's good for the environment *and* the economy.

Innovation and advocacy

The US-based Florida Phosphate Council is supporting these aims by launching the Phosphate Innovation Initiative. This advocacy campaign is helping the phosphate industry achieve its ambitious goal of a 'zero waste' future by targeting the sustainable and beneficial use of phosphogypsum. The new initiative – as well as presenting factual, science-based information on phosphate production – is highlighting opportunities for the beneficial use of its main by-product: phosphogypsum, also known as PG. The campaign also forms part of wider efforts by the phosphate industry to raise awareness about recent production innovations.

Florida's artificial mountains – a valuable resource

Put simply, phosphate is an *essential* nutrient that keeps bodies strong and bellies full. When turned into fertilizer, it helps America's farmers put food on tables across the globe. But the phosphate manufacturing process also generates large volumes of phosphogypsum as a by-product. This is currently stored in flattened pyramid-shaped structures called 'gypstacks'.

Indeed, across Florida, more than one billion tons of phosphogypsum is stored in gypstacks. Furthermore, due to their size, the Sunshine State's 25 gypstacks are a highly visible feature in central Florida's low rise landscape. Yet recycling the PG contained within these artificial mountains also represents an incredible opportunity to reduce waste and boost resource efficiency.

How to recycle PG?

Today in the United States, phosphogypsum is approved for limited use in agriculture and scientific research. Globally, however, scientists have discovered 55 innovative ways to use PG – and that's just so far. Numerous research trials confirm there are many environmentally-safe alternatives to storing PG in gypstacks.

Consequently, other countries are already capturing their phosphogypsum as a valuable raw material, having developed processes that allow its beneficial use. Across the world, PG has been used to help crops grow, replant forests, pave roads and even as a component of building materials (*Fertilizer International* 501, p45). More than 20 countries, including Canada and Japan, currently capture and reuse phosphogypsum, turning it into a valued resource. And, if they can do it, so can the United States.

It's the NORM

Comic books may have led us to think of radiation as the sort of thing that turns regular humans into superhumans. Yet, in real life, low-level radiation is all around us, being present in everyday items. Decorative ceramic dinnerware, granite countertops in our kitchens and even bananas contain it. Radiation in this form is called NORM, short for naturally occurring radioactive materials.

The phosphogypsum produced from phosphate manufacturing, a production process that is common in Florida and so essential to food production, also contains low-levels of NORM. Yet expert scientists, including researchers at the University of Florida, have established that the risk associated with phosphogypsum is low, even for those working near or with PG daily. The science has also been extensively reviewed by the US Environmental Protection Agency (EPA). The Agency's own analyses show that the maximum lifetime exposure to NORM — even for road construction workers — is well below the EPA's risk threshold.

Recycling to help America compete globally

Gypstacks contain the rare earth elements (REE) used in countless technologies that make modern life possible, from automobiles and energy to smart phones and critical defence systems (*Fertilizer International* 504, p44). Scientists are currently developing methods to extract REE from Florida's abundant phosphogypsum reserves. They estimate that more than 200,000 tons of REE are ready to be recovered and recycled, a resource that is being continuously added to by the extra tons of PG produced annually. Florida's gypstacks could therefore provide an important domestic source of rare earths and reduce America's reliance on foreign supplies.

Making gypstacks a thing of the past?

Importantly, when we recycle phosphogypsum, we keep it out of gypstacks, and create the conditions for a cleaner environment. Productive use of PG also reduces the need for phosphate manufacturers to expand or build new gypstacks. Valuably, fewer gypstacks in future will mean more land is available for conservation and for wildlife habitats.

Recycling also reduces our reliance on mining new minerals from the earth, so preserving important green spaces that would otherwise have been negatively affected by raw material extraction. There are even climate benefits, as using PG as a soil medium to regrow the world's forests helps capture greenhouse gases like carbon dioxide (*Fertilizer International* 501, p45).

Innovative technological, economic and environmental factors have all combined together to influence the future of phosphogypsum in ways not foreseen thirty years ago. In our view, as Florida's traditional phosphate operations continue to generate phosphogypsum, now is the time for the industry and regulators to embrace innovative ways of putting PG to beneficial use and, consequently, make gypstacks no longer necessary. ■

You can stay up to date with the latest developments at the Phosphate Innovation Initiative by visiting PhosphateInnovation.com.

Fertilizer International presents a global round-up of phosphate rock, phosphoric acid and finished phosphates projects.

Phosphates project listing 2022

PHOTO: TOMRA

An array of four TOMRA sorting machines at the MWSPC mega project in Saudi Arabia.

Phosphate rock*

Plant/project	Company	Location	capacity ('000 t)	Status	Start-up date
CANADA					
Lac-à-Paul	Arianne Phosphate	Quebec	3,000	FS	n.a.
Sept-Îles	Mine Arnaud/Yara	Quebec	1,300	FS	n.a.
REPUBLIC OF CONGO					
Hinda	Kropz	Hinda	1,000	FS	n.a.
GUINEA-BISSAU					
Farim	Itafos	Guinea-Bissau	1,300	FS	n.a.
SENEGAL					
Baobab	Agrifos	Gadde Bissik	1,000	FS	n.a.
SOUTH AFRICA					
Elandsfontein	Kropz	Elandsfontein	1,000	UC	2022

**Excluding China. Standalone, non-integrated projects only. At present, there are tens of junior phosphate mining projects globally. However, only capacity developments with a published feasibility study are listed here. In general, these projects have yet to secure the necessary finance and, consequently, none have committed to a firm construction schedule and start-up date currently. Africa is undoubtedly the region with the most potential for phosphate rock expansion – although large uncertainties over individual projects and their timescales remain. OCP Group is, however, pressing on with ambitious plans to increase phosphate rock capacity at Khouribga and Meskala in Morocco. Major expansions in phosphate rock capacity are also expected out to 2024 from established phosphate producers in Russia and Kazakhstan (Acron, EuroChem, PhosAgro), Brazil (EuroChem, Itafos) and Mexico (Fertinal). This extra supply will be largely consumed in integrated, downstream operations. Kropz's Elandsfontein one million tonne capacity, export-oriented project in South Africa is due to start production in the first-quarter of 2022.*

Phosphate fertilizer, phosphoric acid and integrated phosphate rock projects**

Plant/project	Company	Location	Product	capacity ('000 t)	Status	Start-up date
BRAZIL						
Santana	Itafos	Para State	SSP	500	PL	n.a.
Serra do Salitre	EuroChem	Patrocinio, Minas Gerais	Phosphoric acid (P_2O_5)	250	UC	2022
Serra do Salitre	EuroChem	Patrocinio, Minas Gerais	SSP	650	UC	2022
Serra do Salitre	EuroChem	Patrocinio, Minas Gerais	DAP/MAP	350	UC	2022
EGYPT						
El Wadi	WAPHCO	Abu Tartur	Phosphate rock	3,000	UC	2021
El Wadi	WAPHCO	Abu Tartur	Phosphoric acid (P_2O_5)	500	UC	2021
El Wadi	WAPHCO	Abu Tartur	DAP/MAP	800	UC	2021
El Wadi	WAPHCO	Abu Tartur	TSP	600	UC	2021
ETHIOPIA						
Dire Dawa	OCP/Ethiopia	Dire Dawa	DAP	1,500	PL	2025
INDIA						
Orissa expansion	Paradeep Phosphates	Paradeep	DAP/NPK	690	UC	2023-2024
Tuticorin expansion	Greenstar Fertilizer	Tuticorin	Phosphoric acid (P_2O_5)	216	UC	2023
Tuticorin expansion	Greenstar Fertilizer	Tuticorin	DAP	650	UC	2023
KAZAKHSTAN						
Taraz	Kazphosphate	Taraz	PPA (P_2O_5)	220	UC	2022
Taraz	Kazphosphate	Taraz	MAP	420	UC	2022
MOROCCO						
Various	OCP Group	Various	Phosphoric acid (P_2O_5)	1,100	UC	2019-2022
Various	OCP Group	Various	Finished phosphates	3,480	UC	2019-2022
NIGERIA						
Lekki	OCP/Nigeria	Lekki	DAP/NPK	650	PL	2024
RUSSIA						
Dorogobuzh	Acron	Dorogobuzh	Phosphoric acid (P_2O_5)	400	PL	2024
Dorogobuzh	Acron	Dorogobuzh	DAP/MAP/NPK	1,000	PL	2024
Volkhov expansion	PhosAgro	Volkhov	Phosphoric acid (P_2O_5)	405	UC	2022
Volkhov expansion	PhosAgro	Volkhov	MAP	1,615	UC	2022
SAUDI ARABIA						
Phosphates 3	MWSPC	Ras al Khair	Phosphoric acid (P_2O_5)	1,500	PL	post-2024
Phosphates 3	MWSPC	Ras al Khair	Finished phosphates	3,260	PL	post-2024
TUNISIA						
M'dilla II	GCT	M'dilla	Phosphoric acid (P_2O_5)	180	UC	2022
M'dilla II	GCT	M'dilla	TSP	725	UC	2022

KEY FOR BOTH TABLES

FS Feasibility study complete
PL Planned
UC Under construction
C Project completed
n.a. Not available
DAP Diammonium phosphate
DCP Dicalcium phosphate
MAP Monoammonium phosphate
PPA Purified phosphoric acid
SSP Single superphosphate
TSP Triple superphosphate

***Excluding China. The International Fertilizer Association (IFA) expects various production investments by OCP Group to collectively add an additional 3.5 million t/a to Morocco's finished phosphates capacity out to 2023. OCP is also pursuing large-scale joint venture projects in both Ethiopia and Nigeria. The third phosphates mega project announced by Ma'aden and its partners should eventually ramp-up product capacity in Saudi Arabia by a further 3.3 million t/a. In Egypt, WAPHCO is currently constructing a major phosphate production complex at Abu Tartur.*

Phosphate technology and engineering profiles

Equipment market reawakens

Paul-Henri Legros, general manager, Profile, a division of Prayon s.a. provides an update on latest industry developments.


PHOTO: PRAYON/PROFILE

Above: Profile's model 30-220 tilting pan filter with a total surface area of 220 m². Installed at OCP's Jorf Lasfar phosphates production complex in Morocco.

"We actually see the phosphate production market awakening after two years of a lot of studies and projections, yet still with a kind of lethargy in reaching the 'go' decision.

Usually the P_2O_5 projects market moves from one continent to another, depending on the business opportunities. But in the last year, projects are blooming in every direction.

Profile and Prayon Technologies are receiving demands from all parts of the world currently – and it makes the future very exciting for our business. Whether on the North and South American continents, from Eastern Europe to Turkey, in the ex-Soviet Union territories of central Asia, in North African and Persian Gulf countries, to India and Far East countries, down as far as Australia, it seems everybody wants to have a shot at P_2O_5 and fertilizer production with new factories or capacity increases.

We're also seeing new companies, usually involved in other chemical industries, showing great interest in P_2O_5 and fertilizer production. There's a general feeling, one that's growing stronger, that countries want to produce locally for themselves to reduce their dependence on global supply chains.

An EU-based company such as Prayon is holding a strategic central place in that play, thanks to the stability of our European politics and economy. As a company, Profile is well-equipped and ready to face the challenge of conducting multiple projects in parallel, with the proven capacities and reliability of our equipment also helping us to be a quick responder to market demands.

Customer wants to maximize the use of available phosphate rock resources and improve the yields of their installations – those are the actual trends we're seeing. Indeed, some are now looking for very large treatment and filtration capacities to optimise the use of low-grade rock that was put aside for years.

As a leader in the supply of P_2O_5 filtration process equipment, and with our renowned *Prayon Tilting Pan Filter*©, Profile has the capacity to answer these demands. We are participating in some projects where our new Prayon *36-330* filter design – with its very large 280 m² of useful filtration surface and 330 m² total surface area – is required to meet expectations. Some projects are even considering doubling their filtration capabilities through the installation of new double filtration lines, or adding a new line to their existing plant.

Equally, Profile in collaboration with its sister division Prayon Technologies is becoming more and more involved in double crystallisation projects. Many phosphoric acid plants that already use the dihydrate process are wishing to switch to a hemihydrate-dihydrate process by installing a second filtration and conversion unit.

> **"In the last year, projects are blooming in every direction. Profile and Prayon Technologies are receiving demands from all over the world.**

Double crystallization can really boost phosphoric plant yield, even if the running of the plant operations are more 'touchy' and therefore need to be more carefully managed with a better control of process parameters. This is where our motto – "a producer developing processes and equipment for other producers" – makes senses, as Prayon has been operating its proprietary double crystallization process at our Engis plant in Belgium for years.

Currently within Profile, we are finalising a two-year project that will completely switch the design and conception of our equipment from 2D to 3D – something we strongly believe will help us to further improve the design and performance of our *Prayon Tilting Pan Filter*©.

This 3D design capability will also help us push to make our equipment more sustainable, while minimising our exposure to the impact of high stainless-steel prices. Maintaining our leading position and edge in the equipment market is a challenge that all the Profile team is ready to meet.

Our main hope for 2022 is for the easing of Covid restrictions worldwide to bring back the possibility of traveling again. There is a real feeling and desire in our commercial and technical teams that we *do* need to be on-site to fully meet customer needs. We also need to re-build our existing network of relationships if we are to pursue new solutions and projects with full force.

At the end of the day, let's all keep in mind that fertilizers do feed the world – and it is therefore a great privilege to be part of this industry!" ■

Alsys International

Alsys International has been developing robots, optimising chemical processes, manufacturing parts and writing software for nearly 30 years, having been founded by the chemical engineer Marc van Beelen in 1992. Marc started developing robotic systems to tackle and overcome the many problems he encountered during his decade-long experiences in the laboratory sector. One particular problem – eliminated by the use of robots – is the high margin of human error in extremely accurate measurements.

Alsys currently has four product lines on the market:

- Fertilizer robot
- End-group (oleochemical) robot
- Compact robot
- Soil robot.

The main benefits of these robots versus manual analysis are:

- Automated sample preparation
- Perfectly integrated analysis techniques
- Reliable analytical results
- Modern data processing
- A safe working environment
- Four-day run time without the need for an analyst.

Alsys has specialised in building lab robots for the sample preparation and analysis of fertilizer industry raw materials and end products for 20 years. Its fertilizer robot (Alsys *RB-247*) analyses for potassium and other key nutrients in fertilizers. This fully automated laboratory unit uses Metrohm titrators, Mettler moisture analyser and Metrohm ion chromatography. Its main functions and operations include:

- Autonomous assessment of solid and liquid samples
- Sample dissolution in water (both cold and boiling) and acid.

The unit has the ability to analyse both raw materials and processed samples. Options include:

- Titration and potentiometric determinations
- Moisture analysis

PHOTO: ALSYS INTERNATIONAL

Alsys fertilizer robot.

- Ion chromatography
- ICP
- Flow Injection Spectrometry.

The latest development from Alsys is the soil robot. By measuring soil nutrients, this will be able to give fertilization advice based on the analytical results obtained. Currently, the company is looking to offer a robot with the capacity to prep and analyse 1,000 soil samples per day. Soil analysis is potentially a lucrative, large-scale market due to the large difference in unit price between manual analysis and that performed robotically. ■

Desmet Ballestra

Milan-headquartered Desmet Ballestra SpA has extensive experience in the design and supply of chemical plants.

For the fertilizer industry, the engineering company offers production plants for sulphuric acid, merchant-grade and purified phosphoric acid (MGA and PPA), single superphosphate (SSP), triple superphosphate (TSP), potassium sulphate and granulated NPK compound fertilizers.

From initial design through to plant start-up, Desmet Ballestra offers support to clients during all of the following project phases:

- Feasibility studies
- Process design
- Detailed engineering
- Material supply
- Project implementation
- Plant start-up phases.

Desmet Ballestra phosphoric acid plants are highly flexible. The design of each plant is bespoke, being specifically tailored to individual client needs. To maximise process efficiency, for example, plants are customised to accommodate different types of phosphate rock.

Under a long-standing agreement with technology licensor Prayon, the company offers phosphoric acid plants based on the following processes:

- DH : Di-Hydrate (single crystallisation)
- HH: Hemi-Hydrate (single crystallisation)
- CPP: Central Prayon Process (double crystallisation DH-HH)
- HDH: Hemi-hydrate to Di-Hydrate (double crystallisation HH-DH)
- DA-HF: Di-hydrate attack, Hemi-Hydrate filtration (double crystallisation DH-HH).

These versatile, well-proven and market-leading processes are widely employed in many phosphoric acid projects around the globe. The most suitable process is selected based on a range of factors, such as rock quality, performance parameters and production economics. All the above processes enable the production of 52-54 percent concentration phosphoric acid, an intermediate in the manufacture of phosphate fertilizers.

Plants can also be configured to allow the recovery of fluosilicic acid (FSA). This is obtained as a process by-product – in concentrations up to 18 percent – and can be sold to market, or converted into valuable anhydrous hydrofluoric acid (AHF) or AlF_3 under a technology collaboration with Buss ChemTech. Alternatively, it can be neutralised for disposal.

Desmet Ballestra has offered a phosphoric acid purification option as part of its chemicals technology portfolio since 2015. The purification process involves a sequence of several steps to remove impurities – typically arsenic, gypsum, heavy metals, fluorine and chlorine – and achieve the target quality at the required yield.

Desmet Ballestra is also an established supplier of SSP and TSP powder plants. These have been developed through a technology partnership with Italy's Industrie Chimiche Puccioni and incorporate proprietary Kuhlman-Den or Broadfield-Den type reactors. These production processes involve reacting phosphate rock with either sulphuric or phosphoric acid, respectively, to generate SSP or TSP.

Granulation plants for SSP/TSP/DAP/MAP and NPK are also available, based on in-house or Incro pipe-reactor technology. The company also offers plants for water-soluble MAP/DAP production through a strategic partnership with leading technology provider GEA. ■

GEA Group

GEA is emerging as a leading technology and equipment provider to the phosphates industry. The Dusseldorf-headquartered group is one of the world's largest production technology and equipment suppliers and employs about 18,500 people across the globe. GEA generates around 70 percent of its revenues from the food and beverages sector – and is the technology leader in this market.

With more than 100 years of experience in crystallisation alone, the company offers a range of production plant technologies able to meet the diverse requirements of the phosphate and fertilizer industries. They include:

- Evaporators
- Crystallisers
- Membrane filtration units
- Centrifugal decanter and separators
- Spray and fluid bed dryers for drying crystals or granulation.

"GEA's technology for water-soluble MAP production has already been successfully implemented by an Eastern European customer.

Operational GEA crystalliser at a fertilizer production plant.

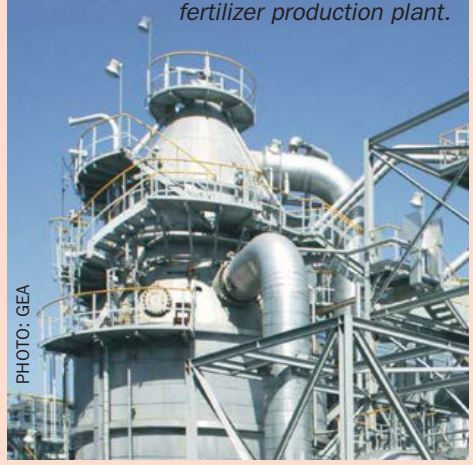


PHOTO: GEA

GEA specialises in the production of water-soluble monoammonium phosphate (MAP) from phosphoric acid. The innovative production technology offered by the company is capable of manufacturing high-quality water-soluble MAP from lower-quality merchant grade acid (MGA). This ground-breaking process reduces opex and/or capex costs as it avoids the need to purchase more expensive purified phosphoric acid (PPA), or integrate a purification line within the fertilizer production plant.

GEA's process firstly produces a clarified liquid stream after an initial reaction and filtration step. Dry, pure and highly water-soluble MAP crystals are eventually generated as an end-product, after a series of further crystallisation and purification steps. Waste from the various purification and filtration steps, in the form of sludges or purges, still contains some valuable P_2O_5. This can be captured by further processing – for example, via the fertilizer plant's blending or granulation units.

GEA's manufacturing process can typically deliver a yield (i.e. the amount P_2O_5 recovered to the crystalline end-product vs the P_2O_5 contained in the feed acid) of between 50-70 percent. The exact yield depends on the impurity levels in the MGA and the purity/quality requirements (non-soluble content) of the final MAP product.

GEA's technology for water-soluble MAP production has already been successfully implemented by an Eastern European customer. The new plant avoided considerable capital and operational expenditure by allowing non-purified MGA to be used as the phosphoric acid feed, while still delivering a pure MAP fertilizer with a high market value as the end-product. As a fertilizer, the crystalline end-product offers the following key benefits:

- High-quality fully water-soluble MAP (typically 12-61-0) with a low insoluble content
- Avoids clogging problems on spray systems and pumps
- Suitable for fertigation, foliar applications and the production of fertilizer blends and nutrient solutions
- Low turbidity after dissolution in water
- High-throughput processing
- Free of chlorine, sodium and other deleterious elements
- Moderate solution pH – safer and less corrosive
- Access to excellent laboratory back-up, support and expertise. ■

Prayon Technologies (PRT)

Prayon Technologies (PRT) is the technology arm and subsidiary of parent company Prayon s.a. With experience dating back more than 60 years, PRT is a global leader in phosphoric acid production technology.

Uniquely, Prayon is both a leading commercial manufacturer of phosphoric acid and its derivatives – purified acid, technical- and food-grade phosphates – and a licensor of phosphoric acid production technology. This provides the Belgium-headquartered company with considerable advantages when it comes to understanding the needs of its technology customers.

A major proportion of the worldwide phosphoric acid production relies on Prayon's process technology. In fact, Prayon Technologies has designed, developed and helped construct more than 135 phosphoric acid plants in more than 30 different countries globally. These plants consume more than 40 different types of phosphate rock and have P_2O_5 production capacities ranging from 25 tonnes up to 2,000 tonnes per day.

Prayon offers flexible production technologies able to respond optimally to the requirements of phosphoric acid producers, offering:

- Reduced energy consumption
- Increased yield,
- Lower production costs
- Excellent environmental performance.

Prayon Technologies essentially offers two types of service: technology licensing and consultancy. Its licensing activities cover:

- Phosphoric acid production – including a full range of processes (DH, HH, DA-HF, CPP, PH_2) producing hemihydrate or dihydrate calcium sulphate with one or two filtration step(s)
- Phosphoric acid concentration
- Fluorine recovery
- Gas scrubbing systems – for F, dust and H_2S reduction
- Phosphoric acid purification – SO_3, Cd, As, F, Al_2O_3, $Fe2O_3$ and MgO reduction technologies
- Phosphogypsum purification
- Uranium recovery from phosphoric acid
- DCP production from low-grade rock and dilute sulphuric acid – the *GetmoreP* process.

Prayon's consultancy activities cover:

- Audits of existing plants with specific objectives
- Phosphate rock evaluations
- Plant operator training. ■

JESA Technologies

JESA Technologies (JT), based in Lakeland, Florida, has proudly served the global phosphate industry for over a half century. The company, part of Worley Group, offers licensed technology to the phosphates industry covering the whole production process, from mine to market. The company is a leading licensor for three process steps in particular: phosphate rock beneficiation, phosphoric acid production and granular fertilizer manufacture.

Additionally, JT offers on-site pilot plants, for both beneficiation and phosphoric acid, supported by a fully equipped analytical laboratory. The ability to combine in-house technical and engineering design know-how – from mined rock all the way through to the finished product – with on-site pilot plants makes JT unique as a licensor.

Since its establishment in 1974, JT has been responsible for the design of over 150 process facilities for the phosphate fertilizer industry in 29 countries. The plants designed by JT include the largest single-train phosphate operations in the world. Notably, these include a phosphoric acid plant with a demonstrated capacity above 3,000 tonnes per day – plus numerous examples of DAP/NPK plants with capacities in excess of one million tonnes per year.

In addition to designing new plants, JT has an extensive track record in revamping operational plants. These revamps have successfully delivered a range of desired outcomes for customers – including increased production capacity, product quality improvements, energy savings and higher environmental performance.

Through its parent company Worley Group, JT is also backed by one of the world's largest engineering and project delivery firms, with proven strengths in resource, energy, and infrastructure markets globally. JT and Worley's combined capabilities offer clients a full spectrum of support covering all aspects of engineering, procurement, programme and construction management, as well as operations and maintenance.

JT's extensive test facilities in Lakeland, Florida, include:

- A comprehensively equipped analytical laboratory
- A bench-scale metallurgical laboratory, capable of testing ore samples obtained from core drilling or pits
- A fully-equipped pilot plant capable of batch or continuous operation
- A continuous phosphoric acid pilot plant.

These test facilities make a vital contribution to feasibility studies. By developing process design data, they enable JT to offer its customers process guarantees. They are also engaged in contract research for clients.

Two case studies of phosphate industry projects recently awarded to JT are provided below:

Client: Verdant Minerals Ltd
Location: Northern Territory, Australia
Project: Ammaroo phosphate project: di-hydrate phosphoric acid pilot plant testing.

Verdant is proposing to develop the Ammaroo phosphate project – the largest JORC-compliant phosphate rock resource in Australia and one of the world's largest undeveloped phosphate deposits. In the project's initial development phase, phosphate rock concentrate and associated merchant-grade phosphoric acid (MGA) will be produced for export to Asian markets through the Port of Darwin.

The proposed phosphate fertilizer complex will produce a high-quality MGA product utilising the most modern equipment and technologies available. These must also provide optimal environmental safeguards. The project's phosphoric acid production capacity is initially set at approximately 500,000 t/a P_2O_5, equivalent to 1,600 t/d.

Client: Ma'aden
Location: Ras Al Khair, Saudi Arabia
Project: Front-end engineering design (FEED) for two large-scale granular fertilizer plants

JT has been selected as the licensor for a major granular fertilizer project as part of Phase 1 of Ma'aden's 'Phosphate 3' mega project. Two large-scale granulation plants, with a total annual production capacity of two million tonnes, will be designed to produce over 25 different fertilizer grades.

As licensor, JT will be involved throughout the life of the project – all the way through from technology and design to staff training and then plant commissioning and start-up, supporting the engineering, procurement and construction (EPC) contractor. JTs' mission is to provide the client with reliable, efficient designs that demonstrate the excellence of its expertise and unrivalled leadership in the phosphate industry. ■

Potash producers smash the price ceiling

BHP is investing $5.7 billion in the 4.35 million tonne capacity Jansen potash project in Saskatchewan, Canada.

PHOTO: BHP

Belarus sanctions, freight costs and strong demand are pushing MOP pricing to new heights, says **Andy Hemphill**, senior editor for potash and sulphuric acid at ICIS Fertilizers.

The global potash industry stands on the brink of an upheaval not seen since major producer Uralkali separated from the Belarus Potash Company (BPC) in 2013. That seismic event shattered a cartel which had previously formed the bedrock of the traditionally slow-moving world potash market.

This time, however, it is BPC – not its Russian rival Uralkali – which is making headlines, having been swept up in a political storm that threatens to disrupt long-established supply routes for the world's 98 m tonnes annual trade in muriate of potash (MOP).

A year of change

The global potash industry, nonetheless, started 2021 on a firm note. Unlike many other industries – and, indeed, rival fertilizer fertilizers – as in, urea was in the toilet, MOP prices remained firm. Fortunately, the necessity of food production insulated the MOP industry from the worst ravages of coronavirus-related lockdowns and the attendant logistical mayhem.

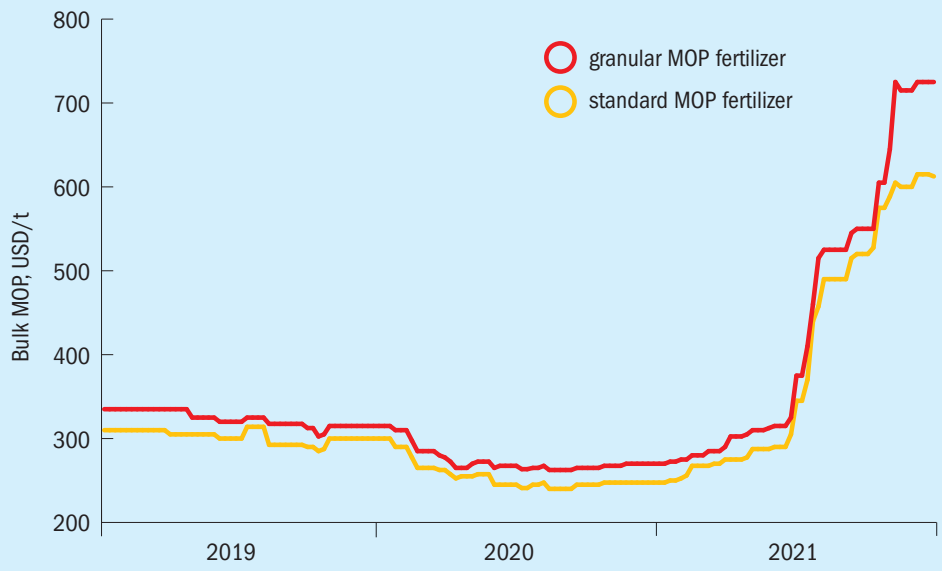
Indeed, by mid-year potash market pricing had generally recovered to pre-pandemic levels, eventually reaching heights not seen in a decade as 2021 progressed. Standard and granular MOP sales into Southeast Asia, for example, breached $400/t cfr in July and then continued upwards. Towards the end of the year, sales of granular and standard product in the region plateaued at around $700/t cfr and 600/t cfr, respectively (Figure 1).

The only real surprise for the market was the weaker-than-expected price points agreed relatively early on in the year between BPC and key buyers in the bellwether nations of China and India.

Long-term supply contacts shock the market

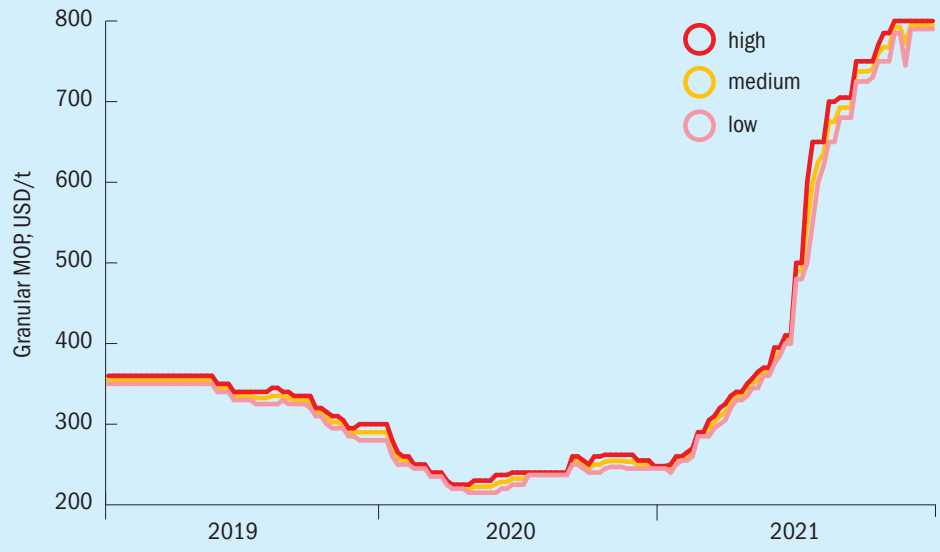
BPC came under fire from rival potash producers in late January 2021 after it signed an 800,000-tonne annual supply agreement with regular customer Indian Potash Limited (IPL). This 12-month contract for the supply of standard-grade MOP, starting February 2021, was con-

Fig. 1: **Weekly Southeast Asia MOP cfr spot prices (mid-range values), 2019-2021: granular and standard products**



Source: ICIS

Fig. 2: **Weekly Brazil granular MOP cfr spot prices, 2019-2021: high, medium and low values**



Source: ICIS

cluded at $247/tonne cfr (cost and freight). Although the agreement was a $17/t hike on the expired 2020 second-half contract price, it was still a far smaller increase than many players in the potash industry had forecast.

Then two weeks later BPC again shocked the market by settling a long-term contract to supply a consortium of Chinese buyers. This settlement, with importers Sinochem, CNAMPGC and CNOOC, was also signed at $247/t cfr – a $27/t increase on the expired 2020 contract – for shipments through to the end of December 2021.

At the time, BPC described this new Chinese deal as the next step in "strengthening the stability of the global potash market, and a positive sign for further price increases in other regions". The settlement reflected "the real market situation" and offered an "incentive for positive price dynamics", BPC added.

However, Canada-based Canpotex, the international potash trading arm of Nutrien and Mosaic, took a very different view. Responding to the Chinese settlement, it judged that the $247/t cfr agreed price was "significantly below current market levels for potash in offshore markets". Other major potash producers were similarly dismissive. Indeed, the widespread disappointment over these settlements led to suggestions that producers might attempt private negotiations to secure their own, separate deals with Indian buyers.

Contrary to the critical comments from its rivals, BPC's belief that its $247/t cfr contract agreements with India and China would provide a springboard for pricing in the wider global potash industry proved remarkably prophetic, as offers did subsequently increase through the first-quarter of 2021 and into the year's second-quarter.

In April, for example, BPC and IPL announced a new higher price of $280/t cfr for a renegotiated Indian contract to supply 600,000 tonnes of standard-grade MOP. BPC followed this up by achieving further price rises in India in May, with Rashtriya Chemicals and Fertilizers (RCF) purchasing 105,000 tonnes of MOP at $290/t cfr. Chinese buyers, meanwhile, refused to follow this trend and instead remained firm at $247/t cfr.

Then, in mid-November, Israel's ICL renegotiated a 150,000 tonne supply contract with IPL for standard MOP at $445/t cfr – a pricing level that will now set the jumping off point for 2022-2023 annual supply contract talks. China's domestic MOP import price for 'white' Canadian potash, meanwhile, also recovered in November to its highest level of the year.

Record prices west of Suez

Elsewhere, Brazilian granular MOP prices stormed ahead as 2021 progressed, repeatedly smashing through the ceiling – firstly, by topping $500/t, $600/t and then $700/t cfr – and showing no signs of stopping (Figure 2). In October, Uralkali hit $800/t cfr on granular MOP sales into Brazil, supplying at least 25,000 tonnes for November loading. As a result, granular MOP pricing into Brazil has passed its record 2009 peak and is now moving into uncharted territory.

Grounded

However, as mid-year approached, western powers began to line up their crosshairs on Belarusian president Aleksandr Lukashenko's prized potash industry.

The spark for this was the forced grounding of a Ryanair flight by Belarusian authorities in late May and the removal of activist and journalist Roman Protasevich – who remains under arrest, even now.

As June progressed, there was widespread speculation that this unlawful action would lead to the imposition of sanctions on Belarus' money-spinning MOP export operations.

This was proven true when the EU Council slapped sanctions on 78 Belarusian individuals and eight entities on 21st June, these including a ban on travel to the EU and the freezing of assets.

"These sanctions… send a further strong signal to the backers of the regime that their continued support for Alexander Lukashenko comes at a substantial cost," the Council said at the time.

The sanctions list notably included entrepreneur Mikhail Gutseriev, owner of companies Safmar, Slavkali, and Slavneft.

But one of the largest impacts of the sanctions was on BPC's longstanding agreement with the port of Klaipeda, Lithuania. The sanctions, by making Klaipeda off limits, removed BPC's access to its primary potash export hub. The consequences of this are likely to be highly significant, given that Belarus is responsible for around 20 percent of the world's potash supply.

Faced by sanctions, speculation on what export options were open to BPC quickly grew. A source at one European potash producer wondered if BPC could skirt the ban on straight MOP trade by switching to the production of nitrogen, phosphorus and potassium (NPK) fertilizer blends instead. A second source at another European producer thought Russian President Vladimir Putin might step in and assist Belarus, its traditional ally, by opening Russian ports to Belarusian potash tonnages.

BHP MUSCLES INTO THE MARKET WITH JANSEN PROJECT

Global mining superpower BHP has finally committed to entering the potash market. In August 2021, the company's board went ahead and approved the $5.7 billion capital expenditure needed to bring the massive Jansen project into production

The final investment decision for the Jansen mega mine in Canada's Saskatchewan Province – announced as part of BHP's annual 2020/21 results – was no real surprise. Especially as BHP had already invested approximately $3 billion sinking two shafts deep into the Canadian earth and constructing the necessary associated infrastructure.

BHP is forecasting that the global MOP market will grow to 89-97 million tonnes by 2035, supporting its case for the 4.4 million tonne annual output from the Jansen project and its expected 100-year lifespan. The company predicts potash demand will catch up with excess supply during the late 2020s and early 2030s – a timetable that neatly fits Jansen's expected ramp-up

Work on both shafts at Jansen is currently around 93 percent complete with first production expected by 2027.

Once Jansen is operational, Canada's Westshore Terminals Investment Corporation will ship large volumes of MOP from the mine to overseas markets via Delta on British Colombia's Pacific coast. Westshore has an agreement – subject to extension – to handle potash from the start of operations until 2051. This deal requires Westshore to complete the infrastructure needed to handle potash at its Roberts Bank Terminal by 2026, including a potash dumper, storage building and associated conveying systems. BHP is providing $33 million to fund the construction.

Announcing Jansen's go ahead, BHP also took the opportunity to take a swipe at the higher costs of rival producers – specifically referencing potash solution mines that flood tunnels with water and then extract the resulting brine-rich fluids for processing on the surface.

"In addition to consuming more energy and water than conventional mines like Jansen, solution mines tend to have higher operating costs and higher sustaining capital requirements," BHP said.

Previously, BHP also described potash extraction from resources owned by its rivals in Belarus and Russia as 'mature', an apparent reference to the ageing equipment and infrastructure operated by BPC and Uralkali.

Only time will tell if BHP's gamble in proceeding with the Jansen mega project will pay off. But, with the global population only expected to increase in coming decades, the odds look good. ■

Sanctions escalate

BPC, meanwhile, reacted to EU sanctions by issuing a press release warning that these could have a widespread impact on global food security. This warning was summarily ignored by the US, Canadian and UK governments when they waded into the fray with a new list of sanctions on 9th August. In a coordinated move, one year on from the disputed election that heralded Lukashenko's return to power, this trio imposed new restrictions on the Belarusian potash industry and its exports. These formed part of wider sanctions on the country's technology and software, dual-use goods and technology, tobacco goods, petroleum products, financial services and aviation sector.

US-backed sanctions were of particular concern to BPC and its buyers. Their worries centred on the fact that the Lithuanian companies underpinning Belarusian exports, most notably the country's railways, rely on US commercial banks for their transaction services. This made the ability of BPC to maintain the flow of payments to Lithuanian companies vital if it wished to secure continued access to the port of Klaipeda, ahead of the 8th December deadline for US sanctions coming into effect.

In comments reported by state-run newswire BelTA, a defiant president Lukashenko reacted by saying:

"[The EU and Western powers] started inventing things, shot themselves in the foot, and now they want to prevent us from using their ports for shipping chemical potash fertilizers. Listen, we will deliver these volumes.

"We will load them in Murmansk, not a problem, and we will deliver them to China via the shortest northern sea route, it is our main market, and to India, the south-east. We have to find a way out of this situation now before we drive each other into a corner – but the ball is on the other side."

Despite this rhetoric, for BPC's customers and market observers, the following key questions remained unanswered:

- If and when Lithuania's Klaipeda port became unavailable, could Lukashenko hammer out an agreement with Putin to transport potash via train to Russian ports for export?
- Would such a route offer the security of supply MOP buyers demand in a market that is experiencing decade-high prices?
- Would the higher logistics costs of transport via Russia allow BPC's rivals to offer more agreeably priced MOP to buyers?

The market has reacted to the uncertainty with global MOP price offers climbing ever higher as the above questions went unanswered. Indeed, at the time of writing, satisfactory answers are still awaited. To compound these difficulties, BPC itself was then specifically targeted by the US – having previously dodged the majority of sanctions which were instead placed on Belaruskali, the country's state-run potash mining arm.

Washington takes aim

In early December, Washington announced it was imposing expanded sanctions on Belarus. Acting in co-ordination with Canada, the EU and the UK, the Biden administration took aim at the country's officials and their defence, security and potash sectors.

This resulted in an additional 20 Belarusian individuals and 12 entities being designated for sanctions by the US Treasury's Office of Foreign Assets Control (OFAC). These were targeted for their role in migrant smuggling into the EU, the ongoing crackdown on human rights and democracy, and for propping up the regime financially. The designations were in response to what OFAC called "blatant disregard for international norms and the wellbeing of its own citizens".

Additionally, to reinforce the actions already being taken by partner countries, the US moved to stop new issuances of Belarusian sovereign debt in the primary and secondary markets.

"The US stands alongside its international partners and allies in imposing costs on the Lukashenko regime for its deplorable behaviour, including migrant smuggling. Treasury will continue to work with the international community to address the Lukashenko regime's repression, corruption, and flaunting of internationally recognised human rights," said Andrea Gacki, control director of the US Office of Foreign Assets. The US Treasury Department has set 1st April 2022 as the deadline for American companies to end their affairs with BPC. This covers BPC subsidiary Agrorozkvit and any other businesses in which BPC and Agrorozkvit hold a stake of more than 50 percent.

Now, as 2022 begins, neither BPC nor the Lukashenko regime have commented officially on how they intend to overcome looming sanctions. A situation that leaves the potash market on the precipice of massive, sweeping changes to long-established global supply/demand dynamics – and without a clear plan of action for dealing with these.

What next?

One day after the US sanctions were announced, a still defiant Belarusian government and its domestic supporters warned of the increased food prices that lie ahead "in all countries of the world".

"The fifth round of sanctions can only benefit the countries that introduced them. And we understand that the US sanctions have no direct jurisdiction in the EU," Andrei Strunevsky, an influential member of the Belarus House of Representatives told state-run newswire BelTA. Strunevsky is a former deputy mine manager at Belaruskali and a member of the country's Standing Commission on Industry, Fuel and Energy Complex, Transport and Communication.

However, Lithuania's government did act in response to international sanctions in mid-January by terminating the MOP transport contract between state-run Lithuanian Railways (LTG) and Belaruskali. Lithuania's transport minister has said the existing contract will expire on 1st February, according to media reports. Also, to avoid potential loopholes, any attempts to transport Belarusian potash via other Lithuanian suppliers will require the approval of the country's National Security Commission.

Adding to the pressure on Belarus, this news came only days after Yara announced it was winding down purchases of Belarusian MOP. The Norwegian fertilizer major said that sanctions have made it near-impossible to continue its longstanding, 26-year business relationship with Belarus.

An 'interesting' year

Despite the bluster and political manoeuvrings, the lack of any official announcement by the Belarusian government and state-run potash firms confirming future potash export arrangement has left buyers deeply concerned – especially given their need to secure tonnes in advance, with lead times from mine to field taking a month or more.

While BPC remains largely silent on the option of exporting via Russia, investors are buying into rival potash majors – and, in some cases, are throwing their lot in with smaller, upcoming potash market players too. Whatever happens, 2022 will certainly be an 'interesting' year for the global MOP business.

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