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The heat is on

Europe sweltered in an unusually early and exceptionally intense heatwave last month. June was the continent’s hottest on record, with the average temperature two degrees above normal. In France, a new national temperature record of 45.9°C was set in Gallargues-le-Montueux on 28th June.

Although it is not possible to categorically attribute a single weather event to global warming, the science on this is improving. An analysis by World Weather Attribution, for example, concluded that climate change increased the probability of the French heatwave by *at least* a factor of five.

Our industry, agriculture, faces a peculiar paradox when it comes to climate change. As a sector, we are both a major contributor to greenhouse gas (GHG) emissions while, at the same time, being particularly vulnerable to the effects of climate change.

It is tempting to believe that climate change is something our children or grandchildren will have to deal with. That time is on our side as we will not have to deliver serious cuts to GHG emissions until mid-century.

How comfortable or uncomfortable we feel about our changing climate is fast becoming a generational divide too. It is often younger people who take climate change most seriously and feel let down by what they see as inaction by leaders in business and government. Teenage climate campaigner Greta Thunberg has articulated such views most clearly and to greatest effect.

This sense of urgency is gaining support. In March, the UK parliament declared a ‘climate emergency’ in what was a highly symbolic though admittedly non-binding vote. The British government, building on the ground-breaking 2008 Climate Change Act, also set a new legally-binding target to bring the UK’s GHG emissions to net zero by 2050, in a new law enacted at the end of June.

Just how concerned should global agriculture be about the pace at which our climate is changing. Is it a clear current danger or largely a future concern?

Well, new evidence published by a team of researchers from the universities of Minnesota, Oxford and Copenhagen concludes that global food production is, in fact, already being hit by climate change.

The world’s top ten crops – barley, cassava, maize, oil palm, rapeseed, rice, sorghum, soybean, sugarcane and wheat – collectively deliver 83 per cent of all the food calories produced on cropland.

Yields for these crops have been predicted to fall under future climate conditions. But new research published in the journal *PLoS ONE* in May shows that climate change is already affecting production of these 10 key food energy sources – with some

regions and countries faring far worse than others. “Change is already happening, not just in some future time,” says Deepak Ray, the senior scientist at the University of Minnesota who led the research.

On average, growing season temperatures for the top ten global crops have increased by 0.5°C to 1.2°C since the 1970s, while rainfall has been variable. The *PLoS ONE* paper* reports that observed climate change causes a significant yield variation in the world’s top ten crops, both positive and negative. Effects range from a 13.4 percent decrease for oil palm to an increase of 3.5 percent for soybean. For the top ten crops as a whole, climate change has on average reduced food calories by around one percent.

The research also reveals that climate impacts on global food production are mostly negative in Europe, Southern Africa and Australia, generally positive in Latin America, and mixed in Asia and Northern and Central America. Critically, though, half of all food-insecure countries are experiencing decreases in their crop production. “There are winners and losers, [but] some countries that are already food insecure fare worse,” comments Dr Ray.

Such findings, say the authors, have implications for major food companies and commodity traders. They are clearly significant for the fertilizer industry too. Long-term decline in palm oil yields, for example, are likely to affect plantation profitability and therefore fertilizer affordability in what is a major end-market for potash.

Fortunately, there are plenty of potential upsides as well. Maintaining yields in a changing climate should make balanced fertilization and upping fertilizer applications rates imperative. Fresh evidence that climate change is affecting crop yields – right here, right now – should also spur action on climate adaptation. In agriculture, this could mean large expansions in fertigation and much wider adoption of precision agriculture. Greenhouse cultivation, by closely regulating growing conditions, can also maximise fruit and vegetable yields.

These agronomic innovations will no doubt require a new generation of speciality fertilizer products to help maintain crop yields. In our warming world, it is increasingly clear that climate-smart agriculture is needed today, not tomorrow. ■

S. Inglethorpe

Simon Inglethorpe, Editor

“New research shows that climate change is already affecting production of key food energy sources.”

*Ray, D. et al., 2019. Climate change has likely already affected global food production. *PLoS ONE*. 14(5).

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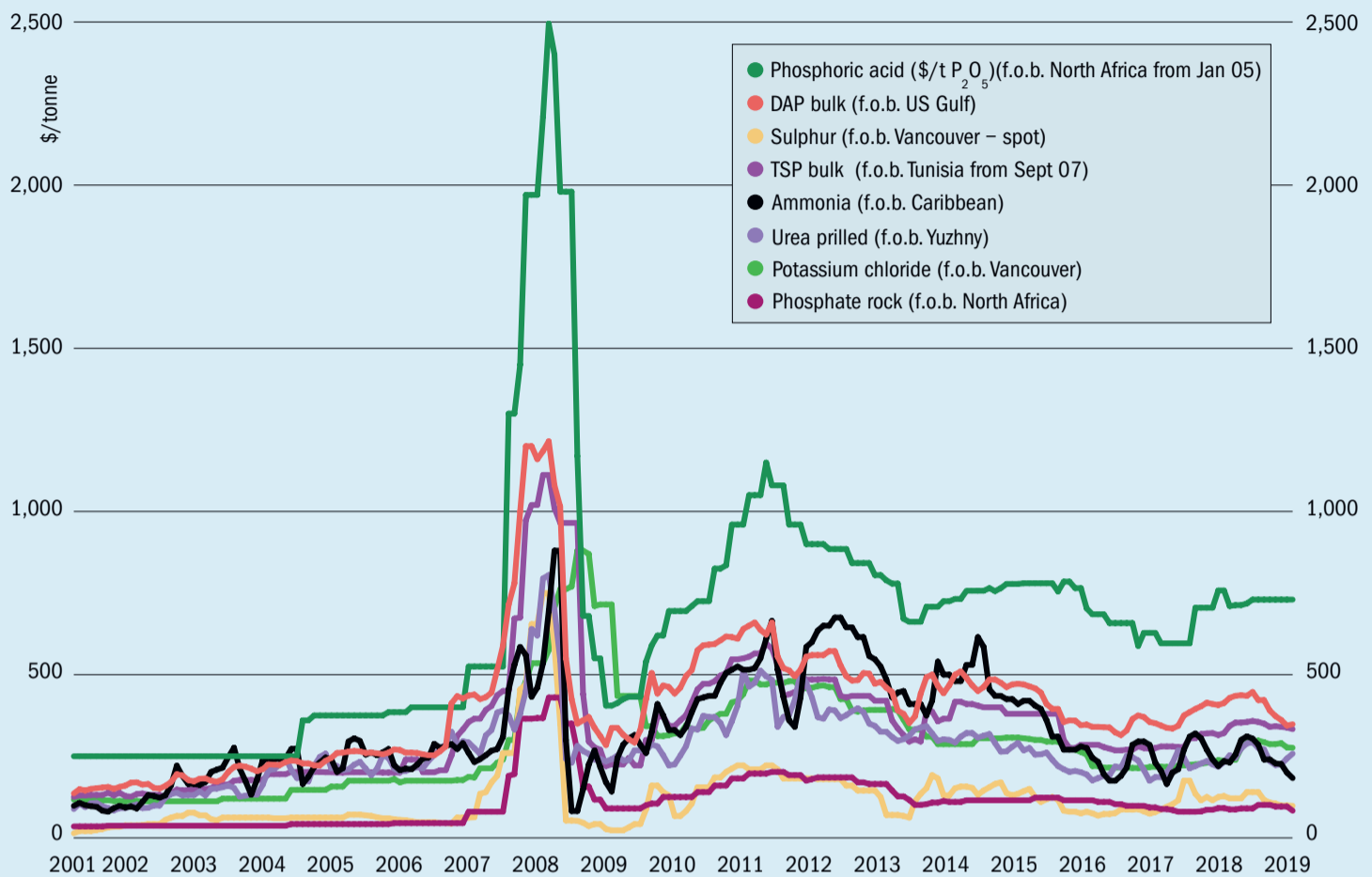
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Market insight

Historical price trends \$/tonne



Source: BCInsight

Market insight courtesy of Argus Media

PRICE TRENDS

Urea: Unusually, the market firmed during the second quarter. Middle East and Egypt f.o.b. prices moved up to \$280/t, while Baltic prills sold in the high-\$250s/t f.o.b., up \$30/t on a year ago. Chinese urea exports have yet to feature significantly in the market this year. Due to outages, India is also producing less urea domestically than planned. While output fell to 400,000 tonnes in April-May, this has not yet been accompanied by a fall in Indian sales. Prices in Brazil have also firmed by around \$10/t over the last month or so.

Phosphates: The global DAP market remains pressurised, particularly in India. During May and June, the subcontinent's DAP price fell by almost \$40/t to \$345/t cfr – these falls being driven by traders aggressively shorting Chinese DAP. With the breakeven price for Chinese DAP at around \$310/t f.o.b., only radical supply-side discipline in China is likely to halt the

slide. India's MRP and subsidy schemes have maintained favourable import economics and kept Indian DAP demand healthy. Pakistan, in contrast, is awash with DAP, with demand there dampened by worries about the monsoon and the weak Pakistan rupee. Although Bangladesh has awarded its 421,000 tonne DAP tender, the price has yet to be agreed, with underlying sentiment weak. West of Suez, prices are more stable. Brazil MAP is currently around \$360/t cfr, for example, but still down \$15-20/t on the beginning of May.

Potash: MOP prices have been in retreat in all the major buying regions since they first began to level-off in November last year. The fall is linked to pockets of weaker demand and supplier expectations, rather than increased output from EuroChem and K+S. A combination of factors – forward buying, high inventories, lower crop prices and new production – have undermined producer attempts to support prices. Producers are, nevertheless, still keeping the

market in balance by maintaining supply discipline. On the demand side, the market has been hit by the droughts affecting South Africa, Kenya, Australia, Thailand, Vietnam and the Philippines, all key MOP-importing countries. A weak US spring season has also weighed on demand.

MARKET OUTLOOK

Urea: The short-term outlook is firm due to tight supply and the prospect of an Indian import tender. The latter should soak up 700,000 tonnes of product for shipment to mid-August. There seems to be little upside beyond this period. Argus is forecasting the market to be in deficit through the third quarter, even allowing for increasing Chinese urea exports from August onwards. On a bearish note, the impact of persistent wet weather on US crops will lead to stock carryover. Corn planting, in particular, was notably at a record low at the end of May.

Phosphates: DAP remains weak east of Suez as the market is fundamentally oversupplied. Indian demand has slowed

Market price summary \$/tonne – End-June 2019

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	175-190	-	f.o.b. E. Europe 112-140	f.o.b. US Gulf	346-349	-	-
f.o.b. Yuzhny	200-210	250-266	-	f.o.b. N. Africa	350-395	320-345	640-740
f.o.b. Middle East	200-215	285-295**	-	c.fr India	351-360	-	655*
Potash	KCl Standard	K ₂ SO ₄	Sulphuric Acid	Sulphur			
f.o.b. Vancouver	252-299	-	c.fr US Gulf	80-110	f.o.b. Vancouver	95-100	-
f.o.b. Middle East	260-313	-	-	-	f.o.b. Arab Gulf	100-104	-
f.o.b. Western Europe	-	500-520	-	-	c.fr N. Africa	88-100	-
f.o.b. Baltic	236-311	-	-	-	c.fr India	110-122+	-

Prices are on a bulk, spot basis, unless otherwise stated. (* = contract ** = granular). Phosphoric acid is in terms of \$/t P₂O₅ for merchant-grade (54% P₂O₅) product. Sulphur prices are for dry material. (+ Quotes for product ex-Arab Gulf). n.a. = not available. Copyright BCInsight

considerably and Pakistan's DAP imports are unlikely to reach the two million tonne heights of last year. This suggests that Chinese producers will have to cut production or exit the export market. While the market west of Suez looks more balanced, there is no upside in MAP spot prices, based on Brazil's local availability and imports.

Potash: Argus expects the market to enter a period of slight oversupply towards the year's end. The new capacity being brought

on-stream by EuroChem and K+S Canada needs to garner market share somewhere. However, ramp-up delays mean EuroChem's VolgaKaliy mine is having less of an effect on supply than was first envisaged. Weaker crop prices and weather-related issues are creating fundamentally bearish demand conditions too. Argus is forecasting a fall in apparent demand to 66.2 million tonnes in 2019, down from 66.7 million tonnes last year, mainly due to weak palm oil and soybean prices. This has been especially true

in Southeast Asia where Malaysian plantation owners have cut demand rather than pay the prices offered. Little price upside is expected in Europe either, as many buyers anticipated price hikes and bought MOP in advance. Only Canada's Canpotex is fully committed across the globe into June. Argus expects the key annual contracts with India and China to settle at somewhere between parity and 10/t above 2018's \$290/t cfr level. India may settle ahead of China due to lower stocks.

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ABU DHABI

New Middle East fertilizer powerhouse

Abu Dhabi National Oil Company (Adnoc) is joining forces with Dutch nitrogen producer OCI to create a new Middle East fertiliser giant.

A joint venture (JV) to combine Adnoc's fertilizer business with OCI's Middle East and North African (MENA) nitrogen fertilizer assets was announced in mid-June.

OCI will own a 58 percent share and ADNOC a 42 percent share of the new Abu Dhabi-based business. This should generate revenues in excess of \$1.7 billion, based on last year's financial performance.

OCI's Middle East assets will transfer to the new business as part of the JV deal. These include the Egyptian Fertilizer Company (EFC), OCI's part ownership of Egypt Basic Industries Corporation (60%) and Sorfert in Algeria (51%), together with its UAE-based global trading platform. Combined, these production assets can produce up to 3.2 million tonnes of ammonia and 2.9 million tonnes of urea annually.

The newly-created entity will be the Middle East's largest nitrogen producer – having a five million tonne manufacturing capacity for urea and the ability to produce 1.5 million tonnes of saleable ammonia annually. The JV will also be the world's largest export-focused nitrogen fertilizer producer, according to both companies.

The new Middle Eastern fertilizer business will run its own centralised commercial team. It will also be highly export-oriented, benefitting from a strong storage and distribution network with good port access to the Mediterranean, Red Sea and Arabian Gulf. The JV should also profit from its ownership of state-of-the-art fertilizer production assets with low maintenance costs.

A desire to improve market access, increase market share

and provide better customer service were cited as the main reasons behind the strategic partnership. Growth opportunities and the potential to generate attractive returns for shareholders were also deciding factors.

The JV's 10-person board will consist of six OCI-nominated members and four Adnoc-nominated members. Dr Sultan Ahmed Al Jaber, Adnoc's CEO and UAE minister of state, will chair the board, while Nassef Sawiris will assume the role of CEO, alongside his current role as OCI's CEO. The JV's joint management team will be formed from a mix of OCI and Adnoc executives.

"I am very pleased to start a long-term strategic partnership with Adnoc, a company which has a clear downstream strategy and drive to unlock value," said Nassef Sawiris, CEO of OCI. "I believe that this platform has significant potential for future growth and value creation."

Dr Sultan Ahmed Al Jaber, Adnoc's CEO, added: "We are extremely pleased to have created this new joint venture with OCI who are a world leader in nitrogen fertilizers and share our ambition and vision to grow our new combined fertilizer business. Pooling our assets and capabilities is a value enhancing step for both companies, allowing us to leapfrog competitors to become the top nitrogen export platform globally. It will also enable us to access new markets, benefitting both existing and new customers."

The JV deal between Adnoc and OCI is expected to close in the third-quarter of 2019, subject to legal and regulatory approval.

In related news, it was also revealed that Adnoc Fertilizers has signed a new long-term gas supply agreement. This will secure competitively-priced feedstock for its Ruwais operations. ■

BRAZIL

New Fertilizantes Tocantins blending plant

Fertilizantes Tocantins, a partly-owned subsidiary of EuroChem Group, has opened a new fertilizer blending plant in Brazil.

The new plant is located at Araguari in Minas Gerais in southeast Brazil. It has a 100,000 tonne storage capacity and will produce up to 6,000 tonnes of fertilizer a day. It will also create 200 new direct and indirect jobs, according to the company.

The new blending plant marks another step in the expansion of Fertilizantes Tocantins, a EuroChem-controlled Brazilian fertilizer distributor. Fertilizantes Tocantins is growing rapidly with Araguari being the latest of three new blending plants opened in Brazil by the company during the past year.

"Brazil is an important growth market for us and our new plant at Araguari marks the latest stage of our expansion in Latin America," said Petter Ostbo, EuroChem's CEO.

The Araguari plant has a direct rail link to Vitoria, an Atlantic seaport located 520 kilometres northeast of Rio de Janeiro. This will enable EuroChem to deliver European-produced speciality fertilizers to local Brazilian farmers. These include the company's *Nitrophoska*[®], calcium ammonium nitrate (CAN) and NPS products.

"The Araguari plant marks our entry into the south-eastern region of Brazil, a strategically important part of the country," said José Eduardo Motta, the CEO of Fertilizantes Tocantins. "After the opening of two other major plants within the past year, at Sinop and Catalão, our focus is now on the consolidation of these new markets, so we can continue to maintain our successful rate of growth."

Fertilizantes Tocantins is one of the Brazil's biggest fertilizer distributors, selling more than 1.8 million tonnes through its distribution network in 2018.

The recently-opened Araguari, Catalão and Sinop blending plants add to six other Fertilizantes Tocantins plants. These are located in Porto Nacional, São Luis,

Querência, Rondonópolis, Barcarena, and Anápolis. The company's corporate office in Goiânia employs 600 people.

EuroChem has moved to strengthen its presence in the fast-growing Latin American fertilizer market. The Group has held a controlling interest (50% + one share) in Fertilizantes Tocantins since 2016. It also established a fertilizer distribution foothold in Argentina in 2017 by acquiring Emerger Fertilizantes.

CHINA

Wengfu-Kailin phosphate mega merger imminent?

The merger between Chinese phosphate producers Wengfu and Kailin could be completed by the end of June, according to commodity research company CRU.

A successful merger would create a new global phosphates giant. Collectively, the two companies produced six million tonnes of diammonium phosphate (DAP) in 2018, more than one-fifth of China's entire DAP output.

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CRU had expected the merger to take 3-4 years to be completed – if at all. However, the merger is being strongly pushed by the Guizhou provincial government. The transfer of Wengfu’s chairman to Kailin in 2018 is also thought to have accelerated the merger.

Combining both companies will create the world’s third largest producer of phosphoric acid and phosphate rock, if and when the merger is completed. Only OCP and Mosaic would be larger globally. Wengfu-Kailin would also become China’s largest phosphate fertilizer producer, according to CRU, leapfrogging the Yunnan-based Yuntianhua Group (YTH).

Wengfu and Kailin first entered merger talks around 18 months ago. Central and provincial government influence is pivotal due to their controlling shares in both companies. The Guizhou provincial government, for example, indirectly owns 100 percent of Kailin and holds a minority share in Wengfu. Additionally, central government interests control almost 60 percent of Wengfu.

The entire industry will be watching the progress of what is potentially a massive and far-reaching restructuring and consolidation of the Chinese phosphate sector.

UNITED STATES

Mosaic closes Plant City

The Mosaic Company has announced the closure of its currently idled Plant City phosphates plant in Hillsborough County, Florida.

Plant City first opened in 1975. It produced around 1.3 million tonnes of finished phosphate products in 2017, its last year of operation. The plant, which has been inoperative for the last 18 months, was one of company’s highest cost production units in Florida.

“Our decision to close the Plant City phosphate facility reaffirms our commitment to low-cost operation,” said Joc O’Rourke, Mosaic’s president and CEO. “We will continue to meet global demand for high-quality phosphate fertilizers with production from our low-cost facilities in Florida, Louisiana, Brazil and Peru, and through our joint venture in Saudi Arabia.”

Plant City’s permanent closure and the write-off of assets is expected to cost Mosaic up to \$390 million – a sum that will be met by annual cash payments over the next five years. Mosaic hopes to mitigate some of the closure costs through innovative water management and by putting part of the plant into productive use.

Mosaic’s current care and maintenance team will remain on site for several years to manage Plant City’s closure and ensure compliance with regulatory obligations.

Nutrien offers customers *xarvio* digital farming app

Nutrien’s North American retail arm, Nutrien Ag Solutions, is to offer BASF’s *xarvio*™ SCOUTING app to its customers.

The decision to provide access to this leading agronomic tool, announced in June, is part of a wider digital collaboration between the Colorado-headquartered farm retailer and the Agricultural Solutions division of BASF.

Providing BASF’s *xarvio*™ SCOUTING app will enable Nutrien’s farm customers to detect and identify weed and pest pressures as they monitor and protect crops during the growing season. The potential for offering the agronomic capabilities of BASF’s *xarvio*™ *Field Manager* are also being actively explored. This app offers crop protection advice, including timings and variable rate applications, for managing weeds, diseases and pests.

“These tools help improve growers’ results and we’re excited to be able to feature the *xarvio*™ SCOUTING app,” said Sol Goldfarb,



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vice president for digital strategy at Nutrien Ag Solutions.

“We are proud to have the *xarvio™ SCOUT-ING* app featured on the Nutrien Ag Solutions customer portal and to explore the agronomic intelligence of *xarvio™ Field Manager*,” added Paul Rea, senior vice president for BASF Agricultural Solutions, North America. “Through our work together, BASF... and Nutrien Ag Solutions can help change the industry by providing growers with the products, services and now digital tools to support their success.”

Compass and Marrone Bio join forces

Compass Minerals and Marrone Bio Innovations are to collaborate on biofertilizers.

The two companies are joining forces to develop new speciality plant nutrient products enhanced with microorganisms. The plan is to bring patented technologies to market and create innovative products to enhance plant health and growth. The new products will increase crop health and reduce crop stress by enabling crops to take up nutrients more efficiently.

The collaboration will combine Marrone Bio’s access to a collection of 18,000 novel microorganisms with Compass Minerals’ expertise in speciality plant nutrition. By improving plant vigour, the resulting value-added products should provide growers with higher crop yields and a better return on investment.

Microorganisms are known to control pests and plant diseases and improve the health of crops. They also reduce drought stress, salt stress and other environmental stresses.

Importantly, by making major nutrients and micronutrients more available, microbes are known to increase nutrient uptake efficiency and improve plant growth. This helps farm profitability and the environment by reducing excess nutrients.

“Compass Minerals Plant Nutrition is excited to have access to the rich collection of Marrone Bio’s microorganisms that have shown the ability to improve plant health and growth,” said Ryan Bartlett, vice president of innovation and product development at Compass Minerals. “This collaboration is an important one as we continue to expand our... plant nutrition portfolio... with this unique line of products.”

“[With] our combined technologies and core competencies, we look forward to working with Compass Minerals Plant Nutrition as a partner in the development of exciting new products that don’t exist in the market today,” added Pam Marrone, CEO of Marrone Bio.



PHOTO: EUROCHEM

The new EuroChem Northwest world-scale ammonia plant near St Petersburg.

RUSSIA

Kingisepp officially opens

EuroChem Group has officially opened EuroChem Northwest, its new ammonia plant located at Kingisepp near St Petersburg, Russia.

The 7th June launch ceremony in St Petersburg was attended by Russia’s industry and trade minister Denis Manturov, Leningrad’s regional governor Alexander Drozdenko, and Sergei Ivanov, a special presidential representative.

EuroChem Northwest took three years to develop and was constructed by two Maire Tecnimont subsidiaries, Tecnimont SpA and Tecnimont Russia. It produces ammonia using KBR’s proprietary *Purifier™* process.

The \$1 billion plant is Europe’s largest single ammonia production unit, with an annual capacity of just under one million tonnes (*Fertilizer International* 489, p15). Around three-quarters of its output will supply EuroChem fertilizer production plants in Antwerp, Belgium, Lifosa in Lithuania, and Phosphorit, the Group’s adjacent phosphate fertilizer complex at Kingisepp. The remaining 25 percent will be sold to third parties.

“The opening of EuroChem Northwest marks an important milestone in the company’s growth story, and cements our position as a global leader in fertilizer production,” said Petter Ostbo, EuroChem’s CEO. “By investing in the latest technologies, this landmark facility will help deliver world-class nutrients to our growing customer base, allowing farmers to get more out of their land.”

Construction of the world-scale plant

required more than 12,000 tonnes of steel and the installation of more than 64 kilometres of piling. Over 5,000 on-site workers were involved in the plant’s construction at its peak. EuroChem Northwest will permanently employ 300 local people now that it has opened.

EuroChem has made environmental protection a priority at Kingisepp.

The new plant, which was built on a brownfield site, incorporates an innovative closed water recycling system. This prevents effluent from discharging into the nearby Luga River and flowing into the Baltic. EuroChem is also preventing water runoff from operations at the Kingisepp site by working closely with the John Nurminen Foundation on a major environmental project.

UZBEKISTAN

Fertilizer complex plan unveiled

thyssenkrupp Industrial Solutions (TKIS) is partnering with Cyprus-based Ferkenesco Management Ltd to develop a new fertilizer complex in Uzbekistan’s Samarkand region. The announcement follows a push by Uzbekistan’s president Shavkat Mirziyoyev to monetise the country’s domestic gas production.

The complex will produce ammonia, urea, ammonium sulphate, melamine and ammonium phosphate under current plans. Although it is anticipated that most of these products will be consumed domestically, the complex will have sufficient capacity to export.

Land owned by JSC Samarkandkimyo has already been set aside for the development of the complex.

UNITED KINGDOM

Sirius signs supply agreement with IFFCO

Sirius Minerals has signed a take-or-pay supply agreement with Indian Farmers Fertilisers Cooperative Limited (IFFCO).

The landmark sales agreement is a first for Sirius in the Indian market. Sirius will supply IFFCO with up to one million tonnes of its *POLY4* polyhalite product annually under the terms agreed.

The 11-year agreement gives IFFCO exclusive supply and distribution rights for *POLY4* throughout India. During this period, the volumes of *POLY4* supplied will ramp-up to one million t/a in year eight.

The agreement also provides IFFCO with the option to purchase an additional 250,000 t/a of *POLY4* by mutual consent, at a price based on cost, insurance and freight (CIF). The agreement includes a break clause for IFFCO after year eight. There is also scope for a 10-year extension of the agreement, should both parties agree.

IFFCO is one of the largest co-operative societies in the world with access to over 55 million Indian farmers. India is also one of the world's top three fertilizer markets with a total nutrient consumption of around 30 million t/a.

Dr Uday Shanker Awasthi, IFFCO's managing director & CEO, said: "*POLY4* offers a unique opportunity for IFFCO to help

deliver our vision of increasing farmer's incomes by increasing crop productivity and the balanced use of energy efficient fertilizers. The multi-nutrient characteristics of *POLY4* are well suited to Indian soils and crops. The partnership between Sirius and IFFCO will have an important role to play for farmers in improving yield, quality and profitability of crops."

Sirius Minerals is currently constructing the Woodsmith mine at North Yorkshire in the UK to develop the world's largest and highest grade polyhalite deposit. The mine is currently scheduled to enter production at the end of 2021.

Chris Fraser, the managing director & CEO of Sirius Minerals, said: "We are delighted to be embarking on a long-term partnership with IFFCO, an organisation with a wide reach and a proud history in India and a substantial profile in the global fertilizer market. *POLY4* can undoubtedly have a hugely positive impact on Indian agriculture, both in terms of yields and sustainability and we look forward to working with IFFCO to deliver these benefits for Indian farmers for many years to come."

NETHERLANDS

Stamicarbon holds 'Future Day'

Industry innovation took centre stage at the Future Day event held by Stamicarbon at the Jaarbeurs Media Plaza in Utrecht earlier this spring.

Attended by more than 130 employees and 40 invited guests, Future Day was designed to inspire, spark discussion and spur collaboration. Topics under discussion included:

- How to feed the world's growing population as it heads towards 9.7 billion by 2050
- How to make fertilizers more efficient, enriching and sustainable
- Digitalisation, drones and robotics
- Vertical farming
- Future food sources such insects and alternative proteins.

"Stamicarbon is determined to be part of the solution. We believe we can best use our 70 years of knowledge and experience to help develop smarter fertilizers and significantly improve the production of fertilizers," said Pejman Djavdan, Stamicarbon's managing director.

Futurist and trend watcher Richard van Hooijdonk kicked-off the event by providing a glimpse of the future of agriculture. He predicted a growing role for all of the following: artificial intelligence; biotechnology; GM crops for greater yields; crop monitoring drones; optimised harvesting using sensors and climate data. Vertical and urban farming also show great potential, in his view, for bringing food production closer to citizens, while at the same time reducing transportation costs and carbon emissions.



The under-construction Woodsmith mine near Whitby, North Yorkshire, UK.

PHOTO: SIRIUS MINERALS

Saskia van den Muijsenberg, director of biomimicryNL, explained the commercial usefulness of biomimicry. This term – derived from the Greek words bios ‘life’ and mimesis ‘imitate’ – literally means ‘imitate life’. biomimicryNL promotes innovation by helping companies learn from nature and translate these into real business opportunities. Saskia provided examples of how nature is inspiring people to design sustainable technologies.

Bas Godschalk of Insects-for-all highlighted the key role insects can play as the ‘food of the future’ by meeting the growing demand for sustainable protein. New production technologies could introduce insect-based foods as a major protein source in human diets, and only require about 40 percent of the energy used to produce conventional animal protein. Attendees were dared to taste several foods made using insects during the event.

Other Future Day speakers included Taylor Pursell of US start-up Pursell Agri-Tech. Taylor revealed how innovative controlled release fertilizer technology was already in operation in North America. While Stamicarbon’s Rob Faessen highlighted recent developments in digitalisation at urea plants.

Pejman Djavdan also used the Future Day event to launch Stamicarbon’s latest innovation agenda and investment strategy. He made clear the company’s commitment to pursuing agricultural sustainability in coming years. Stamicarbon’s ambitions on innovation will focus on three main areas:

- Speciality fertilizers – including controlled release fertilizers, seed cores and micronutrients
- Renewable production of fertilizers – using wind or solar energy
- Digitalisation – optimising plant operations by harnessing the power of real-time data.

Power to Ammonia Conference

The 3rd European *Power to Ammonia* Conference took place on 6-7 June at Rotterdam Zoo in the Netherlands.

The event brought together industry and academics to discuss ammonia’s role in the low-carbon energy transition. Delegate numbers have been growing year-on-year, with 165 participants from 22 countries and 98 different companies, universities and research institutes attending this year.

The theme of this year’s event was how to make power-to-ammonia a reality by

completing all the links in the technology chain. Leading experts, developers and scientists – representing the various links in this chain – shared their latest finding with other delegates.

The conference coincided with the announcement of a new carbon tax for energy producers in the Netherlands, a move likely to make renewable energy more competitive with fossil fuels.

Sustainable ammonia production currently costs around twice as much as conventional production. However, renewable energy costs continue to fall, bringing the prospect of affordable sustainable energy ever closer.

Although the transport and storage of renewable energy remain a major challenge, ammonia is likely to be part of the solution. Indeed, it is thought that the emergence of clean energy could double the demand for low-carbon ammonia.

In the conference’s keynote address, professor Ad van Wijk of TU Delft made the case for ammonia as a hydrogen carrier in the green hydrogen economy. Green hydrogen with almost zero carbon emissions can be produced by water electrolysis using renewable electricity. Renewable hydrogen is already beginning to reach cost parity with fossil fuels in some part of the world. Australia, for example, with its abundant supply of solar and wind energy, looks set to lead the way, and is showing potential for becoming a future renewable hydrogen exporter. The country’s existing natural gas supply network to its regional neighbours Japan and South Korea could also deliver renewable hydrogen in future. Especially as Japan and South Korea are already investing heavily in developing hydrogen economies. The 2020 Tokyo Olympics will showcase hydrogen by using it to fuel the Olympic torch and power public transport.

The conference also highlighted other potential applications for green ammonia in the hydrogen economy. These included its likely use as a fuel in: diesel engines of ships and trucks in the short-term; gas turbines and furnaces in the short-to medium-term; and fuel cells over the longer-term. Ammonia is regarded as a particularly attractive option for zero emission shipping due to its energy density and ease of handling.

A more detailed conference report will be published in the September-October 2019 issue of our sister magazine *Nitrogen+Syngas*.

SPAIN

Muga project receives environmental permit

The Muga potash project has finally received its environmental permit from the Spanish government.

The project’s DIA (Declaración de Impacto Ambiental) was granted by Spain’s Ministry for Ecological Transition in May and officially announced at the beginning of June.

The news is a major achievement for Highfield Resources, the Australian developer behind the project, as it leaves the company free to proceed with the project’s development.

The Muga potash project in Northern Spain is Highfield’s flagship venture. The project aims to produce 540,000 tonnes per annum of muriate of potash (MOP) initially, under current plans, with the potential to double production over the longer-term. Access to international markets is provided through the Port of Pasajes, San Sebastian, 150 kilometres to the west of the proposed mine. Production costs of \$150/t (cost to port) are anticipated.

“The awarding of the DIA is the most significant step for Highfield in de-risking the Muga Project,” said Peter Albert, Highfield Resources CEO. “The Muga Project has the potential to deliver tremendous benefits to all of our stakeholders and the Highfield team is excited to now be able to move towards mine construction.”

Highfield says it will now focus on securing the mining concession and the construction permits needed to move the project to the construction phase. The company is also set to buy items of mining and process plant equipment with long lead times, and will also now complete the project’s final design.

Highfield updated Muga’s ore reserves in January. Last November, the company also renewed a memorandum of understanding (MOU) with contractor Acciona for the construction of the Muga mine.

The environmental permit does come with conditions to minimise environmental impacts. But Highfield described these as “standard practice in these types of environmental approvals”. It also added that “there appear to be no additional requirements that the company was not already aware of and had not already incorporated into its project planning”. ■

People

Mostafa Terrab is the new chair of the International Fertilizer Association (IFA). His appointment was announced in June during IFA's 2019 annual conference in Montreal. Mr Terrab succeeds **Rakesh Kapur**, the joint managing director of IFFCO. The appointment is ground-breaking as Mr Terrab – who is also OCP Group's chairman and CEO – is the first chairman in IFA's 90-year history to come from the African continent.

Mr Terrab says he will prioritise environmental stewardship and sustainable fertilizer use during his two-year tenure. "I am honoured to take on this important responsibility," Mr Terrab said. "IFA is a shared platform for this vital and evolving industry to work together on innovation, best practices, knowledge sharing and thought leadership on how to address, in a sustainable way, the critical challenge of feeding a growing global population."

"The global fertilizer industry remains committed to environmental stewardship and stakeholder relationship building," added Charlotte Hebebrand, IFA's director general. "We are excited to continue on this important path under Mr Terrab's chairmanship."

Prior to joining OCP in 2006, Mr Terrab was the director general of the Moroccan National Telecommunications Regulatory Agency (ANRT) and also worked for the World Bank. He holds a doctorate from MIT.

Petter Ostbo became EuroChem Group's new CEO at the start of June. He was previously executive vice president (EVP) and the chief financial officer (CFO) of Yara International. Petter brings with him a wealth of high-level industry experience. In a prior role as Yara's EVP for production, he was notably

responsible for 28 production sites and four mines in 16 countries.

Dmitry Strezhnev, EuroChem's former CEO, has stepped down from the board after 15 years. The company said he had decided not to stand for re-election – and will instead be focussing on other business ventures outside EuroChem.

"We are delighted to welcome Petter to the company's board. He has a wide range of experience and is highly regarded in our industry," said Alexander Landia, EuroChem's chairman. "I am also grateful to Dmitry for his long service to EuroChem. He has been instrumental in the successful development of the company into a global force in the fertilizer industry and we wish him every success in the future."

CF Industries has announced that **Dennis Kelleher** is to retire as chief financial officer (CFO) at the start of September. Dennis will be replaced by **Christopher Bohn**, the current senior vice president (SVP) for manufacturing and distribution.

"I am grateful for the contributions Dennis has made over the past eight years," said Tony Will, the president and CEO of CF Industries. "He has played a significant role in helping drive financial and operational excellence and creating long-term value for our shareholders. I thank Dennis for his extraordinary leadership and congratulate him on a successful and rewarding career."

Will added: "Chris' selection as chief financial officer is a great example of our internal succession planning program. He is an outstanding executive with proven leadership experience and an unwavering focus on safety. Chris will continue to provide strategic leadership as we capitalize

on the opportunities ahead for CF."

Chris has been with CF Industries for 10 years, having served as the CFO of Hess Print Solutions prior to this. In his current SVP role, he is responsible for overseeing the company's world-class nitrogen complexes and distribution facilities located in Canada, the United Kingdom and the United States. Mr Bohn has held a number of roles during his career with CF, including senior vice president, supply chain, and vice president, corporate planning. He holds a bachelor's degree in finance from Indiana University and an MBA from Northwestern University's Kellogg Graduate School of Management.

In a coordinated move, **Ashraf Malik** is being promoted to fill the SVP role vacated by Christopher Bohn. He is currently CF's vice president, site operations.

The Sulphur Institute (TSI) has named **Tom Simpson**, Nutrien's sulfur purchasing director, as its new chairman. It has also announced the appointment of **John Bryant** as president and CEO, following the retirement of **Robert McBride**. Both appointments were made following TSI's annual general meeting in April.

Tom Simpson said, "It is an honour to be named TSI's chair. I look forward to working with the Institute and its members to advocate on behalf of the sulphur and sulphuric acid industries. I would like to thank Rob McBride for his five plus years of dedicated service as the president and CEO of The Sulphur Institute. Rob came to us at a critical time and he has put the Institute in a great place for future growth and expansion of services. I would also like to welcome John to the TSI management team. He is a veteran in the industry, and I look forward to partnering with him on future endeavours." ■

Calendar 2019

SEPTEMBER

22-24

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

24-26

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

OCTOBER

1-3

Africa Fertilizer Agribusiness Conference 2019, CAPE TOWN, South Africa
Contact: CRU Events
Chancery House, 53-64 Chancery Lane, London WC2A 1QS, UK
Tel: +44 (0)20 7903 2260
Email: conferences@crugroup.com

7-9

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

22-24

2019 IFA Crossroads Asia-Pacific Conference, SYDNEY, Australia
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

NOVEMBER

4-7

CRU Sulphur and Sulphuric Acid 2019 Conference, HOUSTON, Texas, USA
Contact: CRU Events
Chancery House, 53-64 Chancery Lane, London WC2A 1QS, UK
Tel: +44 20 7903 2448
Email: conferences@crugroup.com

THEN&NOW

EMT Blending and Bagging

Fertilizer International is 50 this year. The continuing success of the magazine is built on mutually beneficial partnerships forged over five decades. So, in celebrating our 50th anniversary this year, we will also be profiling a much-appreciated commercial supporter in each issue. This month it is the turn of Netherlands-based blending and bagging equipment manufacturer **EMT**, a valued long-term advertiser. This remarkable company started life as a local agricultural supplier in north Holland more than 100 years ago.



Brothers and EMT directors Gustaaf and Janco Zeeman.

Company profile

The Dutch have always been an outward-looking enterprising people and the Netherlands has long been renowned for its entrepreneurs, traders and travellers. EMT is a fine modern-day example of this tradition. The company is a family business, now in its fifth generation, with roots in the small agricultural town of 't Zand – literally 'the Soil' – in Holland's northern Zijpe region.

EMT has been manufacturing major fertiliser blending and bagging equipment for more than 30 years (see timeline). Machines produced at the company's 't Zand factory are exported worldwide.

These include a range of blending machines (20-200 t/h capacity), most notably the *Weighcont* – EMT's proprietary fully automatic continuous declining blender. The largest of the company's batch blenders can process up to 14 tonnes per batch.

EMT manufactures small and big bag filling machines, as either portable or fixed units. For convenience and easy transport, the portable units (20-80 t/h) are made in standard 10ft, 20ft or 40ft shipping containers. EMT currently offers around 10 different types of small bagging machines (for 20-50 kg bags) and 12 different big bag machines.

State-of-the-art developments

EMT's newest innovation is coating systems able to add micronutrients or inhibitors to fertilizers in powder or liquid form. These systems have a capacity of 50-300 t/h and are computer-controlled.

EMT now supplies transport equipment too, such as elevators, belt conveyors and chain conveyors. These conveyor systems and elevators are fully mobile. EMT's increasingly comprehensive machine package has expanded to include fertilizer screening equipment for lump and dust removal as well. Truck and train discharge units and pits are also supplied. For warehouse filling projects, EMT's designers and engineers use computer-aided design (CAD) to prepare 3D drawings for customers.

1913

The Zeeman family enters into business, founding N.J. Zeeman as a local agricultural merchandise company in the Zijpe region of north Holland

1913-1976

Led by the 2nd and 3rd generation, the Zeeman family business thrives as a supplier to the Dutch farming community.

1976-1989

The family's 4th generation, brothers Gustaaf and Janco Zeeman, join N.J. Zeeman Diervoeders as directors. The company becomes an early supplier of blended fertilizers, sparking in the brothers a keen interest in blending equipment.

1989-2010

Janco and Gustaaf found EMT. The company joins forces with Illinois-based US manufacturer Doyle to import and distribute *Shamrock* drum blenders and weigh hoppers. Its strong, long-standing global alliance with Doyle endures today. But EMT quickly develops its own fabrication factory too, fast establishing itself as a leading blending equipment manufacturer in its own right. The company develops the innovative and market-leading *Weighcont* continuous blender and successfully expands into the European and wider global market.

2010-2019

Two decades on, EMT has supplied more than 400 blending and bagging machines worldwide to over 40 countries. By now, its wide product portfolio encompasses blending, bagging, handling equipment, transport systems, buildings and software. Zico Zeeman becomes the 5th generation of the family to enter the business, joining the company in 2016.

2019

Machines produced at the EMT's 't Zand factory in the Netherlands have been exported to more than 60 countries globally, and the company has executed more than 500 projects worldwide. EMT continues to innovate and grow – recognised within the industry as a Netherlands-based family company with a truly global reach.



EMT staff at the company's 't Zand factory.



PHOTO: ETI BAKIR

Agricultural powerhouse

Turkey is the world's seventh-largest agricultural producer and has the largest agricultural sector in the OECD. Some 24 million hectares of land are devoted to agriculture – half the country's total land area – with more than 85 percent of this land being dedicated to arable farming. A further 22 million hectares is in pasture or meadow, and forests cover an additional 14 million hectares. There are over three million agricultural enterprises nationally and average farm size is around six hectares¹.

Turkish agriculture employs 5.3 million people, about 20 percent of the country's workforce, and contributes around six percent to national GDP¹. Although its percentage contribution to GDP is in decline, agriculture's cash contribution to the economy has continued to grow, increasing by some 40 percent between 2002 and 2016 to exceed \$53 billion.

In terms of agricultural output, Turkey is:

- A world leader in the production of apricots, cherries, figs, hazelnuts and raisins
- A top five producer of chestnuts, cucumbers, green beans, honey, lentils, melons, peppers, pistachios, quinces, sour cherries and watermelons
- A top 10 global producer of almonds, apple, barley, cotton, sunflower, tobacco and wheat.

Turkey's farmers notably produced more than 35 million tonnes of cereals and 32 million tonnes of vegetables in 2016 (Figure 1).

Eti Bakir's new \$1.1 billion Mazidagi Phosphate plant.

Turkey's thriving agricultural sector has created a large and dynamic fertilizer market at the crossroads of Europe and Asia. We report on Turkey's fertilizer market, and how the 2016 nitrates ban has affected production and imports.

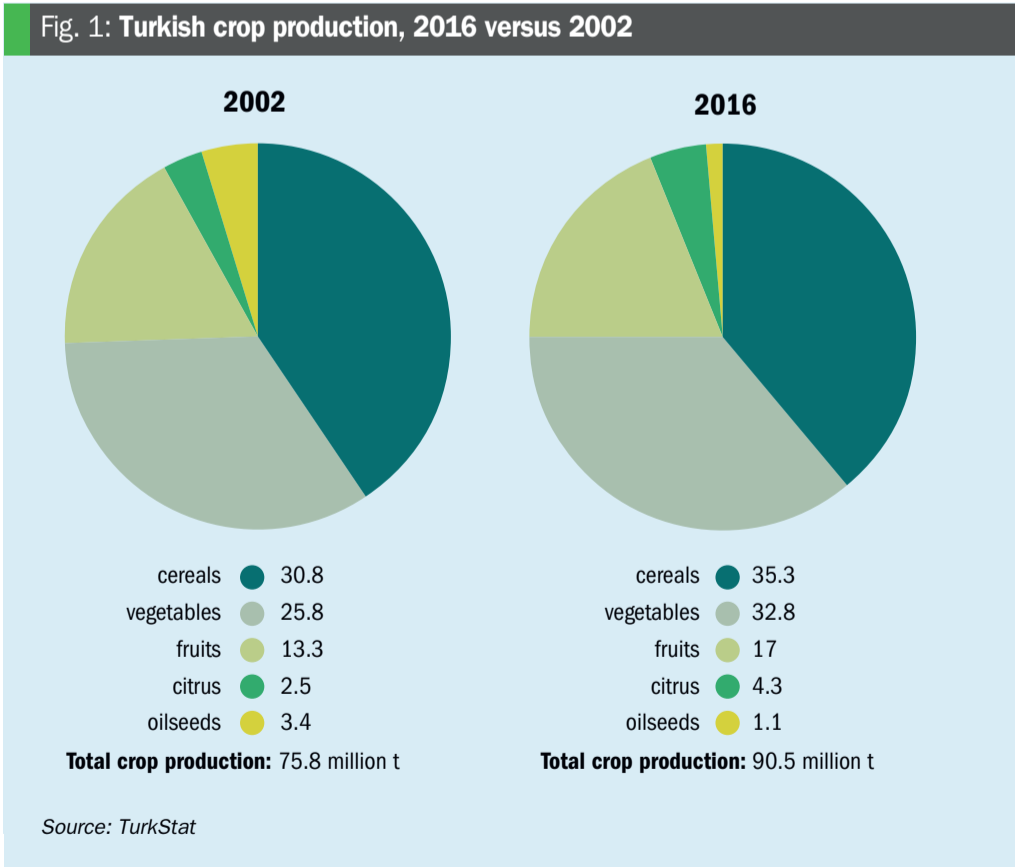
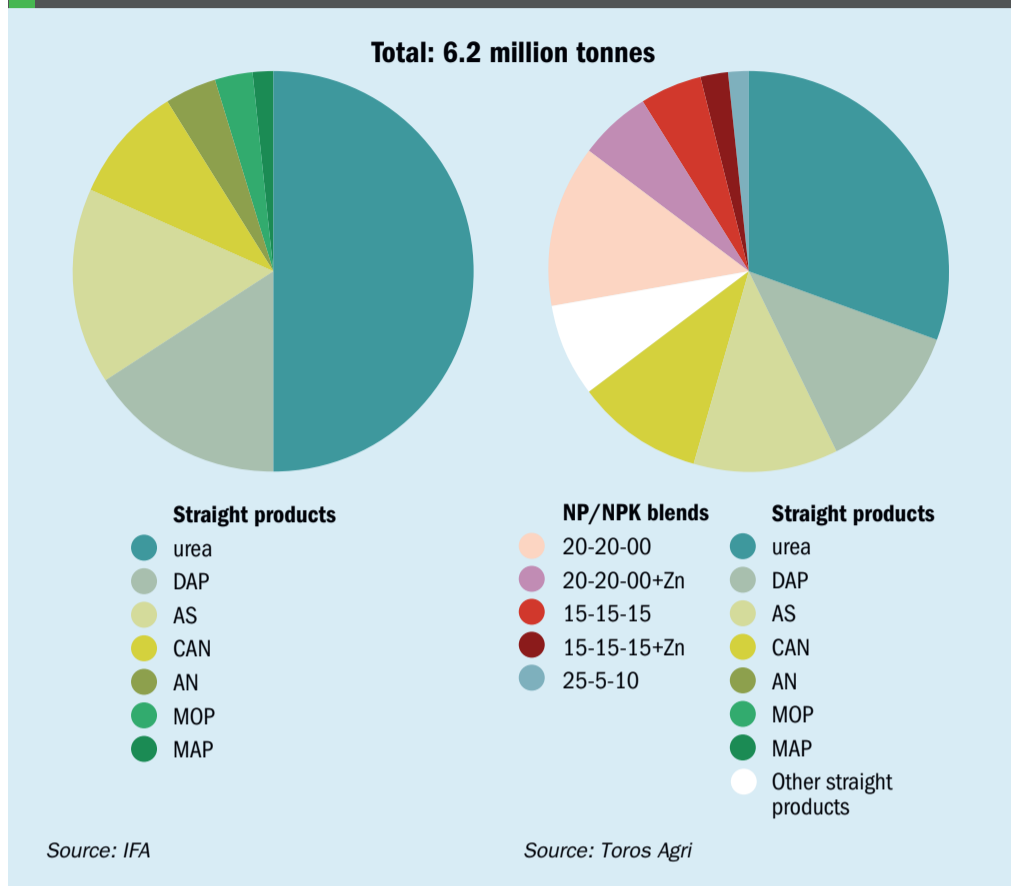


Fig. 2: Turkish fertilizer consumption, 2017:
(A) straight products only; (B) straight products and NP/NPK blends.



The Turkish agricultural sector is becoming increasingly sophisticated, with greenhouse cultivation, in particular, on the rise. With an area of 664,000 hectares under plastic or glass, Turkey is already the world's fourth-largest greenhouse grower. The 6.7 million tonnes of fruit and vegetables grown under cover annually are worth \$3.5 billion. Almost 14 percent of Turkish agricultural land is also under irrigation¹.

Turkey still imports significant amounts of agricultural products, especially oil-seeds (including soybean and soymeal) and grain products. These are needed to satisfy a high demand for animal feed, particularly from the expanding poultry sector. The country's advanced textile industry also tops up its cotton production with imports, as does its food processing and bakery sectors.

Although Turkey needs to import \$15 billion of agricultural products annually to satisfy strong domestic consumption, agricultural exports generate around \$18 billion for the economy each year. Thanks to this surplus, the country remains one of the largest food product exporters to Eastern Europe, the Middle East and North Africa. Around 1,700 types of farm products are exported to more than 185 countries every year¹. Turkey ranks globally as:

- The top exporter of apricots, chickpeas, figs, hazelnuts and raisins
 - A top five exporter of cherries, chestnuts, lemons, lentils, olive oil and tobacco
 - A top ten exporter of cucumbers, grapes, olives, oranges, peppers, pistachios and tomatoes.
- The country is also the world's number one exporter of flour.

Fertilizer consumption

Turkey is by far the largest fertilizer market in West Asia, its scale of demand eclipsing both Iran and Israel. Indeed, Turkey's nutrient consumption – some 2.8 million nutrient tonnes (N + P₂O₅ + K₂O) in 2016 – is responsible for almost 60 percent of regional usage.

Although Turkey's nutrient consumption is sizeable by regional standards, and comparable to that of Russia, its much larger Black Sea neighbour to the north, it still represents less than two percent of global demand.

Turkey's consumption of fertilizer products peaked at 6.7 million tonnes in 2016, according to government/industry estimates, and has fallen back subsequently to 6.2 million tonnes in 2017 and 6.0 million tonnes in 2018 (provisional estimate)¹. The country's annual fertilizer

consumption has generally exceeded five million tonnes since the early 2000s.

Cereals, mainly wheat, account for 60 percent of Turkey's fertilizer use, and are a strong driver of nitrogen and phosphate demand. There is a general buying preference for nitrogen and phosphate products. This is reflected by the country's average N:P:K ratio (1.0:0.4:0.1 in 2015). Commercial fruit and vegetable growing – responsible for 18 percent of total fertilizer use – provides a limited but growing market for potash products.

Fertilizer purchases have traditionally been heavily skewed towards nitrogen products – particularly urea, ammonium sulphate (AS) ammonium nitrate (AN) and calcium ammonium nitrate (CAN) – together with diammonium phosphate (DAP). Urea is the main straight fertilizer with 1.9 million tonnes being applied to land in 2017 (Figure 2).

Turkey is also a large NP/NPK market (Figure 2), consuming around 1.7 million tonnes in 2017, with many of the country's producers having the flexibility to switch between DAP and NPK production. The most widely applied NPK products are 20-20-00 and 15-15-15 and their zinc-enriched variants (Figure 2).

Fertilizer production and imports

Fertilizer availability and product preferences in Turkey partly reflect domestic production capabilities (see map, Figure 3). These include significant manufacturing capacities for AN (1.7 million tonnes), urea (0.6 million tonnes) and DAP (0.4 million tonnes), and fertilizer raw materials such as ammonia (0.8 million tonnes) and phosphoric acid (0.7 million tonnes). Ammonia and urea production are "sporadic", according to the International Fertilizer Association (IFA). This reflects Turkey's reliance on natural gas imports, which are mostly supplied by Russia.

The mismatch between Turkey's fertilizer output and large-scale agricultural demand means the country is heavily important reliant for its most popular products such as urea, DAP and AS (Figure 4).

IFA estimates of Turkish fertilizer production (1.8 million tonnes in 2016) are much lower than government/industry estimates (3.4 million tonnes). This apparent discrepancy is largely due to the inclusion of domestically-produced NP/NPK compounds in the higher estimate – these being partly produced from imported straight fertilizers. Consequently, the Turkish fertilizer

market can be viewed as either 50 percent or 75 percent import reliant – depending on whether the imports used to make compound fertilizers are counted or not.

Fertilizer imports are, in any case, on the increase. The Turkish government’s own figures show they rose from 2.7 million tonnes in 2015 to 3.8 million tonnes in 2016, with imports accelerating by a further 18 percent year-on-year in the first nine months of 2017¹.

IFA estimates are even higher. These suggest that Turkey’s fertilizer imports exceeded 4.7 million tonnes in 2017. Incoming urea deliveries (2.8 million tonnes) alone accounted for almost 60 percent of this import volume. GTIS fertilizer trade data for 2017 also reveal the following large import dependencies:

- 2.8 million tonnes of urea – mainly from Egypt (1.4 million tonnes), Iran (559,000 tonnes), Russia, (320,000 tonnes), Ukraine (176,000 tonnes) and Turkmenistan (120,000 tonnes)

- 965,617 tonnes of AS – including large quantities from South Korea (204,000 tonnes), China (411,000 tonnes), Belgium (131,000 tonnes) and Ukraine (105,000 tonnes)
- 725,000 tonnes of DAP – mostly from Morocco (234,000 tonnes), Jordan (220,000 tonnes) and Tunisia (183,000 tonne)
- 184,000 tonnes of NP – largely supplied by Greece (100,000 tonnes), Norway (40,000 tonnes) and Russia (33,000 tonnes).

Turkey’s production of phosphate fertilizers such as DAP and triple superphosphate (TSP) also relies on external supplies of phosphate rock and phosphoric acid. GTIS trade data show the country imported:

- 1.0 million tonnes of phosphate rock in 2017, sourced from Morocco (766,000 tonnes), Israel (262,000 tonnes) and Egypt (6,000 tonnes)

- 338,000 tonnes of phosphoric acid, mainly supplied by Morocco (162,000 tonnes), Tunisia (100,000 tonnes) and Israel (57,000 tonnes).

Dramatic market changes

Two major policy changes introduced in 2016 have led to profound changes in the Turkish fertilizer market – and the scale and pattern of consumption. Firstly, the government abolished VAT on fertilizer products at the start of 2016 as a market stimulus to improve their affordability. This resulted in a 22 percent boost (+1.2 million tonnes) in fertilizer buying by Turkish farmers in 2016 compared to the previous year. Although fertilizer consumption did fall back in 2017 it has remained above six million tonnes.

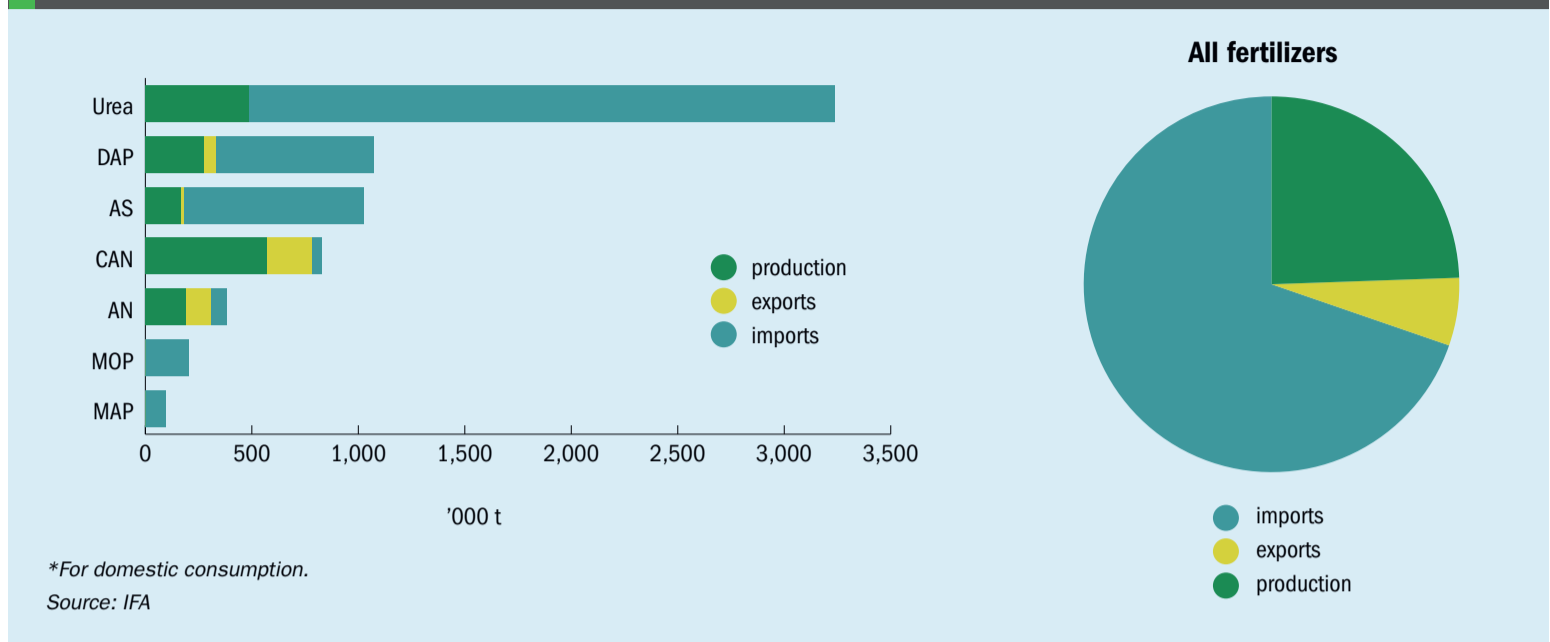
Secondly, a ban on the sale and movement of nitrate fertilizers was suddenly introduced by the Turkish government in

Fig. 3: Turkey’s main fertilizer producers

Source: Toros Agri



Fig. 4: Turkey: fertilizer production*, exports and imports, 2017



mid-2016. The decision to block the sale of ammonium nitrate (AN, 33% N) was taken in response to a series of terrorist attacks in the country. These culminated in the June 2016 car bombing in Istanbul. During this attack, an ammonium nitrate bomb was remotely-detonated during the city's morning rush hour, killing 11 people. The government's response was rapid and draconian – a ban on nitrates being introduced the day after the attack.

Turkey was a major market for ammonium nitrate prior to the ban. Fertilizer-grade AN imports totalled 625,000 tonnes in 2014, for example, supplemented by domestic production of 306,000 tonnes. Predictably, the ban's introduction prompted a collapse in domestic AN sales. Initially, these declined

modestly from 876,000 tonnes in 2015 to 804,000 tonnes in 2016, only to fall to almost zero – a lowly 4,000 tonnes – in 2017, according to producer Toros Agri².

Looking ahead, Turkey looks set to remain a sizeable and growing fertilizer import market.

The absence of AN from the market – and the removal of VAT – has largely benefitted urea imports. These have increased by more than one million tonnes since the nitrates ban, increasing stepwise from 1.6 million tonnes in 2015 to 2.3 million tonnes in 2016 to reach 2.8 million tonnes in 2017¹.

The nitrates ban initially covered a range of other nitrate fertilizers as well, including calcium ammonium nitrate (CAN, 21% N and 26% N) and potassium nitrate (NOP). The ban on these nitrate products was, however, lifted in January 2017, subject to new monitoring and tracking

regulations. Turkey remains a significant CAN producer with a domestic output of 782,000 tonnes in 2017.

Fertilizer tracking system

In April 2017, the Turkish government announced new rules to monitor the domestic movement of chemical fertilizers. The new system is designed to track and trace fertilizers throughout the supply chain, from their point of origin, at ports or the factory gate, to their final destination on farms. It does this by combining the barcoding of packaging with the DNA tagging of fertilizers¹.

The new system was introduced for bagged CAN products in January 2018 and was then rolled out to all chemical fertilizers from July 2018 onwards. Fertilizer distributors are also required to install surveillance equipment at their sites as part of new monitoring arrangements.

Recent developments

Producer **Toros Agri** is Turkey's leading fertilizer producer, owning almost four-tenths of the country's production capacity. The company operates three fertilizer manufacturing complexes at Mersin, Ceyhan and Samsun (Figure 3). Combined, these sites provide a total installed capacity of two million t/a – with around 1.85 million t/a of production currently in operation.

The company responded quickly to the collapse in AN sales in 2017 by introducing a new urea ammonium sulphate (UAS) product, *Ultra-N*, as a substitute with an identical nitrogen content. *Ultra-N* is produced



Eti Bakir's new Mazidagi Phosphate plant provides around 0.7 million tonnes of additional DAP/NP capacity.

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by combining crystalline ammonium sulphate with urea melt in a granulator. It contains 33 percent nitrogen. Urea provides 24 percent of the nitrogen content, with ammonium sulphate contributing the remaining nine percent nitrogen in NH₄ form².

Other raw materials such as sulphuric acid, anhydrous ammonia and water are consumed during the manufacturing process for *Ultra-N* to regulate granulator bed temperature. A magnesium filler is also fed to the granulator to improve granule hardness².

Toros Agri built the new *Ultra-N* line at its existing Samsun NPK manufacturing plant on the Black Sea coast. Production began in May 2017, ramping up from 700 t/d initially to eventually reach 1,000 t/d. The new product has been a success, becoming widely adopted by Turkey’s farmers as a substitute for AN since its introduction, according to Toros Agri².

Producer **Eti Bakir** also eased Turkey’s phosphate import dependency by starting production at its new \$1.1 billion Mazıdaği plant last year. The new plant – said to be the biggest single private sector investment in East and Southeast Anatolia – provides the country with an additional 200,000 t/a of DAP capacity and 500,000 t/a of NP capacity.

Short-term headwinds

Looking ahead, Turkey looks set to remain a sizeable and growing fertilizer import market. Fertilizer demand in Turkey will certainly need to grow if the country is to intensify agricultural production and improve crop yields and match the fertilizer application rates of its neighbours.

Turkey’s average fertilizer application rate (106.7 kg/ha) is low compared to world (138.9 kg/ha), OECD (133.6 kg/ha) and EU (157.2 kg/ha) averages. Cereal yields (3.1 t/ha), although on the rise, also fall short of the world average (4.0 t/ha) and are well below those of EU member states (average 5.2 t/ha) and OECD countries (average 5.6 t/ha).

The outlook for speciality fertilizer consumption in Turkey also looks solid, thanks to the rise in greenhouse cultivation of fruit and vegetables and the increasing use of irrigation.

Turkey’s fertilizer market is, however, facing headwinds over the short-term, with IFA forecasting a “sizable contraction” in Turkish fertilizer demand in 2019/20. This is a consequence of currency falls and the country’s dependency on fertilizer imports.

The Turkish lira declined drastically last year, falling 45 percent against the US dollar in the 12 months to September 2018, making fertilizers more expensive for farmers. The fact that most of the country’s agricultural output is sold and consumed domestically also means that the potential upside to any devaluation – farmers achieving higher international prices for their crops when expressed in liras – is limited compared to other more export-based agricultural economies.

More positively, the anticipated drop in Turkish fertilizer demand, during this year and into next, is likely to be temporary and short-lived rather than structural in IFA’s view. ■

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1. Goral, H., 2018. Update on Turkey’s agriculture and fertilizer industry. *CRU Phosphates 2018*, Marrakech, Morocco, 12-14 March 2018.
2. Turan, H., 2018. Turning a challenge into an opportunity: a new line of production sparking from a ban in Turkey. *IFA Global Technical Symposium*, Madrid, Spain, 9-12 April 2018.



**TAG.
TEST.
TRUST.**

Trace the product,
not the packaging.

SafeTraces provides the only on-product safety solutions that deliver full transparency into the safety and provenance of food and agricultural products. They enable producers and processors to protect their brands, and reduce food waste and recall costs.

Full Transparency – it’s in our DNA.



Trace the product, not the packaging

A number of fertilizer manufacturers have received an innovative DNA tagging system developed by Californian technology company SafeTraces. This ground-breaking system rapidly produces a unique DNA barcode that is sprayed onto fertilizer as each bag is filled. DNA tagging, when paired with blockchain technology, provides an unmatched level of traceability, as **Anthony Zografos**, the company's CEO and founder, explains.

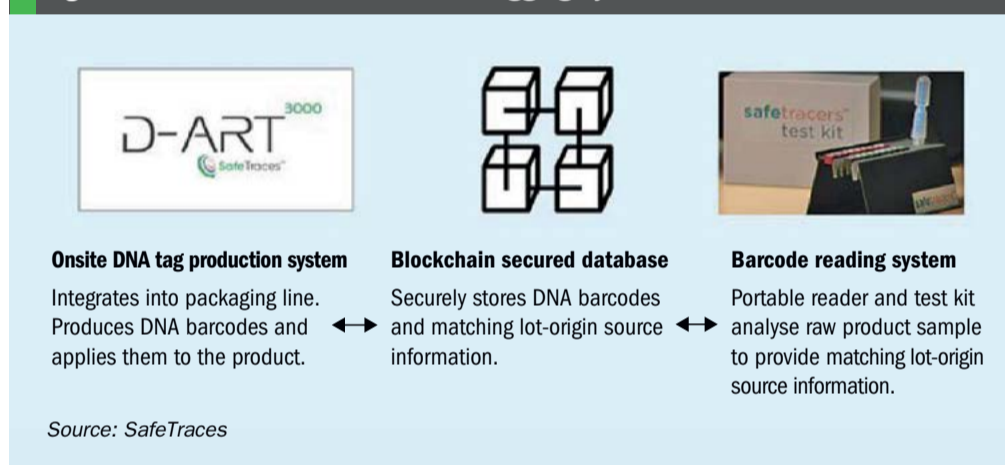
The ground-breaking DNA tagging system from SafeTraces has already been deployed to fertilizer manufacturing plants in Europe and the Middle East. The system, known as *D-ART 3000*, can be seamlessly integrated into manufacturing lines for products of any size, solid or liquid, including a wide range of agricultural inputs. Once applied, the DNA tracer provides an unbreakable link between the physical product and its digital blockchain-secured certificate. An easy-to-use barcode reading system identifies the DNA tracer and can recover information on the origin of the product at any point in the supply chain.

Proof positive traceability

The need to establish iron-clad traceability all the way along agricultural and food supply chains is becoming increasingly clear, and even urgent. Establishing the provenance and quality of fresh food products is one priority, for example, while detecting adulteration is a pressing issue for agricultural inputs. But safety and security are the most urgent concerns driving the introduction of traceability for fertilizers such as ammonium nitrate (AN).

Keeping close tabs on bulk chemicals is simply good supply chain management practice. This is especially true of AN – a fertilizer produced and distributed globally that also poses a serious risk due to its use in improvised explosive devices (IEDs). A 2014 study found that more than 95 percent of terrorist attacks worldwide were carried out with IEDs containing fertilizer-grade AN¹. Unsurprisingly, therefore,

Fig. 1: SafeTraces' *D-ART 3000* DNA tagging system



keeping close forensic-level tabs on AN is becoming a required practice in certain countries.

The Turkish government's response to terrorist activity within its borders led to a ban on the sale and distribution of AN-based fertilizer in June 2016 until effective tracking was established. In January 2018, Turkey became the first country to mandate DNA tagging of all locally produced and imported AN-based fertilizer². The new requirements, now implemented, include DNA tagging, secure packaging, and a code registry system that allows the contents of each bag of AN to be traced to its source.

Until just a few years ago, such requirements would have been impossible to meet. DNA tagging technology was limited to applying DNA-tagged ink on packaging or adding a purchased DNA marker to a product. "The ability to produce and track DNA barcodes onsite so that the content of *each* bag is tagged with a unique DNA

marker – at the rate of a high-volume fill line – started to become a reality just a few years ago," Anthony Zografos, CEO and founder of SafeTraces noted. "Technologies for creating a secured fool-proof DNA tagging system had been developed individually, but they had not been adapted to serve the agricultural sector."

Protecting fertilizer safety, security and quality

As of January 2018, Turkey's AN production industry was no longer on hold. Part of the solution was the deployment of SafeTraces *D-ART 3000* systems to provide state-of-the-art traceability (Figure 1).

Safety concerns about AN are prompting interest in tracking requirements in other countries too. In the United States, the Department of Homeland Security is considering implementing an AN registration programme³. The introduction of DNA tagging at AN manufacturing sites in the

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*Toros Agri, the flagship company under Tekfen Agri-Industry Group, was founded in 1974 in order to operate mainly in the agricultural inputs sector. With 2 million tpa installed capacity in 3 plants, Toros Agri is the largest manufacturer and market leader in Turkey holding 38% share of the total installed capacity. Conducting its manufacturing operations at 3 plants located in Ceyhan, Mersin and Samsun, the Company has introduced first organomineral fertilizers to the market in 2017 in addition to its Ammonium Nitrate (AN)/Calcium Ammonium Nitrate (CAN), Diammonium Phosphate (DAP) and compound (NPK) fertilizers.

United States would certainly create the basis for a robust audit trail. In Europe, adding DNA markers to fertilizers immediately after manufacture could guarantee that customers are receiving high quality products by ensuring no adulterants enter the supply chain. This could be achieved by measuring DNA marker concentration at a number of control points.

Keeping adulterants out of agricultural inputs becomes more challenging further down the distribution chain, particularly in developing nations. A 2015 study by the International Food Policy Research Institute, in cooperation with USAID, found that in Uganda as much as 67 percent of urea fertilizer samples were adulterated, as were other agricultural inputs⁴. Unscrupulous business practices of this type exacerbate farmer poverty. The presence of substandard products on the market means smallholder farmers lose out twice: once at the beginning of the growing season by spending their scarce resources on ineffective fertilizers, and again at harvest time due to poor crop yields. The resulting food insecurity impacts on the local economy as well as impoverishing the farmer.

The need for high-quality agricultural inputs in relatively poor farming countries and regions is therefore acute. Indeed, levels of mistrust in the efficacy of fertilizers is often justified in certain markets, as rampant adulteration has been substantiated by laboratory analysis and reduced harvests. One solution is removing the incentive for adulteration by making it possible to identify and reject counterfeit products with an easy-to-use DNA barcode reading system at the point of distribution. Deploying next-level DNA barcoding for source and purity assurance has multiple benefits: it protects the reputation of fertilizer brands, improves trust in high-quality fertilizer inputs, and helps boost crop yields by eliminating adulteration.

How DNA barcodes work

The SafeTraces *D-ART 3000* system combines up to 32 DNA sequences to produce a practically unlimited number of unique *safeTracers*[™] DNA barcodes. These are safe, tested, and fool-proof. Each *safeTracers*[™] solution is sprayed onto the product as it is packaged while production information is simultaneously recorded in a blockchain-secured database.

Each unique DNA barcode consists of short (<100 base pair) non-living, non-viable DNA sequences encapsulated in food-grade

materials such as gums, resins, proteins, and lipids such as carrageenan, albumin, and soy lecithin. All formulations are GRAS – ‘generally recognized as safe’ by the United States Food and Drug Administration – and have no impact on product quality, shelf life or taste. *safeTracers*[™] can be formulated for granular products, such as fertilizers and grains, as well as product coatings and liquid products.

Once *safeTracers*[™] are on the product, they are invisible and cannot be removed or adulterated, locking in a level of traceability that package labelling cannot provide. The DNA barcodes are detectable only with the matching DNA barcode reading system. This comprises a small portable reader, an easy-to-use test kit and authorised access to the database. The time taken from sampling the product to identifying and confirming a match for the DNA barcode takes no more than 15 minutes. For certain commodities, the system is also capable of detecting if dilution or adulteration has occurred by measuring changes in the DNA tracer concentration.

Stability and integrity

For ammonium nitrate, the stability of *safeTracers*[™] has been tested in the laboratory at room temperature under ‘worst case’ chemical conditions. Stability has also been tested with canola seeds stored at 60 degrees centigrade to approximate a greater than 16-fold acceleration. Results show that both DNA barcode formulations were stable for the equivalent of two years.

The integrity of the system – i.e. the probability that the complete system will correctly identify a DNA barcode as assigned and applied to a product lot – has also been rigorously tested. Field test results indicate that 99.4-99.9 percent of *safeTracers*[™] DNA barcodes will be accurately delivered. Indeed, accuracy can be improved to over 99.99 percent with a forensic-based test. SafeTraces has made its detailed stability and integrity testing methodology and results available⁵.

A breakthrough in DNA tagging technology

The capacity to produce billions of unique DNA barcodes – at a rate of up to 60 per minute on high volume filling lines – is a breakthrough. Especially when this is coupled with the capacity to manage each DNA barcode and its associated product



PHOTO: SAFETRACES

SafeTraces *D-ART 3000* DNA-based barcode dispenser.

origin information accurately, securely and indefinitely in a blockchain secured database. The resulting capability for nearly 100 percent verifiable traceability along the supply chain is unparalleled.

The technology is also incredibly easy to install. The *D-ART 3000* system integrates seamlessly into any production plant that can accommodate its 0.75 x 1.5 metre footprint, and where there is access to a dispensing nozzle in a bag or bottle filling system.

In conclusion, the SafeTraces *D-ART 3000* system is a practical traceability solution for any high-volume facility that require a large number of unique DNA barcodes. A simpler system for dispensing a single DNA tracer that marks one lot with the same DNA barcode is also available from SafeTraces, as are other applications, test instruments and test kits. The company also provides papers on ongoing research and applications. See www.safetraces.com for additional information. ■

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Plant revamp experts

We profile some of the leading players in the global ammonia and urea plant revamp business, including Casale, Johnson Matthey, KBR and Stamicarbon.

Inevitably, the relative production costs of nitrogen plants rise and become less competitive over time as they age and their technology becomes increasingly outmoded. Newly-constructed plants, in contrast, have an immediate cost advantage over their older rivals. They are typically larger in scale, incorporate the latest technology, and are often specifically located to benefit from lower feedstock costs.

Improving the cost position and profitability of existing plants therefore requires periodic revamps – modernisation projects that upgrade production by installing more reliable and cost-effective state-of-the-art equipment and technology.

The main drivers for nitrogen plant revamps include:

- Increases to output capacity
- Energy efficiency improvements
- Greater operational reliability
- Controlling and limiting emissions
- More product flexibility.

Periods of low and volatile product prices also add to the cost pressures on older plants and make improving production economics a priority for their operators.

While driving down operating costs and improving profitability – typically by increasing plant capacity and making energy savings – are often primary revamp objectives, external pressures on operators – such as environmental regulation, feedstock changes and market demand for more diverse products – can be equally important

factors. Other operational necessities such as greater reliability and higher safety standards can also make revamps imperative.

A selection of current global nitrogen revamp projects globally is presented in the table below.

Johnson Matthey *STREAMLINE*[™] retrofits

Johnson Matthey offers a range of options for enhancing the performance of existing ammonia plants, as part of its wider package of technology, catalysts and services to the ammonia industry. In particular, Johnson Matthey has extensive pre-reforming experience, offering the catalytic rich gas (CRG) range of catalysts. The company is the sole licensor of the CRG technology originally developed by British Gas in the UK in the 1980s.

It is important to consider the wider ammonia plant when looking to maximise operational efficiency. While the steam reforming stage alone offers plenty of opportunity for improving ammonia plant performance, two other major areas for improvement – the **pressure drop** over process equipment and **heat integration** – also deserve attention. Johnson Matthey has developed suitable technologies, and has the necessary plant design and revamp experience, to address both these issues.

The company has a comprehensive understanding of pressure drop at shift

converters in ammonia plants, having studied in-depth the contribution made by individual vessel components. These included the inlet nozzle, inlet distributor, hold down material, catalyst, support system, outlet collector and exit nozzle.

Johnson Matthey is also able to analyse flow patterns within existing vessels at operational plants using state-of-the-art computational fluid dynamics (CFD). Based on the results of CFD analysis, Johnson Matthey is able to offer bespoke designs to customers specifically tailored to their needs.

The *STREAMLINE*[™] retrofit service from Johnson Matthey comprises:

- A complete study to identify accurately all of the sources of vessel pressure drop in a converter
- A solution based on a proven specially shaped support material under the catalyst
- Installation and discharge assistance.

A *STREAMLINE*[™] retrofit increases throughput at a constant suction pressure. It achieves this by reducing the front-end pressure-drop of an ammonia plant and allowing a reduction in compressor power requirements. More than 30 *STREAMLINE*[™] installations are currently operating in large plants worldwide, these typically achieving single vessel pressure-drop savings of 0.4 bar.

STREAMLINE[™] reduces pressure drop in fixed-bed vessels, and is suitable for many different types of converter. For example, it significantly reduce the pressure drop in the annulus around the collector – a zone where radial flow and high velocities can result in high pressure drops – using a novel catalyst support material. The material is ideal for this purpose, having high voidage, high strength, large particle size and low silica content.

Contractor	Licensor	Company	Location	Product	mt/d	Start-up date
China Chengda	Stamicarbon	Inner Linggu CICL	Jiangsu, China	Urea	n.a.	2018
SKW Piesteritz	Stamicarbon	SKW Piesteritz	Lutherstadt, Germany	Urea	960	2018
n.a.	Casale	Zuari AgroChem	Goa, India	Ammonia	1,050	2020
n.a.	KBR	Haifa Chemicals	Mishor Rotem, Israel	Nitric acid	240+147	2019
OCI Nitrogen	Stamicarbon	OCI Nitrogen	Geleen, Netherlands	Urea	n.a.	2019
Casale	Casale	EuroChem	Nevinnomyssk, Russia	Urea	1,600	2019
n.a.	KBR	Acron	Dorogobuzh, Russia	Ammonia	2,100	2019
n.a.	Stamicarbon	Uralchem	Perm, Russia	Urea	+770	2019
Al Jubail Fert Co	Stamicarbon	Al Jubail Fert Co	Al Bayroni, Saudi Arabia	Urea	n.a.	2019
n.a.	Johnson Matthey	CF Industries	Billingham, UK	Ammonia	1,500	2020
PCS Nitrogen	Stamicarbon	PCS Nitrogen	Geismar, LA, USA	Urea	+250	2019

Source: Nitrogen+Syngas 358, p30

JOHNSON MATTHEY CASE STUDIES

Low temperature shift converter case study

One ammonia plant in the Asia Pacific region has saved over \$250,000 per annum (based on a gas price of \$3/million Btu) in energy costs by installing a system comprising *KATALCO™ 83-3* and *STREAMLINE™* in their low temperature shift (LTS) converter vessel.

Johnson Matthey completed a detailed study of the LTS vessel installation, including CFD modelling. This showed that minor modifications to the exit nozzle and the installation of the *STREAMLINE™* system would reduce the pressure-drop by 0.9 bar from 1.25 bar to just 0.35 bar. This pressure-drop reduction was confirmed by subsequent plant performance.

Pre-reformer case study

This European 1,000 t/d plant, based on a Kellogg design, was built in 1968. It had been continuously revamped over the years to improve both production rate and energy consumption. The objectives of the latest revamp involved the installation of a CRG pre-reformer to:

- **Increase production rate:** installing a pre-reformer reduces the load on the induced draft fan, thereby enabling an increase in plant capacity.
- **Decrease energy consumption:** installing a pre-reformer allows better energy integration within the primary reformer convection banks.

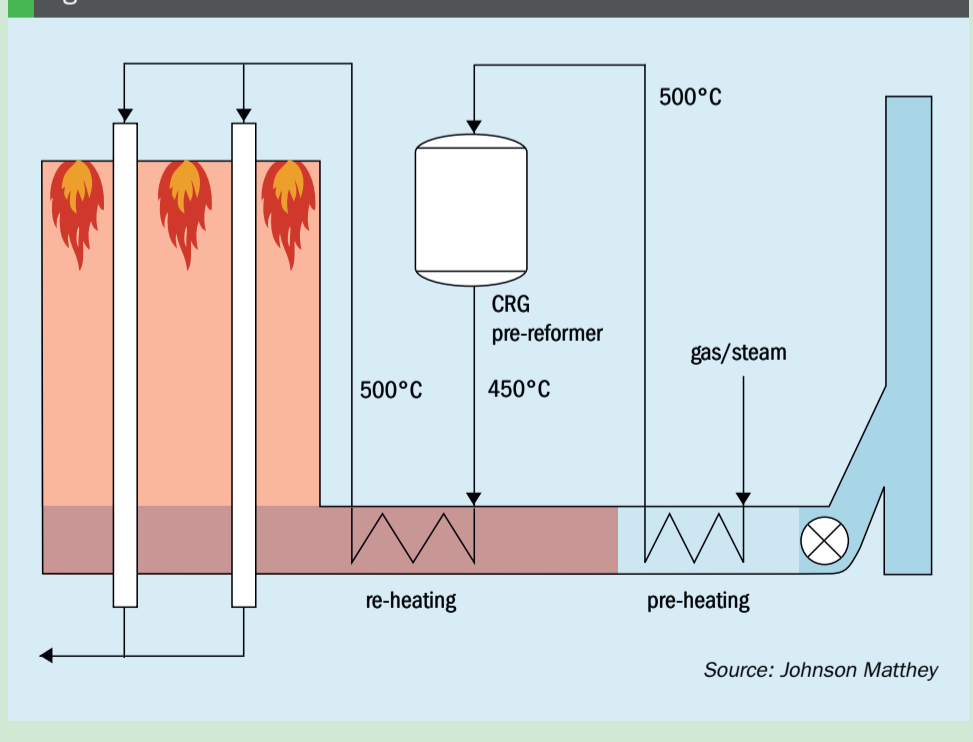
Minimisation of the front-end pressure was also important, and therefore a low pressure-drop, cloverleaf-shape *CRG-LHCR* catalyst was used.

As well as providing the pre-reformer technology licence and catalysts for the debottlenecking project, Johnson Matthey also offered other services including validation of the proposed design.

Commissioning of the new pre-reformer equipment went smoothly, with minimal changes to normal plant start-up, and project targets for capacity increase and energy reduction were both reached. Debottlenecking achieved a production increase of 10 percent on a daily basis soon after plant restart and stabilisation. Further tuning resulted in a rate increase of 15 percent after one month, with an associated five percent reduction in energy consumption.

A pre-reformer retrofit is shown schematically in Figure 1.

Fig. 1: Pre-reformer retrofit



KBR ammonia revamp technologies

KBR, a market leader in ammonia technology, has licensed, designed, engineered and/or built more than 235 grass roots ammonia plants worldwide. The Houston-based company has also revamped over 100 ammonia projects globally and has a dedicated ammonia revamp technology team.

The revamp solutions offered by KBR help plant operators reduce their natural gas consumption, energy requirements and emissions per tonne of manufactured product. Indeed, KBR says its upgrades and revamps can increase ammonia plant capacity by 25-50 percent by reducing the high feedstock and fuel consumption of older plants.

Examples of commercially-proven KBR upgrade technologies for ammonia plants are described below.

The **KBR Reforming Exchanger System (KRES™)** is used to revamp the reforming section of ammonia plants. It boosts front-end capacity for raw synthesis gas by working in parallel with conventional primary and secondary reformers. *KRES™* captures the high-temperature process heat that exits the secondary reformer and produces syngas from this by reforming an additional flow of natural gas and steam. *KRES™* revamps are typically able to increase ammonia plant capacity by a quarter and deliver an energy saving of 0.13-0.60 Gcal/tonne, according to KBR figures.

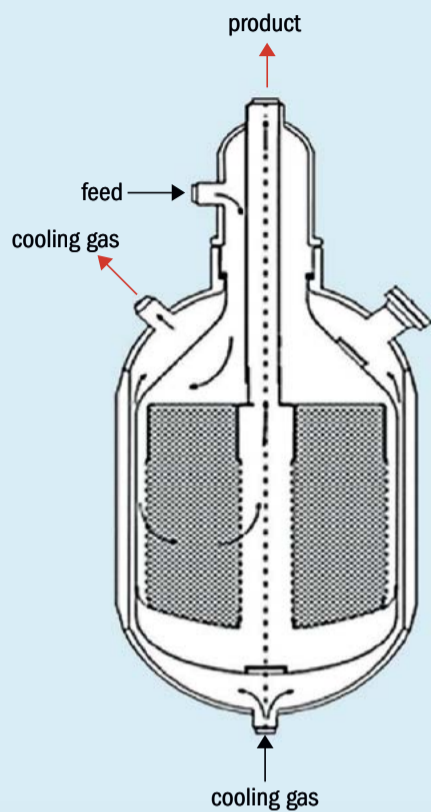
The technology is tried and tested having been in operation at ammonia plants in Methanex, Canada, since 1994 and in Liaohe, China, since 2003. Examples of successful plant capacity increases achieved using *KRES™* retrofits include:

- An increase from 1,680 t/d to 2,140 t/d at PCS Nitrogen, Lima Ohio in 2015
- An increase from 1,600 t/d to 2,000 t/d at CFCL-1, Rajasthan, India in 2009.

KBR's proprietary **floating-head water tube boiler** achieves a high-level of heat recovery downstream of the secondary reformer. This natural-circulation, floating-head type of waste heat boiler has a well proven, mechanically robust design that provides superior, reliable performance. The new design also replaces all three heat exchangers in the legacy design with one floating head exchanger.

Floating-head water tube boilers are in successful operation at over 40 ammonia plants. Recent retrofit experience includes two US plants:

Fig. 2: KBR cold wall add-on converter



Source: KBR

- One plant is designed for a capacity increase from 1,450 t/d to 1,675 t/d and is expected to enter operation this year
- The other is designed for a capacity increase from 1,300 t/d to 1,727 t/d and is due to become operational in 2020.

- Capacity increases from 1,600 t/d to 2,000 t/d at CFCL-1, Rajasthan, India, in 2017
- Capacity increases from 1,600 t/d to 2,000 t/d at CFCL-2, Rajasthan, India, in 2018.

For those shift reactors with an axial flow design, pressure drop eventually becomes a critical issue at legacy plants during their operational life. The pressure drop issue can be addressed by replacing the reactor internals with a radial flow design. KBR's recent retrofit experience with **radial flow shift reactors** includes an ammonia plant in the US. This is designed for a capacity increase from 1,300 t/d to 1,727 t/d and is expected to become operational in 2020.

One of the keys to debottlenecking the synthesis loop is to increase the converter exit ammonia concentration. KBR has achieved capacity increases using a **true cold wall one-bed radial flow add-on converter** (Figure 2) to increase ammonia concentration. This avoids all the known reliability issues with the hot wall design. This add-on converter was installed in the following recent retrofits:

KBR has been offering **unitised synthesis loop chillers** as standard for new projects since the late 1980s. The chiller is a specially designed, multi-stream heat exchanger that cools the effluent from the ammonia synthesis converter with recycle gas and ammonia refrigerant. Its design saves pressure drop in the synthesis loop and reduces capital cost by combining several heat exchangers, drums, and expensive high-pressure piping and fittings into a single item of equipment.

Unitised chillers are currently in operation at over 40 ammonia plants. The most recent unitised chiller was installed as a part of revamp project for a confidential client in the US. The capacity of the newly revamped plant is expected to increase from 1,300 t/d to 1,725 t/d when it enters operation in 2020.



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Casale's approach to ammonia revamping

Casale is the world leader in ammonia plant revamping, with a reference list comprising 33 complete plant revamps and more than 240 partial revamps.

Casale's approach to ammonia plant revamping depends on the ultimate objective. Usually, in a standard revamp – where the aim is to simply achieve moderate capacity increases (up to 130%) or energy savings – the focus is on finding bottlenecks in individual plant sections, and then installing more advanced equipment to improve efficiency. Casale's recent revamp of the Toyo Engineering (TEC) designed ammonia plant at Nevinnomyssk in Russia is a typical example of this type of project.

In contrast, more ambitious revamp targets, such as a large capacity increase (up to 200%), can require drastic changes to the process line. Casale delivers this through its proprietary *Super Revamping™* scheme. This can typically double the plant's original nameplate capacity and involves the installation of an oxygen-blown autothermal reformer (ATR). Although this revamping concept has yet to be applied as a whole, all of its individual building blocks have been demonstrated and installed at ammonia plants.

Casale: standard revamp scheme

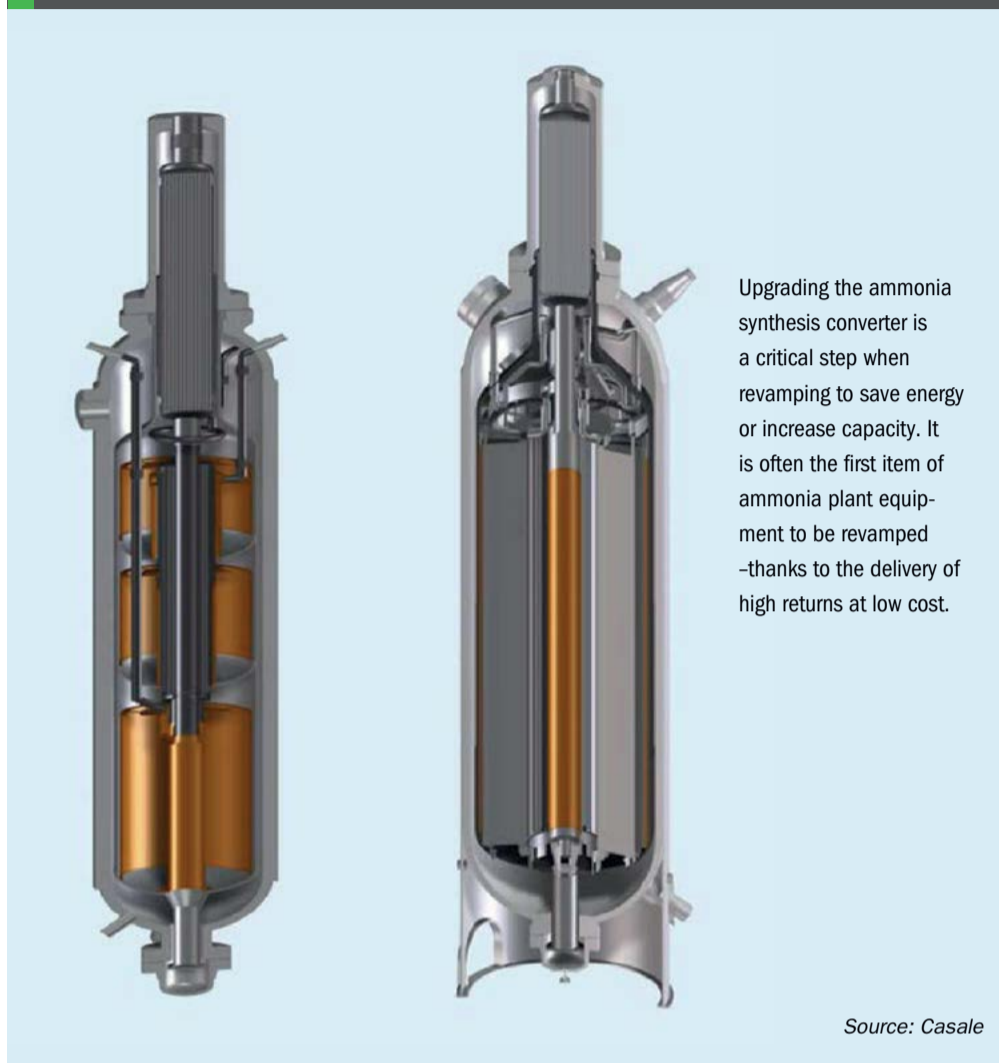
Casale uses a 'standard' revamp scheme at ammonia plants when the objective is to achieve a moderate capacity increase. This scheme makes maximum use of existing equipment, while leaving the main process line unchanged¹. Plants bottlenecks can be eliminated by installing one or more of the following:

- Air compressor boosters
- Pre-reformer
- Primary waste heat boiler
- Shift converters with axial-radial catalyst bed
- Additional converters in the synthesis loop.

The installation of a booster for compressor suction can increase **air compressor** throughput by up to 30 percent. This was adopted by Casale in a revamp of Kellogg plant in Saudi Arabia and achieved a 15 percent capacity increase.

Using a **pre-reformer** increases capacity by allowing about 10-15 percent of the reforming reaction to be carried out outside the primary reformer. Casale uses

Fig. 3: Casale ammonia converter revamp: adiabatic and isothermal (IAC) design



axial-radial catalyst bed technology in its pre-reformer reactors.

A pre-reformer of this kind has been installed in a Kellogg ammonia plant in Australia. This increased the plant's capacity from its original nameplate of 545 t/d to 1,100 t/d (although it had previously been running at 850 t/d). Casale currently has five axial-radial pre-reforming converters operating on-stream.

The **shift converter** design developed by Casale is based on an axial-radial catalyst bed. This configuration has an inherently low pressure-drop. It also remains more stable over time, making it possible to use a smaller-sized, more active catalyst which is resistant to poisoning. At the moment Casale has 27 revamped shift converters on-stream. These include a successful installation in a Kellogg ammonia plant located in China.

The most effective way to debottleneck the synthesis loop is to boost the conversion rate. This is typically achieved by revamping the synthesis converter internals using Casale's axial-radial technology. **Additional converters** can then be

installed in the synthesis loop without affecting the pressure drop.

Casale has nine references for additional converters. One of these was installed in a Trinidad & Tobago ammonia plant as part of a revamp to increase capacity and save energy. The 10 percent increase in capacity was achieved while decreasing the synthesis loop operating pressure. Outlet ammonia concentration from the converter was also increased to 20 percent.

Casale: energy saving revamps

The **primary reformer**, being the most expensive and most energy-intensive item in an ammonia plant, has a strong impact on overall plant performance. Casale has been revamping primary reformers for many years and has modified 14 units to date.

Casale has also revamped 21 **CO₂ removal sections** world-wide. These include sections for hot potassium carbonate systems in collaboration with Giammarco-Vetrocoke, and amine-based

systems in co-operation with BASF. Replacing a hot potassium carbonate system with an amine-based system can be an attractive revamp option. This potentially delivers greater energy savings – as high as 0.4-0.5 Gcal/t of ammonia – but does require more extensive modifications and investment. This energy saving modification has been successfully carried out at four ammonia plants belonging to the Indian Farmers Fertilizers Cooperative (IFFCO).

The **ammonia washing unit** (AWU) is a synthesis loop device installed to remove water from the make-up gas. This simple modification typically achieves an energy saving of up to 50,000 kcal/t of ammonia with a payback of 3-5 years, depending on energy costs. Casale currently has 14 AWU references.

Upgrading the **ammonia synthesis converter** is a critical step when revamping, whether to save energy or increase capacity. Indeed, it is often the first item of ammonia plant equipment to be revamped – thanks to the delivery of very high returns at relatively low cost.

Casale has been responsible for a number of fundamental innovations in converter revamping and design. Its isothermal ammonia converter (IAC) offers a higher conversion rate than other commonly-used designs (Figure 3). Four IAC converters are already on-stream. The most recent installation in a North American plant in 2013 achieved an energy saving of around 0.3 Gcal/t of ammonia.

Casale: urea plant revamps

Casale is now the world leader in urea plant revamping, having carried out more than 150 plant revamps in recent decades. These have ranged from replacement of single items of equipment to comprehensive revamps to achieve massive increases in capacity.

Clients benefit from Casale's wide experience of revamping urea plants of any technology – including CO₂ stripping, ammonia stripping and total recycle plants. Casale offers a tailored set of revamping schemes for all three of these major urea technologies.

Several urea plants have been revamped to date using Casale's *Split Flow Loop*[™] CO₂ stripping process. This option for **CO₂ stripping plants** is also offered in combination with *Full Condenser*[™], Casale's proprietary high pressure carbamate condenser design. Combining *Split Flow Loop*[™] with *Full Condenser*[™] offers a very powerful way of debottlenecking CO₂ stripping plants with only minor modifications. The combined technologies can increase the capacity of the high pressure loop at urea plants by as much as 30-50 percent.

Casale also offers the installation of an additional medium-pressure (MP) pre-decomposer as a revamp option for **ammonia self-stripping plants** to enhance capacity and efficiency. Casale has successfully designed and installed several MP pre-decomposers as part of major ammonia stripping plant revamping projects.

For **total recycle plants**, Casale offers the *High Efficiency Combined (HEC) Process* as a revamp option. This can increase capacity by 50-60 percent above the original nameplate value. Casale also has the capability to convert total recycle plants to the ammonia stripping process. This is recommended for revamps where the objective is to achieve massive capacity increases (up to 100% of the nameplate capacity) and/or energy reductions.

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Stamicarbon's revamp approach

A number of economic, technical or legal issues can affect the status and viability of urea plants, even when they are designed to perform optimally throughout their life.

A plant may no longer be economically viable due to outdated technology, for example, or because changes to the market require a more diverse range of products, such as UAN or deNOx-fluids. Technically, corrosion can make the replacement of some high pressure (HP) equipment a necessity too.

In response to new, more stringent legislation, producers are also needing to find ways to reduce their environment impacts and manufacture urea in a more sustainable way. However, environmentally-friendly plant improvements are becoming a growing challenge – as they typically provide a low or even negative return on investment for plant owners.

Increasingly, therefore, urea plant revamps need to turn an apparent disadvantage – the need for environmental investments – into a net benefit, by offering substantial energy cost reductions in

Table 1: Stamicarbon capacity increase revamp options

Type of EVOLVE CAPACITY™ design	capacity increase (%)
More-in-more out	10-30
Double stripper	30-40
MP add-on / Mega	30-50
Pool Reactor / Pool condenser	50-100

Source: Stamicarbon

combination with production increases, with the option for product diversification.

While revamps will always need to focus on keeping urea production competitive, there is now a need to do this in a more sustainable way. This sums up the current approach taken by Stamicarbon, the innovation and license company of Maire Tecnimont Group.

The company has successfully completed more than 100 revamp projects, improving plant performance, increasing capacities, reducing energy consumptions and emissions, while minimizing investment in additional resources and infrastructure².

Thorough plant assessment

In a potential urea plant revamp, it is generally more cost-effective to have a thorough plant assessment, rather than doing multiple quick fixes to solve each issue in isolation, according to Stamicarbon, based on more than 70 years of experience.

A revamp project usually starts with an inspection report or an on-site plant assessment and debottlenecking study. These determine the current performance levels of the plant and identify opportunities for increasing capacity and/or for reducing emissions and energy consumption. Calculating the return-on-investment (ROI) of the revamp is essential at this stage. This ensures the revamp is properly validated, and that the proposed technology and retrofit will actually pay off.

Emissions control

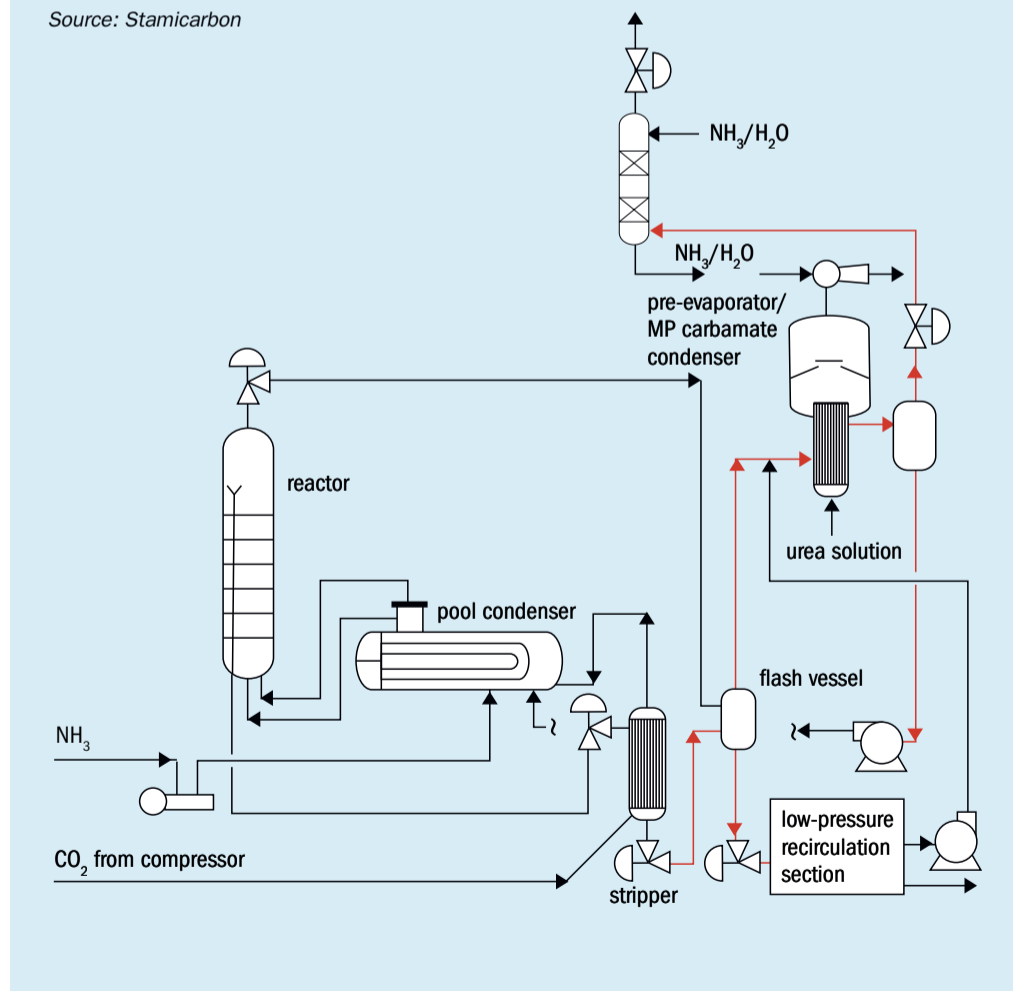
Stamicarbon and EnviroCare International have co-developed the *MicroMist™ Venturi (MMV) Scrubber*, a multi-stage gas scrubber for granulators and the *Jet Venturi Scrubber* for prill towers (*Fertilizer International* 485, p25). Both scrubbers can be installed as part of retrofits. The MMV granulation scrubber can easily achieve a dust removal efficiency in excess of 99.9 percent. Even lower emissions can be obtained, if necessary, by adding on a wet electrostatic precipitator (WESP). The *Jet Venturi Scrubber* can be installed on the roof of prill towers and has been shown to reduce ammonia and dust emission levels to below 10 mg/Nm³.

EVOLVE CAPACITY™ revamp options

Stamicarbon's *EVOLVE CAPACITY™* concept offers several technologies capable of increasing the nameplate capacity of urea plants by between 10 percent and 100 percent (Table 1). The actual capacity increases achievable may exceed this, depending on the original design margins of the HP equipment.

Fig. 4: Stamicarbon's flash design

Source: Stamicarbon



EVOLVE ENERGY™ revamps

Urea synthesis is the heart of the urea plant. Naturally, this section is therefore the main focus when it comes to optimising the plant's energy balance. This is simply because urea synthesis is directly responsible for the consumption of high pressure (HP) steam (25 bara) and the production of low pressure (LP) steam (4 bara).

Stamicarbon's *EVOLVE ENERGY™* urea plant revamp concept involves the installation of a replacement high pressure (HP) stripper made from the latest generation of *Safurex®* materials – namely *Safurex® Star** and *Safurex® Degree°*. The new HP stripper is used in combination with Stamicarbon's *Flash Design* technology to save steam and energy (Figure 4).

Investing in the replacement of HP equipment at the end of its technical or economic lifetime, to achieve a lucrative performance improvement, is a key part of Stamicarbon's *EVOLVE ENERGY™* concept. The use of *Safurex® Star** in the new HP stripper offers:

- An increase not a loss of capacity
- A higher level of safety
- Lower weight
- Higher synthesis load.

Additional tubes in the new *Safurex®* HP stripper configuration increase net capacity by around 12 percent. This capacity increase is vital as it provides a substantial part of the desired return on investment in the business case.

As well as replacing the HP stripper, *EVOLVE ENERGY™* revamps use Stamicarbon's *Flash Design* technology to save steam and energy. The technology

combines an adiabatic flash step with heat recovery (Figure 4).

Flash Design helps balance and optimise the plant's overall energy usage. It reduces HP steam demand by around 100-150 kg of HP steam per tonne of urea. This corresponds to a \$3 million per year saving for a world-scale urea plant.

The other benefits of Stamicarbon's *Flash Design* include:

- **The production of other urea grades:** the urea solution is more concentrated and contains less ammonia, making it suitable for high-value *AdBlue®*/diesel exhaust fluid (DEF) production.
 - **Its modest investment cost:** *Flash Design* modifications typically consist of just three items of equipment (a flash vessel and low pressure pre-evaporator with corresponding condenser). These new items can usually be installed outside the existing plant structure too.
 - **Better safety:** the safety level of HP synthesis improves in cases where the reactor off gases are sent directly to the flash section.
 - **Increased capacity:** *Flash Design* can also be applied with other revamp concepts, such as Stamicarbon's *EVOLVE CAPACITY™* MP add-on which increases capacity while lowering energy consumption.
- Stamicarbon's *Flash Design* technology has been in operation since 2015. This includes a 2,860 t/d capacity plant in China and a 2,200 t/d capacity plant in

the US. Various other plants are also in operation and under construction currently.

EVOLVE ENERGY™ revamp conclusions

EVOLVE ENERGY™ revamps to replace the HP stripper have been shown to optimise urea plant performance by substantially reducing environmental footprint, while at the same time increasing production capacity.

The modifications can be installed during a regular plant turnaround, achieving a 12 percent increase in capacity and a 10-15 percent energy saving. This revamp option has an attractive payback period too, typically less than five years. Importantly, *EVOLVE ENERGY™* revamps have shown that reducing the environmental footprint of urea plants can be a profitable and safe investment – if based on a thorough plant assessment and using the right technology. ■

Producers need to find ways to reduce their environment impacts and manufacture urea in a more sustainable way.

Author's note

This article is partly based on a 2018 feature on 'Cost Effective ammonia plant revamping' in *Nitrogen+Syngas* magazine (*Nitrogen+Syngas* 352, p38).

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Sackett-Waconia tower blending system for FCI, North Carolina.

PHOTO: SACKETT-WACONIA

Handling, bagging and blending

An update on the latest in fertilizer handling, bagging and blending, including new contracts, company news and advances in technology.

New portal reclaimer for SOCAR

AMECO has over 80 years of experience in the bulk handling business. Notably, the company designed and manufactured the world's first portal reclaimer for Morocco's phosphate mines in 1965. The Alsace-based French firm also went on to start-up the first portal reclaimer in the United States in 1969.

AMECO currently supplies stackers, reclaimers, blending systems and shiploaders for fertilizer, pulp, biomass and coal power plants and port terminals. The company recently commissioned a portal reclaimer for the State Oil Company of Azerbaijan Republic (SOCAR). This was installed at SOCAR's new urea plant in Sumqayit, near Baku in 2018. It is able to handle 210 t/h of urea and has a total storage capacity in excess of 60,000 tonnes. AMECO designed, manufactured and supervised the installation of this 43-metre rail span portal reclaimer. Erection and commissioning was carried out jointly with Samsung Engineer-

ing and Construction Ltd, the project's EPC contractor.

AMECO also completed a revamp of a 1,000 t/h shiploader in Bahrain for Gulf Petrochemical Industries Co (GPIC) in 2018. Spare parts were provided and the shiploader's instruments, cables, automation system and operator's cabin were all upgraded. This refurbishment, and the access to spares, ensures GPIC will be able efficiently load bulk urea granules for onward shipment in future.

AMECO's other recent major fertilizer references, all for urea handling, include:

- **Agrium**, Borger, Texas: 480 t/h portal reclaimer
- **Toyo**, Palembang, Indonesia: 138/t/h conical rotary scraper
- **Petrobras**, Tres Lagoas, Brazil: 636 t/h portal reclaimer
- **Matix**, Panagarh, West Bengal, India: 160 t/h conical rotary scraper
- **Engro**, Daharki, Pakistan: 120 t/h elevator travelling scraper and 160t/h conical rotary scraper
- **Sorfert**, Arzew, Algeria: 500 t/h portal reclaimer

Bedeschi partners with Borealis and Yara

Bedeschi is a well-established supplier of crushing and handling machines for cement, steel, coal, mining and other industrial processes. The Italian industrial manufacturer moved into the marine sector 15 years

ago and now offers a range of large-scale onshore shiploading equipment.

An innovative feature of Bedeschi's shiploading technology is the sealed conveyor and telescopic chute system developed by the firm. The system is highly-effective at dust prevention during the port-side unloading, handling and bagging of fertilizers.

Bedeschi recently carried out a highly ambitious bulk handling equipment project for Borealis Group, one of Europe's leading fertilizers producers (*Fertilizer International* 488, p40). Borealis supplies and distributes more than five million tonnes of fertilizers and technical nitrogen products annually.

Bedeschi secured a contract from Borealis to install a new shiploading system in the port of Rouen in northern France. The contract also included the installation of the conveyors needed to transport products from a Borealis-owned manufacturing plant to the port. The project presented Bedeschi with some notable challenges:

- The product being handled – calcium ammonium nitrate (CAN) – is extremely aggressive in terms of corrosion
- A special rubber tyre mounted shiploader machine was necessary, because of the limited space available on the dock
- Project management, particularly health and safety, was also a major concern, as the shiploader would need to be installed while the production plant remained in operation

- Finally, the time available for delivery, installation and commissioning of the equipment was extremely short.

Bedeschi's wide experience of handling corrosive materials, gained over more than 100 years, allowed the project team to develop a bespoke totally stainless steel shiploader system for Borealis. The use of stainless steel extended to all of the conveyor components too. This ensured that all of the project equipment provided was highly durable.

Good project management, including 'lean' management methods, enabled Bedeschi to supply and install the 400 t/h capacity shiploader, and all of the associated plant, in about 10 months.

Bedeschi also has a strong, longstanding partnership with Yara International. Yara has awarded the company a total of four shiploader contracts over the past 15 years.

Their relationship dates back to the supply of a shiploader at the port of Ravenna in Italy in 2004. Bedeschi also engineered, erected and commissioned a new shiploader at Brunsbuttel, Germany, in 2012, as part of a turnkey project with Yara Germany to replace its existing shiploader at the port.

Bedeschi also commissioned a new urea shiploader for Yara France at the port of Le Havre in 2017. The new replacement machine at the terminal will load vessels of up to 20,000 dwt capacity at a maximum loading rate of 250 t/h. The shiploader is a 'luffing and travelling' type equipped with a traditional belt conveyor boom. The terminal is the main export route for Yara's nearby Le Havre urea plant.

In January 2017, Bedeschi was awarded the contract to supply a shiploader at Yara's Sluiskil plant in the Netherlands. Sluiskil is a major fertilizer production complex and the largest manufacturing site for ammonia and nitrate fertilizers in Europe.

The complex comprises of three ammonia plants, two nitric acid plants, two nitrate granulation plants and two urea plants, one for prilling and the other for granulation. The complex is located close to Antwerp with direct access to the North Sea. A new slewing shiploader with a 600 t/h design capacity was installed at Sluiskil to efficiently load barges and shipping vessels under heavy duty conditions.

Bedeschi announced in May that it had been selected by ADM Fertilizers as the supplier for a new US project.

Sackett-Waconia - Precision Fertilizer Blending®

Sackett-Waconia has been offering engineering, equipment, and systems to the global fertilizer industry for more than 120 years. The company specialises in designing and supplying complete systems for:

- Terminals
- Fertilizer blending, granulation and compaction
- Super phosphate production
- Coatings, both powders and liquids
- Water-soluble fertilizer blending.

Along with its African and Brazilian partners, Bagtech International and Sackett do Brasil, Sackett-Waconia provides safe, reliable and efficient equipment with advanced automation to customers worldwide. The company's overall goal is to promote balanced nutrient use and increase nutrient use efficiency, while maintaining production speed and never compromising on safety.

Sackett-Waconia's current focus is on advanced and automated *Precision Fertilizer Blending®* (PFB) systems. The accurate and precise blends produced by the company's PFB systems (NPKs plus micronutrients) provide a balanced mix of nutrients and are able to meet soil-specific nutrient requirements.

Sackett-Waconia offers many system designs and blending options to suit the varied requirements and locations of its customers. These range from tower blending systems, with in-floor reclaim systems and overhead storage, to its *Precision Horizontal Blending* (PHB) system. The latter combines Sackett-Waconia's *Loss-in-Weight* (declining weight) dosing technology with the high-quality blending capabilities of its *Precision Batch Blenders*.

The company's *Precision Fertilizer Blending®* systems can be found through-

out Africa, the Americas, and Oceania. The installation of a PFB system for Fertilizantes Agricolas Hondureños in Honduras is a notable recent example. This project required a low-profile tower system to minimise the overall footprint – while maintaining the premium blend quality that only *Precision Fertilizer Blending®* can provide. The solution was to implement a tower system in which the discharge from a *Precision Batch Blender* is conveyed to a 100 t/h bagging system. This enabled the height of the tower to be dropped, while retaining the benefits of overhead hoppers, reduced moving parts and minimum load cells.

Other *Precision Fertilizer Blending®* systems feature the Sackett-Waconia orbital blender. Mayafert in Guatemala, for example, required a 75 t/h horizontal blending and bagging system (pictured). Sackett-Waconia designed, built, and supplied the company with a suitable *Precision Horizontal Blending* system to match Mayafert's requirements. By combining a *Loss-in-Weight* dosing system with the blend quality and precision of the orbital blender, this PHB system stores materials in floor-based hoppers and then elevates the blended product for bagging. This demonstrates that PHB systems are an excellent option for installations where height is a concern.

Sackett-Waconia also recently installed a tower system for agricultural services company FCI at North Carolina in the US. This has ability to load-out material in bulk to trucks, tenders, and spreaders, while also being able to discharge to 50 lb (22 kg) bags and 1 ton 'supersacks'. The system is designed for high speed, high efficiency, advanced automation and robotic palletizing. It provides precise, accurate fertilizer blends with added micronutrients, and also has the flexibility to produce enhanced efficiency nutrient formulations.



Sackett-Waconia Precision Horizontal Blending system for Mayafert, Guatemala.

PHOTO: SACKETT-WACONIA

PHOTO: EMT



EMT Weighcont blender and bagging machine at a fertilizer blending factory in Ghana.

EMT - automated continuous blending machines

Blending and bagging equipment manufacturer EMT has been a major supplier to the fertilizer industry for more than 30 years. Machines produced at the company's 't Zand factory in the Netherlands have been exported to more than 60 countries worldwide. The company, which has executed more than 500 projects globally, also enjoys an alliance with the US blending equipment manufacturer Doyle.

EMT developed the well-known and market-leading *Weighcont* blending system. This is a computer-controlled and fully-automated weight-based continuous blending line. It can be supplied with an unlimited number of hoppers and has a 3-240 t/h capacity range.

The company also offers more than 20 different bagging systems to the industry, including big bag fill and small bag systems. As well as being installed in fixed positions in a factory or warehouse, EMT's bagging machines can also be constructed within a container. This allows the machines to be mobile and moved to different locations such as product storage areas or port-side locations next to ships.

EMT also produces conveying equipment including chain conveyors, belt conveyors and elevators. It also offers fertilizer screening, lump crushers, conditioners and coating machines as part of its equipment packages. All of the company's machines are constructed in stainless steel and are easy to transport in containers. Its blender lines are either based on batch blending or a continuous process like that used by *Weighcont* machines.

Blending and bagging projects are all engineered and constructed by an in-house technical team at EMT. The company installs machines on a turnkey basis and supplies customers with all the necessary electrical and computer control components. Notable recent projects are described below.

Ghana: EMT installed a *Weighcont* blender and bagging machine at a fertilizer blending factory in Ghana (pictured). This 120 t/h capacity factory blends NPKs and micronutrients. The *Weighcont* blender line supplied (140 t/h capacity) was a double-unit small bag fill system. This enables 60 t/h of feed to be simultaneously but separately discharged to both trucks and storage (120 t/h total). The new system can also add coatings and liquids to the blend.

Vietnam: EMT manufactured a *Bag Input Continuous Blending* system for a customer in Vietnam. Material is transported to four bagging lines which have a total output of 120 t/h. The unit can be filled with big bags, while the blending equipment is running continuously, to maintain a throughput of 120 t/h. Another input line allows the intake of bulk material from trucks to be discharged into the same bagging lines. The system can both blend and add liquids.

Algeria: EMT installed two blending and bagging lines, including a complete box fill system, for the fertilizer industry in Algeria. Fertilizer is distributed from a pit through an elevator and conveyor system (150 t/h capacity) to the right bulk bay in the factory. An additional continuous bulk blending *Weighcont* system (120 t/h capacity) is used to blend the fertilizer before it is bagged in small bags.

In recent years, EMT has developed new equipment that adds liquids to blends or coats fertilizers with liquids. The range of different coating units developed by EMT benefit from the ingenious software the company uses for its machines, and from EMT's extensive knowledge and experience of fertilizer blending. With growing demand for equipment that adds micronutrients or slow release agents to fertilizers, EMT is capable of providing its customers with tailor-made solutions matching their requirements.

Bag & Bulk Handling (BBH)

South Africa's **Bag & Bulk Handling (BBH)** was established in 1999. The company specialises in the design and fabrication of high-speed blending and bagging plants, particularly for the fertilizer industry and related sectors. The company offers customised batch or continuous blending systems. These can accept micronutrients and liquid coatings as standard.

BBH's standard single-line bagging unit has a capacity of up to 60 t/h. The company says its bagging plants combine high-speed bagging with repeatability and accuracy, typically being capable of filling 1,200 fifty kilo bags per hour (60 t/h) at a tolerance of 15 g. Its duplex (double-line) unit delivers in excess of 2,400 bags per hour, and is capable of filling 10 kg, 50 kg, 500 kg and 1,000 kg bags simultaneously. BBH's bagging plants are generally compatible with high-speed automatic bag placing and robotic palletizing systems, according to the company.

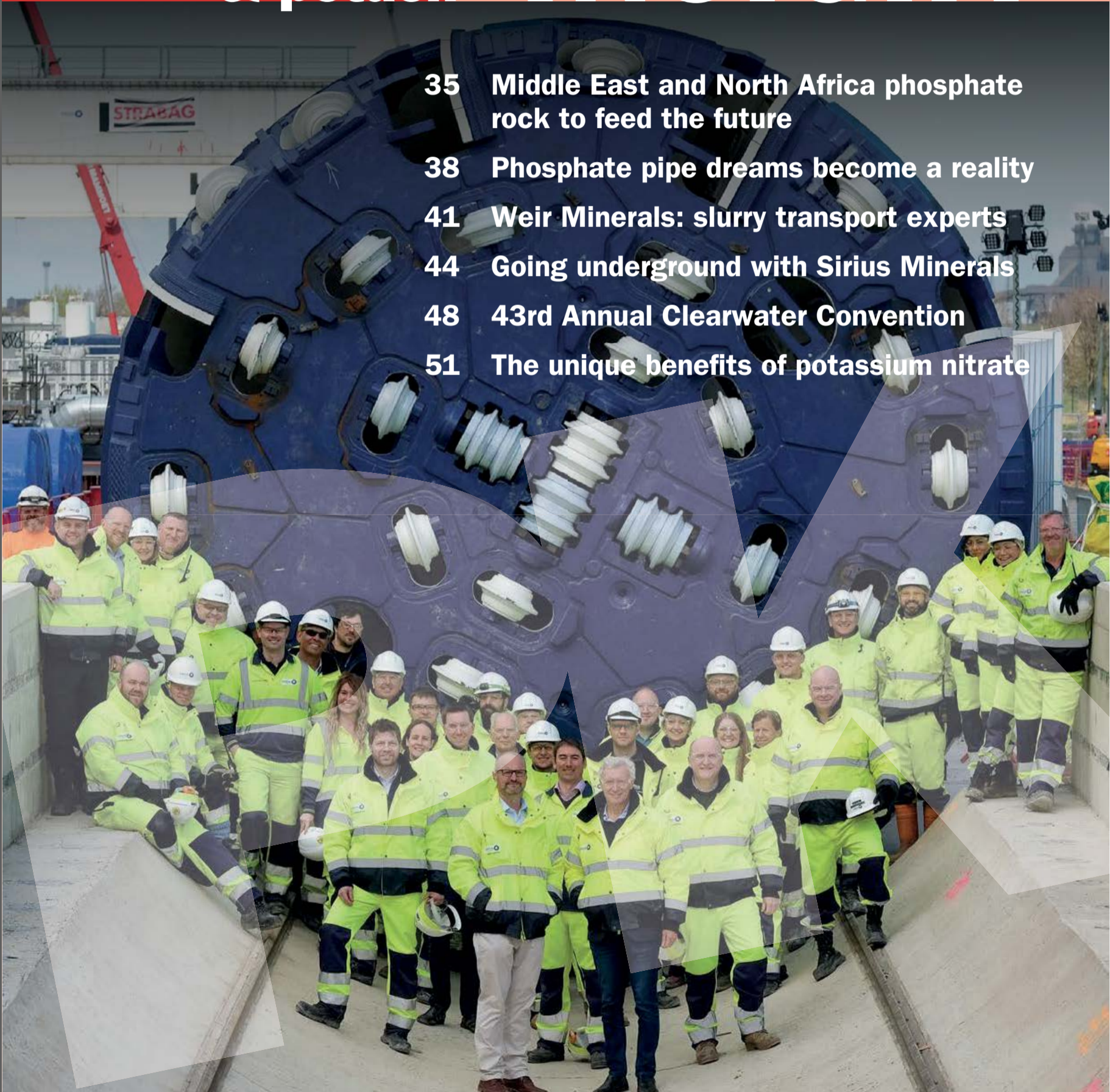
Notable customers include Yara International and Kynoch Fertilizers, a leading importer, blender and retailer of granular, liquid and speciality fertilizers in Southern Africa. BBH recently added Malawi Fertilizer Company (MFC) to its client list.

To date, BBH has converted two of MFC's duplex lines to a high-speed single weigher/controller system, and is currently upgrading other lines for the company. This has enabled MFC to cut down on shift work by ending the need to weigh each and every bag. BBH has also submitted a proposal to MFC to equip a new plant with fully automated bagging lines. The proposal includes automatic bag placing, high-speed bagging, robotic palletizing and a rail off-loading pit. The new plant has a total bagging capacity of 200-250 t/h and needs to accommodate both big bag (FIBC) and standard 50 kilo bag (OMB) types. ■

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phosphates & potash

INSIGHT



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Middle East and North Africa phosphate rock to feed the future



Haul truck in Khouribga, Morocco.

PHOTO: CRU

CRU are forecasting increases to both phosphate rock supply and demand over the medium-term. Rock superpowers the United States and China will decline in relative importance, while the Middle East & North Africa (MENA) region will continue to rise. Although some regulatory challenges lie ahead, MENA's advantageous cost position will see the region become increasingly important in feeding a growing population in the future. CRU's **Alexander Derricott** and **Glen Kurokawa** summarise the latest trends and developments in the phosphate rock market.

Phosphate rock is a critical resource and – as a key nutrient source – will continue to play a vital role in feeding the world in the future. It is also the most important cost component in phosphate fertilizer production. Monitoring the rock market is therefore essential.

CRU provides market-leading analysis on the phosphate rock market. Historically, we have seen rock supply and demand grow steadily – a trend we forecast will continue through to 2023. We judge that growing downstream production and demand, especially for NPK fertilizers, will provide the phosphate rock market with substantial support.

This overall global growth trend masks a diverging outlook for those regions which are most important to the rock industry. In

the United States and China, for example, rock production and demand are expected to continue falling as costs rise. This is due to environmental issues, declining rock reserves, and downstream production becoming less competitive. Production and growth in demand for phosphate rock, in contrast, is forecast to be the highest in the MENA region, as it ramps-up rock production to supply integrated downstream facilities at Jorf Lasfar, Morocco, and Wa'ad Al-Shamal, Saudi Arabia. India, which has limited phosphate reserves, remains reliant on imports. Its demand is expected to grow, matching greater industrialisation and continued Indian government support for the domestic fertilizer industry.

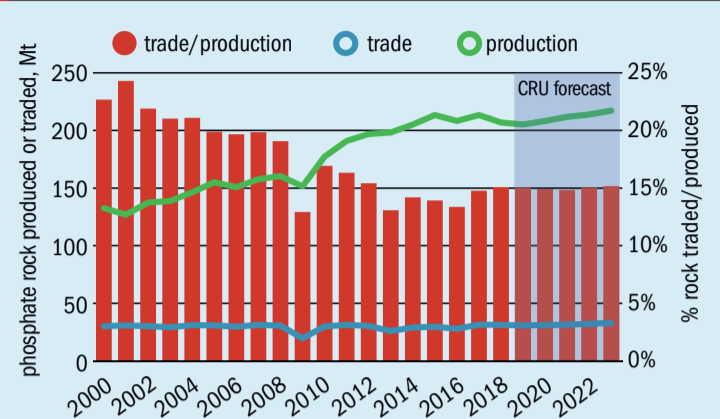
Despite high import demand from India, traded volumes for phosphate rock

have been relatively flat throughout the last twenty years (Figure 1). At the same time, global rock supply and demand have risen, resulting in a decrease in the percentage of rock being traded. This trend is explained by greater vertical integration within the industry, with lower cost rock producers such as Morocco choosing to invest heavily in downstream capacity. We forecast trade to increase only marginally to 2023 and for the percentage of traded rock to remain at around 15 percent.

Superpowers retreat

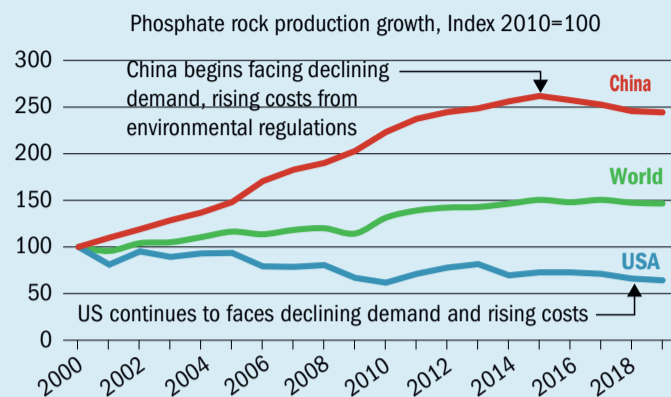
Both China and the United States have historically been major actors in the rock market. Until recently, the United States was the largest exporter of phosphate fertilizer

Fig. 1: Production has generally outpaced trade since 2010



Source: CRU Phosphate Rock Market Outlook

Fig. 2: US and China rock production decreasing



Source: CRU Phosphate Rock Market Outlook

globally, and remains the third-largest rock producer. China has emerged as the world's largest rock producer, its production having more than doubled since 2000. However, rock output in both China and the United States is now in decline (Figure 2), with the two countries facing broadly similar issues: namely, declining demand and increasing costs from environmental compliance. Consequently, these two superpowers are now experiencing a period of reorganisation.

US rock demand has fallen significantly over the last two decades, from 39.1 million tonnes in 2000 to 25.9 million tonnes in 2018. The decline is due to decreased downstream production, coupled with challenges in rock production.

Significant restructuring of the North American market in the last three years has also reduced rock demand. Agrium and PCS merged to form Nutrien, which then closed downstream production at Geismar in 2018 and Redwater in 2019. Mosaic also closed Plant City in 2017, purchased Vale's South American phosphate assets (including the Miski Mayo mine which exports rock to the US), and entered into a joint venture with Saudi Arabia's Ma'aden and SABIC.

CRU forecasts that US rock capacity will fall from 29.9 million tonnes in 2018 to 26.1 million tonnes by 2023. While the US has a long history of rock production, some mines are now approaching their end of life. Rock capacity must be replaced, but challenges around permitting and the costs required to commission new sites both pose difficulties.

Chinese rock demand has also been falling – and it is set to decline further as downstream production and demand are forecast to decrease over the medium-term. Fertilizer application rates are another factor. These are inefficiently high, and the central government has targeted

a negative growth rate for fertilizer use. Increasing production costs due to environmental regulations have also resulted in falls in Chinese rock supply, while labour costs have increased sharply.

These pressures have brought down the curtain on a golden period in Chinese rock production – a period that was marked by two stages of growth. In the first stage, rock production increased dramatically from 28.8 million in 2004 to 73.1 million tonnes in 2011, primarily to supply downstream plants selling into the domestic market. In the second stage, rock production eventually reached 92.8 million tonnes by 2015, as Chinese phosphate fertilizer producers turned their attention to the export market.

The peak in Chinese rock production in 2015 came at a time when the Chinese government also began enforcing environmental regulations. The government's new stringent approach to environmental protection has subsequently disrupted rock production and demand. The widespread closures of rock mines in northern Sichuan province for nature conservation have been one consequence. In Hubei province, the Yichang region has also continued its 10 million tonne per year quota on rock production. The capital investment needed to conform to environmental regulations has been an extra burden, adding to the other cost increases affecting Chinese rock producers.

India: dominant importer with few options

As the world's largest rock importer, no discussion of the phosphate rock market would be complete without an analysis of India. The Jhamarkotra phosphate rock mine in Rajasthan remains India's only significant domestic supply source. However,

its 0.9-1.4 million t/a production output is not enough to support the agricultural sector's need to grow food for nearly 1.3 billion people. Moreover, its production costs are relatively high. As a result, India is the world's largest importer of phosphate rock, all of which is directed to domestic downstream phosphate fertilizer production.

The country has no significant rock projects in development either. But, with Modi re-elected, the country's 'Make in India' policy of increasing manufacturing and import substitution is likely to continue. Looking ahead, with the cultivated crop area increasing and more downstream phosphate production, Indian rock imports are set to grow. CRU forecasts that the country will increase its rock imports by 10 percent to 7.7 million tonnes by 2023.

It should come as little surprise that India is the highest cost producer of phosphate fertilizers globally, given the country's lack of phosphate resource and the diversion of domestically-produced ammonia for use in urea production only. Furthermore, India's impoverished farmers (some of the world's poorest) are unable to afford phosphate fertilizers priced at global market levels. The government therefore heavily subsidises the fertilizer industry, resulting in a hefty fiscal burden. This means that policy developments in India will continue to be critical in determining global phosphate rock and fertilizer demand.

Although the reliance on subsidies is particularly acute in India, it is not the only country to face this dilemma. Most Southeast Asian countries also directly subsidise their fertilizer industries. Indonesia, for instance, needs to import virtually all its requirements, having no significant rock production, and in 2018 imported an estimated 2.8 million tonnes of rock. Prices are consequently

high, incentivising government subsidies. Indonesia's rock imports are forecast to increase, as phosphate fertilizer demand grows in response to rises in application rates and the country's cultivated area.

MENA producers lead next era

The phosphate rock market is entering a new era of growth, one driven by producers in the Middle East and North Africa (MENA). The traditional major producers, China and the United States, face headwinds. The traded rock market also remains a stagnant and sluggish component of total phosphate rock demand. That leaves Morocco and Saudi Arabia as the main engines of both supply and demand growth, with both countries investing heavily in the phosphates supply chain.

Ten years ago, the main focus of Morocco's phosphate industry was the production and export of phosphate rock, with only limited downstream production. This changed in 2008 with OCP's announcement of its ambitious industrial development plan, and the subsequent rapid expansion of downstream production at Jorf Lasfar. Four production units, with phosphoric acid capacities of 450,000 tonnes P_2O_5 each, have already commissioned. A further six similar size units are expected to arrive between 2024 and 2030. OCP is promising to commission these new units, maintain its rock export levels, and aims to supply 50 percent of global phosphate demand growth. These commitments suggest overall rock supply and demand will grow rapidly over the medium-term (Figure 3).

While Saudi Arabia is well known for other commodities, the country has emerged to become a major phosphate rock producer and phosphate fertilizer exporter in just eight years. The commissioning of

the first of Ma'aden's ventures in 2011, including the five million t/a capacity rock mine at Al-Jalamid, marked Saudi Arabia's debut in the industry. The country further expanded rock capacity in 2017 through its 5.3 million t/a capacity Al-Khabra mine, which feeds the nearby Wa'ad Al Shamal downstream complex. CRU forecasts that rock production in the country will reach 8.1 million tonnes by 2023.

Morocco and Saudi Arabia will continue to expand their rock capacities over the medium-term, albeit at slower rates than originally expected back in 2008. Morocco will require more rock capacity as it continues to expand downstream production at Jorf Lasfar, Safi and Laayoune. We judge that the Ouled Fares rock project, although still in the study phase, could commission at the end of the medium-term forecast period. In Saudi Arabia, future rock capacity expansion will be driven by the Ma'aden-III project, which could commission by 2024.

Anticipated growth in MENA rock demand and supply is not, however, forecast to lift the traded rock market – simply because many producers in the region are vertically integrated. The percentage of traded rock is instead forecast to remain steady. Non-integrated phosphate projects may also struggle to compete with the low costs of MENA rock production. Instead, those projects that focus on rarer high-grade rock (33% P_2O_5 and higher) are more likely to commission over the medium-term in CRU's view.

Health concerns push EU to agree on cadmium limits

Cadmium is potentially linked to osteoporosis and kidney cancer, if it enters the body in sufficient concentrations.

(Although exactly how much cadmium the human body absorbs from food still remains unclear.) Acting on these human health concerns, the EU finally agreed to set a maximum cadmium level in phosphate fertilizers in 2018, following years of negotiation. Updated rules stipulating a limit of 60 mg Cd per kg P_2O_5 in fertilizers are set to enter into force in three years.

The EU's new cadmium limit could raise costs for some producers. We expect OCP to adjust its internal rock mix, so that more of its lower-cadmium rock is designated for export to Europe. Producers using higher-cadmium rock may need to use calcination or other costly decadmiation technologies to comply with the new regulations (*Fertilizer International* 487, p48).

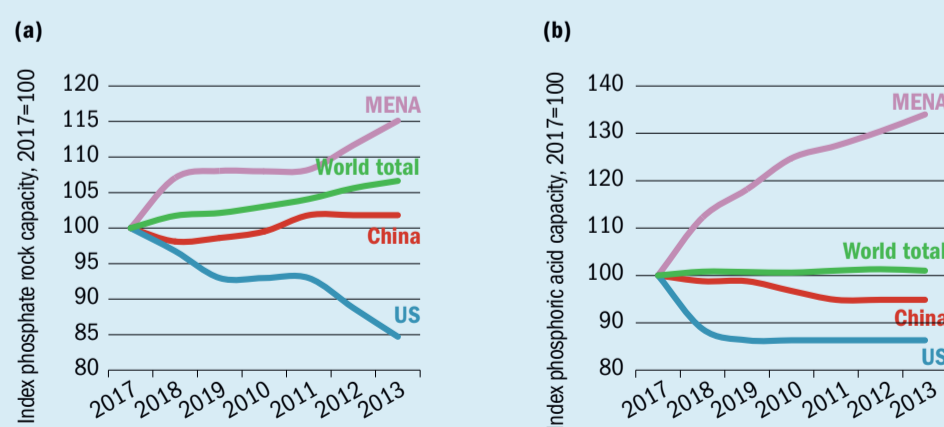
The new cadmium limit also looks set to change European rock demand over the medium-term. With the EU and Norway combined importing some 6.5 million tonnes, or 85 percent of their rock demand, the legislation could affect European rock imports and trade flows. Europe will continue to rely on Russian rock, which is igneous and therefore contains very low levels of cadmium. Europe could also diversify its sourcing of rock imports to include low-cadmium rock projects, such as those in Canada, Guinea-Bissau, and South Africa. It may concurrently increase imports of finished phosphates with low cadmium levels.

Back to feeding the future

We forecast that world phosphate demand will increase by 1.5 percent year-on-year in 2019, and will then continue to grow at a similar rate over the medium-term. Similarly, global phosphate rock production is expected to keep pace with demand growth and reach 217 million tonnes by 2023.

The ascendancy of the Middle East and North Africa is a key market development. Indeed, the geographical centre of rock production and demand growth is shifting away from the United States and Chinese superpowers to the MENA region. Much of this growth is captive, driven by expanding downstream fertilizer production, leaving less room for rock exports. It is still possible that rock-limited countries such as India and Indonesia will find affordable rock to keep their fertilizer production industries alive. However, this will be dependent on continued government support. With ample reserves and low-cost access to the market, the future of the phosphate rock industry will revolve around MENA. ■

Fig. 3: MENA rock capacity growth outpaces world growth (a)... but this will be consumed in new phosphoric acid capacity (b)



Source: CRU Phosphate Rock Market Outlook

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PHOTO: ONURDONGEL/ISTOCKPHOTO.COM

Phosphate pipe dreams become a reality

Long-distance slurry pipelines installed by OCP and JR Simplot have delivered significant economic, environmental and security benefits.

Bigger, better, cheaper

When it comes to transporting minerals over large distances, slurry pipelines offer clear economic, environmental and security advantages over the rail and road alternatives.

For one thing, pipelines can shift far greater tonnages – in the region of 15-40 million tonnes annually. That compares with the 10 million t/a typical capability of a modern rail system, with even that requiring flat terrain. And trucking minerals along the single lane of a highway can usually deliver just 350,000 t/a maximum.

Long-distance mineral transport via slurry pipelines is much cheaper too, falling to less than \$1/t for distances over 100 kilometres. That compares with transportation costs of \$5-6/t for trucking and around

\$1.5-5/t for rail, according to pipeline system manufacturer Brass International (*Fertilizer International* 440, p44). Long-distance slurry pipelines are also very reliable, typically providing 99 percent availability.

Pipelines may also be the only viable option in some circumstances. As a general rule, mineral transport through a pipeline is necessary if:

- The annual transportation volume exceeds 50 million tonne kilometres, e.g. one million tonnes transported over 50 kilometres, or 0.5 million tonnes transported over 100 kilometres
- The transport route is inaccessible by road or rail.

Pipelines can also be concealed underground, and cross much more difficult terrain and steeper slopes than either a road or railway.

The mining industry's increasing focus on developing large-scale, high-quality ore deposits in remote regions also favours slurry pipelines.

"These remote projects have... poor infrastructure and inaccessible terrain that makes conventional bulk transport of the mineral to port challenging," comments Angus Paterson of Paterson & Cooke, a leading slurry pipeline company¹. "Mining companies are increasingly looking to slurry

pipeline technology as a viable and competitive option to rail and rapid transport, as demonstrated by recently commissioned projects such as Minas Rio's 529 kilometre iron ore pipeline in Brazil and OCP's 187 kilometre phosphate pipeline in Morocco."

OCP's slurry pipeline

The Jorf Lasfar-Khouribga phosphate slurry pipeline in Morocco is one of the world's largest slurry pipelines.

The pipeline has the capacity to transport 38 million tonnes of phosphate ore annually, compared to the 18 million tonne capacity of the rail system it replaced. As well as boosting ore transport capacity by more than 200 percent, the pipeline has also yielded major economic and environmental benefits. The switchover from rail to slurry pipeline has cut phosphate ore transport costs by 90 percent, for example, and cut CO₂ emissions by 930,000 t/a, according to OCP Group. It also saves three million cubic metres of water each year.

Importantly, the pipeline is buried to avoid disruption to farming and surface transport along the route between Khouribga and Jorf Lasfar.

Commissioned by OCP Group in April 2014, The main pipeline receives phosphate

rock ore from three wash plants located up to 22 kilometres away at Ben Amir (El Halassa), Merah Lahrach (MEA) and Sidi Daoui. The ore from these plants – which varies in grade and quality – is stored in separate agitated slurry tanks at Khouribga. This phosphate slurry is then pumped from the Khouribga head station, in batches separated by water, through a distance of 187 kilometres to the terminal station at Jorf Lasfar. In doing so, it drops from a height of 766 metres at Khouribga to just 66 metres at Jorf Lasfar².

Vast and complex engineering

The new pipeline forms a vital part of OCP's expansion plans and has helped revolutionise the group's industrial capabilities by fully integrating upstream mining and mineral processing operations at Khouribga with downstream chemical production at Jorf Lasfar.

Building the pipeline required 50,000 tonnes of steel and 1.7 million man-days of time. Some 1,800 people were employed and around 800 construction machines were in operation at the height of construction.

OCP first unveiled the phosphate slurry pipeline project in May 2010, having secured €240 million (\$306 million) in project financing from AFD, the French government's development agency.

OCP awarded the slurry pipeline construction contract to a consortium led by **Tefken**. Other partners included **Paterson & Cooke**, who were tasked with the project's detailed design and engineering. As part of its remit, Paterson & Cooke provided a review, feasibility study and cost estimate for the entire 227-kilometre long slurry pipeline system. The contract for the design and basic engineering of the pipeline went to **Ausenco PSI**. This company also carried out the design and basic engineering of the beneficiation plants and terminal facilities at Jorf Lasfar.

Weir Minerals won the £8.6 million contract to supply *Warman* centrifugal high-pressure pumps to the project. Several *500 U-HTPP* high pressure pumps are installed in series at the start of pipeline with other Weir pumps deployed at three pumping stations along the pipeline's route. The company also supplied standby pumps for the project¹.

The walls of slurry pipelines suffer from high internal abrasion from suspended mineral particles. The Khouribga pipeline is no exception. Switzerland's **Rosen Group** won a contract from headline contractor Germany's **Tip Top Oberflächenschutz Elbe** to supply the project with internal pipe coatings. Rosen coated a total of 704 metres of piping with its abrasion-resistant *RoCoat*

300 polyurethane. This was the only high performance coating capable of meeting client specifications, according to Rosen¹.

The engineering project to build the pipeline was vast in scale and complex. Contractors were required to deliver a pipeline system robust enough to transport tens of millions of tonnes of phosphate slurry, yet still be able to track different product batches through the system, while monitoring and responding to small changes in flow, pressure and density.

"The requirement to transport varying grades of ore in intermittent batches, each with different flow properties, means the design must cater for a wide range of operating conditions," explains Angus Paterson¹. "This is done by controlling the pipeline by varying the pump pressure, based on feedback from a series of pressure monitoring stations, and a variable choke station at the terminal that ensure the pipeline remains fully pressurised."

It is particularly vital for the following conditions to always be met during the pipeline's operation²:

- There must be no slack flow at any point along the route
- Flow velocity must remain high enough to prevent solids deposition
- Slurry flow must remain turbulent rather than laminar

Fig. 1: The Khouribga-Jorf Lasfar slurry pipeline

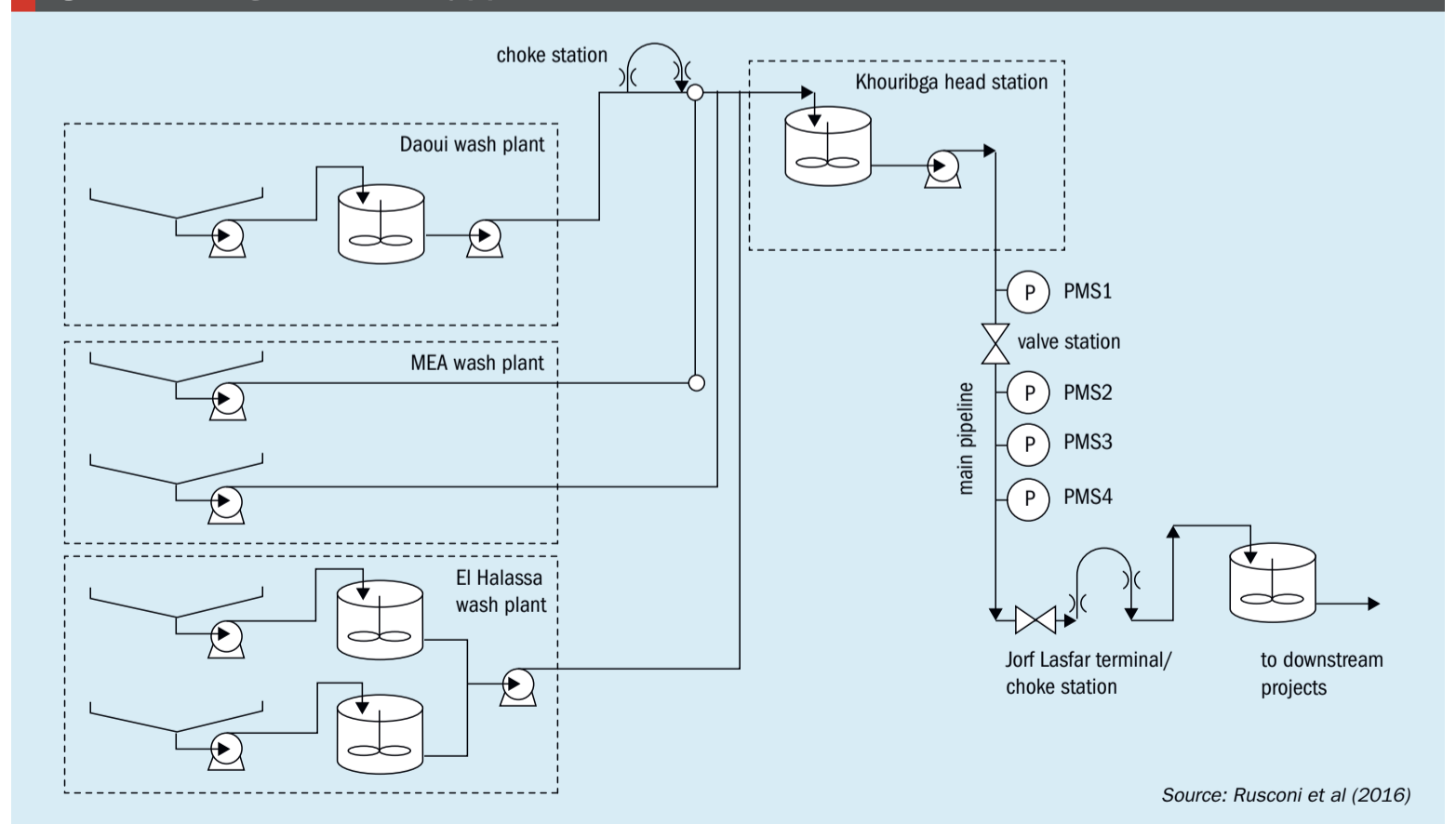
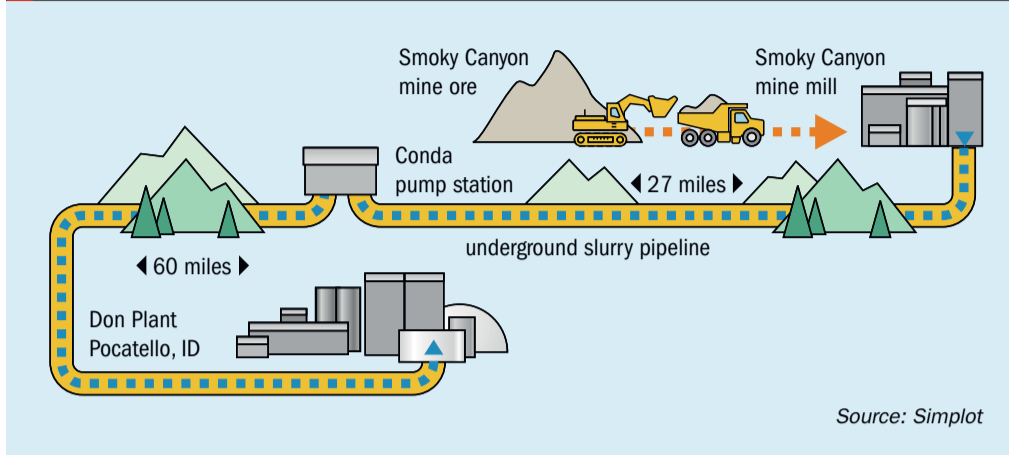


Fig. 2: Simplot's Smoky Canyon-Pocatello slurry pipeline



- Flow rates must not exceed the maximum design limits.

Main pipeline system

The main pipeline is designed to transport between 26 million and 38 million tonnes of slurry annually. The automated system is controlled from a central control room at the Khouribga head station. Alarms alert control room operators when pipeline operating conditions fall outside the design range. If this happens, the automated system will also take action to prevent equipment damage².

Different phosphate grades from individual wash plants are kept apart during transfer to Jorf Lasfar by sending these down the pipeline in batches separated by plugs of water to minimize intermixing. The key components of the main pipeline (Figure 1) are listed below²:

Head station: Feeder pipelines from the three wash plants discharge slurry into the four tanks at the head station. Slurry is fed from these tanks to one of two centrifugal pump trains – one operational train and one standby train – each of these being equipped with six pumps in series. Process water required for batch separation, pipeline flushing and wash-down is sourced from a 15,000 cubic metre reservoir located about five kilometres away via a gravity flow pipeline².

“Due to the high volumes and moderate pressure requirements, the single pump station consists of two trains of six centrifugal pumps in series,” explains Angus Paterson¹. “Each pump is fitted with a 1,850 kW motor and the pump discharge pressure is maintained by varying the speed of several of the pumps.”

Main pipeline: The main long-distance slurry pipeline runs from the Khouribga head station to the terminal station at Jorf Lasfar. The DN 900 steel HDPE-lined pipeline is 186

kilometres long and predominantly downhill, with a capacity to carry around 4,400 t/h, depending on slurry properties. Flow, density and pressure transmitters installed at the head station enable flow monitoring, batch tracking and leak detection. Four pressure monitoring stations (PMS1, PMS2, PMS3, and PMS4) installed along the route also monitor intermediate pipeline conditions (Figure 1). The data they provide supplement pressure readings from the head station, an intermediate valve station, and the terminal station².

Terminal station: Eight agitated storage tanks receive different grades of slurry in batches from the head station. The terminal station can direct slurry to either Jorf Lasfar’s chemical production plants or to the export facilities. Slurry pumped to the export facilities is analysed to verify its phosphate grade².

Choking is carried out using ceramic chokes at the terminal station, and is necessary to maintain a full pipe at lower flow conditions. However, very little choking is required when the pipeline is operated at maximum design throughput, as friction losses in the pipeline consume most of the available head between the Khouribga pump station and the terminal station².

Detectors installed in the pipeline at the terminal station provide live density, flow and pressure measurements. These are necessary for tracking incoming batches and leak detection. Pinpointing and tracking individual phosphate batches along the pipeline is vital to ensure they are allocated to the correct tanks on arrival at the terminal station².

JR Simplot's long experience

US phosphate producer **JR Simplot** has been operating long-distance slurry pipelines for decades (*Fertilizer International*

440, p44). The company transports phosphate slurry from its Smoky Canyon phosphate mine, near Afton, Wyoming, via an 87-mile underground pipeline to its Don fertilizer manufacturing plant near Pocatello, Idaho (Figure 2).

The Smoky Canyon open-pit mine extracts more than two million tons of phosphate ore annually. This is milled to a fine powder and mixed with water to create a slurry. The mine, located near the Wyoming-Idaho border in the upland Caribou National Forest region, opened in 1984 following depletion of ore reserves at Simplot’s Conda mine in Idaho.

A 27-mile section of slurry pipeline linking Simplot’s Smoky Canyon phosphate mine with Conda, near Soda Springs, Idaho, opened in 1984. This was followed in 1991 by the opening of a second 60-mile section to connect Conda with the company’s Don fertilizer plant. Because of the steep terrain and elevation changes along the route, the pipeline is re-pressurised at a pumping station at Conda.

Around 4,000-5,000 tonnes of pulverised phosphate ore is moved through the pipeline each day. Simplot calculates that it would take a 3.8 mile-long train of 420 cars to move the equivalent amount of phosphate from Smoky Canyon to the Don plant each week.

Two 1,000 horsepower piston pumps at Smoky Canyon push the slurry through the pipeline at a flow rate of six feet per second. During the first section, the pipeline initially climbs 900 feet and then drops nearly half a mile as it crosses three mountains and four streams *en route* to Conda. The pipeline successfully moved over 22 million tonnes of phosphate slurry during its first 20 years of operation.

Since 1986, Simplot has also been operating a second 96-mile underground pipeline to move phosphate rock from the company’s Vernal mine in Utah to its Rock Springs fertilizer manufacturing plant in Wyoming.

Both pipelines, despite their initial capital costs, have kept Simplot’s per tonne phosphate rock transport costs low for many decades, helping the company keep its overall fertilizer production costs competitive. ■

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An operational GEHO® positive displacement pump.

PHOTO: WEIR MINERALS

Weir Minerals: slurry transport experts

The efficient and reliable operation of long-distance slurry pipelines depends on high performance pumps, explains **Weir Minerals**. The company is renowned for its robust *Warman*® range of centrifugal slurry pumps and advanced *GEHO*® positive displacement pumps.

Transporting minerals as a slurry through long-distance pipelines is more efficient than the traditional methods of carrying minerals by road or rail. The advantages of pipelines become even more pronounced when mines are located in remote areas.

Slurry pipelines have also grown in length over the past 20 years, as distances between the mining sites and processing plants have increased. One of the world's longest slurry pipelines is in Brazil. It carries iron ore from remote inland mines in

Minas Gerais state across difficult terrain to Rio de Janeiro on the Atlantic coast, a distance of around 550 kilometres.

Many companies are now choosing slurry pipelines over other transportation methods. They are much less expensive to operate and require less labour compared to loading and offloading minerals from a fleet of vehicles, for example.

"Through the use of an integrated slurry pipeline system, operators can effectively transport their slurry over long distances, overcoming terrain constraints such as

mountains and rivers. The alignment of a pipeline is flexible and can easily be adjusted around a number of obstacles; enabling solids transportation in remote areas," comments Erik Vlot, global sales manager for *GEHO*® *Slurry Pumps* at Weir Minerals.

For mining companies around the world, long-distance slurry pipelines – despite their higher upfront costs – have become the most popular mode of mineral transportation, as they minimise operational expenditure and ease of operation is guaranteed.

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Engineering an efficient and reliable pipeline

Designing a long-distance pipeline is a complex task. Efficient and reliable operation hinges on finding a very specific balance between:

- The rate of flow
- The concentration of the slurry
- And the size of the particles present.

Solids in the slurry need to be kept in motion above a minimum velocity – the settling velocity – to remain suspended. The minimum velocity is not the same for every slurry as it depends on the particle size of the solids present – the larger the particles, the higher the velocity required.

For pipelines to operate reliably, the flow velocity needs to be above the settling velocity for the specific slurry mixture being carried. But excessive velocity also has downsides, as more energy is required and abrasion and pipe wear increases if flow is too high.

Flow therefore needs to be maintained within a relatively narrow velocity band for slurry pipelines to operate at optimum efficiency. This is what makes pump selection and evaluation such a vitally important part of pipeline design and engineering.

Careful slurry preparation is also essential – as any variation in properties can cause significant changes in the performance of the pipeline system. The maximum gradient encountered by the pipeline along its route is another critical consideration. This is because mineral solids have a tendency to settle at low points in the pipeline, potentially causing blockages which are costly to clear.

Different types of pumps

There are two types of slurry pumps that can be used and act as benchmarks in slurry pipeline systems: centrifugal pumps and positive displacement pumps.

Centrifugal pumps arranged in series have been the traditional choice in slurry pipelines. Modern centrifugal pumps are able to handle dense high viscosity slurries at high pressures. However, the latest **positive displacement pumps** are also able to handle higher throughputs and larger size solid particles – making them increasingly viable as an alternative to centrifugal pumps.

Because of the overlapping capabilities of centrifugal and positive displacement



PHOTO: WEIR MINERALS

An operational Warman® centrifugal pump.

pumps, the selection of pumping equipment for slurry pipelines requires thorough evaluation. Achieving the lowest total ownership cost for the customer should be the deciding factor when choosing pumps for a project.

The selection of either a centrifugal slurry pump or a positive displacement pump depends on a number of largely case-specific factors. Both pump types can also be used in combination. The new generation of centrifugal pumps, for example, – which have flow inducer style impellers – can operate effectively as the feed pump for positive displacement pumps handling high density and paste-type slurries.

Positive displacement pumps

For long-distance slurry transportation, Weir Minerals advise that positive displacement pumps are used, as they are specifically equipped for high discharge pressures. The performance and technology of these pumps have continued to improve over the years. Increased flow and pressure capabilities mean they can now successfully transport slurries over long distances. Developments such as optimised pulsation dampening and pump synchronisation have also contributed to the smooth operation of pump stations.

Weir Minerals' **GEHO®** pumps, among the world's most advanced positive dis-

placement pumps, are expertly designed to transport slurry over long distances. Impressively, **GEHO®** crankshaft-driven piston diaphragm pumps can transport slurry through a 550 kilometre pipeline and pump slurry more than 2,000 metres uphill.

"We have continued to increase our pump capacity based on our extensive installation experiences and in-depth research and development," says Erik Vlot. "Our pumps have operated in the most demanding applications in more than 500 different projects. At a project in Madagascar, 10 **GEHO®** pumps transport nickel slurry at temperatures of more than 100°C whilst in Siberia, Russia, 19 **GEHO®** pumps operate under extreme weather conditions for an ore pipeline. This proves that our **GEHO®** pumps can withstand the most demanding environments."

High-pressure centrifugal pumps

Pumps used in slurry handling applications need to incorporate high technology materials if they are to perform well and withstand arduous and demanding operating environments. Centrifugal pumps, because they are widely used to transport highly abrasive and corrosive slurries, are particularly prone to erosion wear.

Weir Minerals is dedicated to providing the best-in-class wear material technology

for their renowned *Warman*[®] slurry pump range. These heavy-duty slurry pumps are highly engineered by industry-leading experts. Much of their strength lies in their high-performance wear and corrosion resistant materials.

The encased inner liner is a critical and essential design feature of high-pressure slurry pumps. The outer casing needs to properly support the inner liner so it carries all of the internal pressure load. This allows the liner to be used until it is completely worn out, instead of having to be replaced early due to lack of strength. If the liner is holed, the outer casing will largely contain any high-pressure leaks – with any sign of leakage signalling to the operator that the liner needs to be replaced.

Many factors are considered when initially selecting materials for slurry pumps, including slurry particle size, shape and velocity, operating temperatures and the presence of acids. The material scientists at Weir Minerals are constantly improving the materials selected for specific pumps, in response to changing customer operating conditions, and as new manufacturing processes are developed.

“From our world-class laboratories, we conduct significant wear testing on a range of our *Warman*[®] slurry pump materials to ensure optimum performance. Focused on continuous improvement, our materials meet the ever increasing demands of the market,” says Edward Humphries, the director of the applied materials technology group at Weir Minerals. “With an extensive range of erosion wear-resistant materials, we have a unique offering for our customer, whatever the application may be.”

Slurry pipeline performance

Performance testing and evaluation is an integral part of the development process for slurry pumps and pipelines.

Weir Minerals has access to unparalleled expertise and technology for the in-house testing of slurries and pipeline behaviour for customers. This is what sets the company apart from other slurry pump suppliers.

A one-size-fits-all approach is not an option when it comes to designing slurry pipelines. This is why Weir Minerals invested in the Weir Technical Centre, based in Melbourne, Australia. The Centre offers a proprietary pipe loop facility to support mining operators in the design of

site-specific transport systems.

Weir Minerals, through the testing of materials and equipment, is able to gain a deeper understanding of how selected pumps perform when transporting solids. This, in turn, provides valuable insights into pump performance, efficiency and predictive maintenance.

In recent years, the pipeline transportation of mineral slurries has become a viable alternative to other modes of transportation in an increasingly wide range of scenarios – especially when the terrain is unsuitable for rail or road infrastructure.

The demand for multi-stage centrifugal slurry pumps and pipeline installations is set to increase in the future. This is being driven by growing environmental pressures and the need for more efficient, higher density slurry systems with lower water usage.

These developments should provide the pump manufacturing industry with great opportunities in the future. But significant R&D work is also needed on the physical limitations of pipelines – making them viable for an even broader range of transport applications. ■

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Going underground with Sirius Minerals

Sirius Minerals has started constructing its long-distance, large-scale mineral transport system (MTS). This 37 kilometre underground tunnel will invisibly convey millions of tonnes of polyhalite from the company's Woodsmith Mine in the North York Moors National Park all the way to its Teesside processing plant on the UK's North Sea coast. The MTS avoids the noise, light and emissions impacts of other transportation options such as a rail or road transport, as **Maurice Rankin** from Sirius Minerals explains.



PHOTO: SIRIUS MINERALS

Sirius Minerals team at the launch of the Stella Rose tunnel boring machine (TBM) on Teesside.

£3bn capital project

Polyhalite is a valuable natural source of potassium, magnesium, sulphur, calcium and micronutrients. Sirius Minerals is planning to mine and sell polyhalite to customers around the world as a multi-nutrient, low-chloride fertilizer with a low environmental impact. The company is making a £3 billion capital investment in the UK-based Woodsmith Mine, located close to Whitby, North Yorkshire, on England's North Sea coast. The mine will extract the polyhalite, a naturally-occurring evaporate mineral, from a deposit located 1.5 kilometres beneath the North York Moors.

This polyhalite deposit formed when the ancient Zechstein Sea evaporated some

260 million years ago. It stretches underneath the North Sea as far as Poland, but is found at its thickest and highest grade in north east England. Sirius first became aware of the polyhalite deposit in the region while researching oil, gas and potash exploration reports from the mid-20th century.

The project was originally going to use polyhalite to create SOP (sulphate of potash, K_2SO_4). These plans changed following discussions with potential customers and when the massive scale of the polyhalite deposit (the company has a resource of some 2.69 billion tonnes) and its agronomic value became clear. It was instead decided to keep the polyhalite as mined and market it as a new, natural multi-nutrient product under the trademark *POLY4*.

Designing a sustainable mine

The major challenge facing Sirius Minerals was that the only location to access and extract the mineral – at the place where the polyhalite seam is at its thickest – was within the boundary of the North York Moors National Park. UK planning regulations for areas within the park are extremely restrictive because of its designation as an outstanding landscape. Major development is only permitted in exceptional circumstances, with tight limits placed on how a project can be developed and its environmental impacts.

Sirius therefore went about designing a mine that was in keeping with and sympathetic to its sensitive location. There was a need to minimise the surface impact and

Fig. 1: Route of the mineral transport system (MTS) between the Woodsmith Mine and Teesside



park necessary. The MTS would meet the project's environmental constraints by invisibly transporting polyhalite from the Woodsmith Mine to the processing plant tens of kilometres away (Figure 1).

Mineral transport system (MTS)

Underground mineral transport via a tunnel avoids the noise, light and emissions impacts of other transportation options such as a rail or road transport. Sirius chose a high-capacity, fully-lined tunnel design for the MTS. This will contain a single-track conveyor belt as well as the power and communications cabling for the mine. This low impact infrastructure will ensure that no mineral will come to surface until it leaves the national park and arrives at the Teesside processing plant.

"Our engineering philosophy is actually quite a conservative one," says Sid Brady, chief mechanical engineer and a UK mining veteran who worked at Selby coalfield and Boulby potash mine for many years. "We've always said we will use tried and tested technology because we need a system that works efficiently. Yes, our mineshafts are deep and the tunnel conveyor is long, but there are many deeper mineshafts and longer conveyors throughout the world. What is unique and

disruption to the local community, while also enabling the efficient mining and processing of up to 20 million tonnes of polyhalite annually.

The solution was to house the Woodsmith Mine's winding towers in 50 metre deep chambers and place bunds around the perimeter to shield the mine and help it blend into the landscape. These bunds

are made from excavated material and then landscaped and planted. The project's environmental impact was further reduced by locating the processing plant outside the national park, on an industrial area in Teesside, 37 kilometres north of the mine. This decision, in turn, made the construction of an underground tunnel and mineral transport system (MTS) beneath the national

Fig. 2: Woodsmith Mine schematic showing the mineral transport system (MTS)

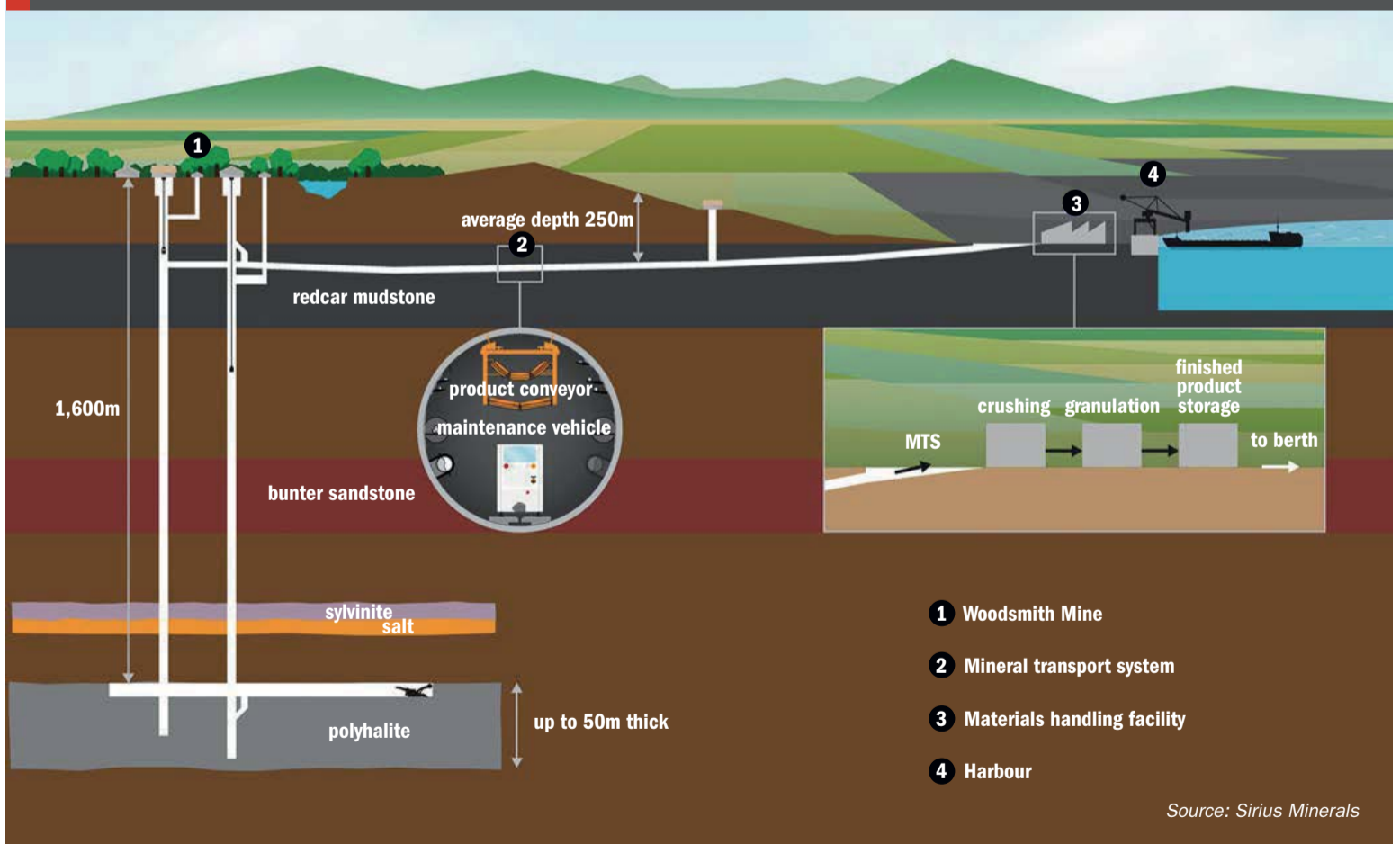




PHOTO: SIRIUS MINERALS

The first tunnel boring machine Stella Rose at entrance of Teesside tunnel.

innovative about our project is the way we've linked the two elements to produce a mine that, when complete, will be practically invisible to anybody in the national park."

Efficient, automated, low emissions system

At a length of 37 kilometres, the MTS tunnel will be only slightly shorter than the combined lengths of the Crossrail tunnels under London, the UK's biggest infrastructure project currently. But it has some way to go to beat the world's longest mine conveyor – the 98 kilometre-long Bou Craa phosphate ore conveyor in the Sahara desert.

The conveyor itself will consist of a conventional 1,200 millimetre-wide trough belt with the capacity to handle up to 20 million t/a. Once the mine is fully operational, the extracted polyhalite will be hoisted up the mineshaft in skips, 39 tonnes at a time, to a cavern 360 metres below ground, where the ore is transferred to the conveyor belt and taken to the processing plant (Figure 2).

Once the ore comes to surface, it will undergo a simple process of crushing, grinding, granulation, screening and drying to produce the finished granular POLY4 product. No chemical processing is involved, producing a fertilizer product suitable for organic use and with one of the lowest CO₂ footprints in the industry.

The finished product will then be moved on another conveyor belt from the processing plant to a quay 3.5 kilometres away, where shiploaders will transfer it into the holds of waiting ships, for onward transport and distribution around the world. The whole journey from mine to port can take less than five hours, through a transport system that is reliable, low-maintenance and low-cost.

Construction

Construction of the Woodsmith Mine commenced in summer 2017, with work on the tunnel for the MTS starting a year later. The design and build of the tunnel is being completed by **Strabag**, one of the world's leading civil engineering and tunnelling contractors. The tunnel is being constructed using three **Herrenknecht** tunnel boring machines (TBMs). These will excavate the tunnel in three independent drives launched from three locations – Wilton, Lockwood Beck and the Woodsmith Mine (Figure 1).

The first tunnel boring machine (TBM 1) – named Stella Rose – was launched from a portal at the surface on Teesside in April 2019. It will excavate Drive 1, the Wilton-Lockwood Beck tunnel section. The two other TBMs will start tunnelling their drive sections from Woodsmith Mine and Lockwood Beck, respectively, in mid-2020. Unlike TBM 1, however, both machines need to be lowered piece-by-piece to launch caverns 360 metres below ground and re-assembled before commencing tunnelling. The shafts and caverns at the Woodsmith Mine and Lockwood Beck therefore need to be completed before tunnelling at both sites can begin.

The three TBMs will excavate the rock using disc cutters mounted in their cutter heads. Excavated material from the tunnel face is carried through openings in the cutter head to a belt conveyor running through the machine. This is then removed from the tunnel and transferred to the surface using another conveyor system. Once above ground, the excavated material will be incorporated into the landscaping of the project's Woodsmith Mine, Lockwood Beck and Wilton sites.

The first 100 metres of tunnelling at Wilton on Teesside began in early 2019 using conventional excavation techniques. TBM 1 then entered this tunnel, inserting concrete lining segments as it went. By June 2019, TBM 1 had reached the bedrock, the Redcar Mudstone geological formation, allowing tunnelling to begin in earnest. TBMs 2 and 3 will not start tunnelling until mid-2020, owing to the shaft and cavern construction required.

The future

Sirius Minerals expects its mineshafts to first strike polyhalite in late 2021, and tunnelling to be completed in 2022, followed by a fit-out period. This should allow production levels to ramp-up to 10 million t/a by 2024 and 13 million t/a in late 2026. An expansion to 20 million tonnes could be achieved by 2029.

Chris Fraser, the CEO of Sirius Minerals, is justifiably proud of the project: "As the world's population grows, we are going to need to think of different, more innovative and sustainable ways to feed people, and that means finding more innovative and environmentally friendly ways of producing crops and fertilizer. Our project proves that, if you bring the right team together, aren't afraid to innovate, and you maintain a firm belief in your vision, you can achieve your goal. Our goal is to change the fertilizer industry by creating the world's first bulk speciality fertilizer. In doing so, we will help drive more sustainable farming practices and set new environmental standards for the mining industry. Our low impact, innovative and efficient mineral transport system is a major enabler of that vision." ■



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43rd Annual Clearwater Convention

The AIChE's 43rd International Phosphate Fertilizer & Sulfuric Acid Technology Conference was held at its usual venue, the Sheraton Sand Key Resort, on Florida's Gulf coast on 7-8 June.

For more than 40 years now, industry engineers have gathered at Florida's idyllic Clearwater Beach for the AIChE's two-day annual convention on sulphuric acid and phosphate fertilizer technology. The convention, which is always run on a Friday and Saturday, is renowned for its relaxed atmosphere and ability to combine business with friendship, food and family. The usual eclectic mix of international and North American delegates attended the 2019 convention.

Water treatment workshop

Proceedings began with Friday afternoon's water treatment workshop, run in parallel with the convention's 22nd annual sulphuric acid workshop. The workshop's theme was improving the performance of boilers, surface condensers and cooling water systems. Water discharge from mineral processing plants was also covered.

Alum in Florida mine water treatment

Louis Irwin of Arrmaz opened the workshop by presenting some findings on the use of alum ($Al_2(SO_4)_3 \cdot nH_2O$) in the treatment of Florida mine waters.

Alum is known for clarification and phosphorus removal in lake waters. It functions by precipitating P as aluminium phosphate and also decreases pH. In his opening presentation, Louis looked at:

- The effect of alum dosages on pH, turbidity and conductivity
- A dual system (alum plus coagulant) option for water treatment.

He concluded that dual systems do work best. Combining a moderate alum dosage

(60 ppm) with a coagulant (3 ppm), for example, was able to reduce mine water turbidity below Florida's state specification. Achieving the same results with alum alone, in contrast, required much larger dosages (up to 360 ppm).

Cooling water system monitoring

Nick Borisow of Suez described a novel measuring tool for performance monitoring in cooling water systems. The tool – known as *Monitall* – measures pH, phosphate and cleanliness, and is an effective early indicator of operational excursions.

The tool can give real time alerts via mobile phone when a pH excursion event is happening at a cooling water tower. *Monitall's* sleeve, a transparent casing, shows observable fouling and scale formation after an excursion event. The tool has proved its worth. When used to monitor three water cooling towers, for example, *Monitall* revealed 11 excursions events per tower per year.

Monitall is not a new, admitted Borisow, but is instead "a new spin on an old technique". However, by improving response times when phosphate scaling/deposition event occurs, *Monitall* can help keep heat exchangers clean, extend asset life, improve reliability and increase run cycle time.

Nalco corrosion stress monitor (NCSM)

Poor water treatment remains the biggest cause of boiler repairs, noted John Landy of Nalco. There are generally two main issues:

- Mineral scale – forms when dissolved minerals exceed solubility

- Corrosion – from the presence of carbonic acid or oxygen.

These are addressed, respectively, by use of scale inhibitors and dosing with an oxygen scavenger.

Nalco now offers a corrosion stress monitor (NCSM) for pre-boiler corrosion control. The monitor is part of its proprietary *3D Trasar* system for boilers. NCSM minimises boiler corrosion by monitoring the oxidation-reduction potential (ORP) of the feedwater. It then adjusts the scavenger control programme (e.g. by adding sulphite to the boiler water) to maintain a constant ORP.

NCSM offers continuous monitoring and automatic control and is 200-1,000 times more sensitive than conventional ORP measurement. It also reacts faster and indicates redox stresses for longer than DO-type meters. NCSM offers simple and accurate control of oxygen scavenger dosage, without the need for operator intervention, and should ensure that boilers remain free of corrosion damage.

Condenser performance and plant operations

Steam condensers for turbines are widely used in both power plants and the chemicals industry – ammonia plants being one example. In an authoritative presentation, Kevin Boudreaux of ChemTreat explained the importance of condenser monitoring, a neglected topic in his view. The key performance indicators (KPIs) necessary for effective monitoring were described. Five case studies were also used to illustrate key factors affecting condenser performance.

Condenser monitoring is imperative, in Boudreaux's view, given that turbine efficiency is compromised any by back pressure (BP) resistance in the condenser. A one inch BP penalty, for example, equates to a two percent loss in turbine efficiency.

Boudreaux highlighted the four main types of resistance to flow and heat transfer in steam condensers:

- Rt – tube-side resistance
- Rf – tube fouling resistance
- Rm – tube metal resistance
- Rs – shell-side resistance.

Tube fouling (Rf) can be biological in nature or due to silt or scale. Air-in leakage, because the shell-side is run under vacuum, can also create resistance (Rs) problems that affect steam condenser performance.

Vaughn Astley of Dr Phosphate was named this year's Hero of the Industry, while Miguel Bravo of The Mosaic Company was announced as Young Engineer of the Year. The accolade Engineer of the Year this year went to Nicole Christiansen, also of Mosaic. Delegates will convene again in Florida for the 44th Annual Clearwater Convention on 12-13 June next year.

The convention's well-attended **phosphate fertilizer technology session** (Session 1) on Saturday morning featured eight presentations:

New impeller technology

Modern impellers in phosphate reactors can maintain the good performance levels of traditional impellers while eliminating their disadvantages, suggested **Michael Preston** of Lightnin Mixers.

Traditional types of impeller such as pitch blade turbines (PBTs) are flexible, operate predictably and are well understood. But they can have disadvantages such as poor solids suspension and blending, high swirl, poor corner mixing and surface vortices. The tip speeds of foil impellers may also cause high internal wear in phosphate reactors.

In contrast, new impeller types – such as the A320 wide blade hydrofoil from Lightnin Mixers – provide more uniform solids suspension, rapid dispersion, improve the homogeneity of reactants and achieve higher bottom velocity. Compared to PBTs, using wide blade hydrofoils in a reactor creates:

- A smaller, unsteady vortex
- Better corner motion
- Noticeable sweeping of corners
- Good recirculation up wall.

Key advantages of such impellers are higher flow-per-power and lower swirling potential. Existing impeller technology cannot optimise phosphate reactor operation, Preston concluded. In contrast, the A320 wide blade hydrofoil has been shown to produce better results than traditional impellers in lab trials, by successfully addressing some of the weaknesses of PBTs and other traditional impellers.

Gypsum stacking technology update

Ashraf Riad and **Mohamad Al Hawaree** of Ardaman & Associates looked at advances in gypsum stacking technology since the late 1970s. Movingly, their presentation was dedicated to Dr Nadim Fuleihan, Ardaman's former president, who sadly passed away last July.

Ardaman has worked with more than twenty companies on 77 gypsum stacks outside of North America, and 22 stacks in the Central Florida area alone. The company has undoubtedly made major contributions to improvements in gypsum stacking technology over the last 40 years.

For example, Ardaman helped develop many of the recognised rules governing the

current design and management of phosphogypsum stacks in the United States and elsewhere. These include the rim ditch technique, with inner and outer dike construction, an innovation introduced by Ardaman in the 1970s, as well as perforated pipe drainage systems and inverted composite liners.

Remarkably, many of these improvements in phosphogypsum stack design and management can be traced back to a ground-breaking technical paper presented by Dr Anwar Wissa, another former president of Ardaman & Associates, at the 1977 AIChE Clearwater Convention. As well as consulting for industry, Ardaman has influenced the environmental regulation of stacks by advising the federal EPA and others.

Purification of fertilizer-grade phos acid

Tino Prado of Prado & Associates presented recent laboratory findings for the purification of phosphoric acid by partial precipitation.

This was Tino's 43rd Clearwater Convention, having attended every meeting since its inception. He has presented a remarkable 20 papers at the convention over the years.

Prado & Associates are exploring lower-cost alternatives to expensive solvent extraction used in food-grade acid purification. The purification of phosphoric acid is becoming more of a priority, Tino suggested, due to falling phosphate rock grades and the evidence on cadmium accumulation in soils.

Purification needs to target and remove a number of "bad actors" (Al, As, C, Cd, Fe, Fl, Hg, Pb, Mg etc.), Tino suggested. The concentration of several of these elements (Al, Fe and Mg), relative to P₂O₅ content, determines the minor element ratio (MER) – a key calculation that determines fertilizer granulation properties and behaviour.

In Prado's lab-scale partial precipitation experiments, an unnamed reagent was added to fertilizer-grade acid and deleterious elements were then removed by filtering out the resulting precipitate. Test results show the process was able to reduce levels of toxic elements such as arsenic (down from 22 ppm to <1 ppm) and also had the benefit of reducing MER (down from 0.123 to 0.071), mainly

through magnesium removal (down from 1.4% to 0.25%). While this partial precipitation process was "not free" – due to the cost of reagents – it would certainly be cheaper than the approach used to produce food-grade acid, in Tino's view.

The Umm Wu'al success story

James Byrd of Worley (formerly Jacobs) and Mosaic's **Tom Miller** described how three operational phosphoric acid plants were successfully designed and constructed as a part of the Umm Wu'al project in Saudi Arabia.

Ma'aden and Mosaic jointly managed what was a highly complex and schedule-driven project. The project's design basics were as follows:

- Integrated, robust phosphoric acid plant (PAP) design
- Total capacity of 1.5 million tonnes P₂O₅ annually
- Provided by three trains – each with a nameplate capacity of 1,615 t/d
- A challenging water source – hot groundwater full of dissolved salts
- Need to concentrate weak acid to merchant grade acid (MGA) on-site for onward transport
- Recovery of product-quality fluosilicic acid (FSA)
- Disposal and storage of phosphogypsum by wet stacking.

Jacobs, now part of Worley, provided the di-hydrate (DH) phosphoric acid technology, the process design package (PDP) and basic engineering (BE) for the project. South Korea's Hanwha built the plants, as the engineering, procurement and construction (EPC) contractor, with site construction overseen by Mosaic. Hanwha also provided detail engineering with support from Jacobs. Once built, each phosphoric train was scheduled to start-up one month apart.

Success is ultimately judged on plant performance. On this basis, both Mosaic and Jacobs are pleased with the outcome of the Umm Wu'al project. The two partners commented: "A perfect start-up has likely never occurred in a phosphoric acid plant – but this one was close. Feed from the beneficiation plant was variable and lower quality than the design basis. But the robust design of the PAP ensured full production rates were met within one week of the start-up of each train."

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Innovations in granulator design

Hatch's **Robert Tinsley** explained a new advanced approach to granulator design.

Most modern phosphate fertilizer plants produce diammonium phosphate (DAP) and monoammonium phosphate (MAP) using a TVA-style drum granulator. Historically, granulators have been designed using an empirical approach, based on design parameters and calculations set out in the Friedman and Marshall equation.

Hatch, however, have been exploring a new approach to granulator design, one that combines discrete element modelling (DEM) with computational fluid dynamics (CFD). These modern numerical methods have the potential to replace the current trial-and-error approach used to position granulator internals such as the sparger. With more validation work and industry collaboration, DEM simulations could become the standard way of optimising granulator design and maximising efficiency and production in future, Tinsley suggested.

High performance evaporator circuit pumps

Sulzer's **David Krebs** provided a comprehensive overview of axial flow pumps and their selection, installation, operation, and maintenance.

Evaporation circuits are commonly employed at phosphoric acid plants to increase acid concentration. This is a critical process step in which pumps perform a vital role. Indeed, the plant's overall efficiency and production rates may depend on pump reliability and performance.

Axial flow pumps are commonly used within the evaporation circuits of phos acid plants as they offer high flow rates at a relatively low discharge pressure. However, such pumps do run at high and very specific speeds – and can destroy themselves if operated outside of their narrow speed envelope. This performance characteristic makes proper maintenance of both axial flow pumps and associated heat exchangers essential.

The condition of axial pumps needs checking, Krebs advised, if there is increased scaling in the heat exchanger, or if pump noise or vibration is observed. Nevertheless, axial flow equipment can provide a reliable pumping system able to meet the requirements of evaporation circuits, with years of maintenance-free operation, Krebs suggested.

New defoaming agitator design

Agitators with a new impeller configuration should be capable of degassing a phosphoric acid reactor without the addition of defoaming agents, according to **Todd Hutchinson** of Philadelphia Mixing Solutions. The new agitator configuration – a combination of up-pumping and down-pumping impellers – has been successfully demonstrated by computational fluid dynamics (CFD) modelling.

The main function of agitators used in phosphoric acid reactors – commonly known as acid attack agitators – is to disperse gypsum and help remove carbon dioxide. A typical agitator contains a foam-breaker and one or more down-pumping impellers. But these can result in poor surface and corner flow. Splashing of droplets on the reactor walls and ceilings can also lead to a build-up of gypsum that requires frequent cleaning. If left uncleaned, large chunks of gypsum can even fall off, causing agitator damage.

The new impeller configuration eliminates surface splashing and greatly increases the volume of slurry being pumped to the surface, Hutchinson suggested. Valuably, this agitator configuration, with up-pumping and down-pumping impellers, also increases the wall and floor velocities of slurry within the reactor, so eliminating gypsum formation, Hutchinson concluded.

DIABON graphite equipment

Andre Boucaut of SGL Carbon Group described the innovative use of graphite in phosphoric acid plant equipment. Graphite's corrosion-resistance and high thermal conductivity make it an ideal material for equipment such as heat exchanger tubes. The material is also well-suited to equipment used in high-purity phosphoric acid production.

SGL manufactures *DIABON*, a resin-impregnated graphite, for heat exchangers, axial pumps, flash tanks and columns. *DIABON* confers a number of specific advantages. Heat exchangers with fully graphitised *DIABON* tubes, for example, offer higher radial heat conductivity, lower steam pressure and less scaling, according to Boucaut. He also suggested that fully graphitised tubes experience up to four times less fouling and 30 percent less downtime, compared to conventional tube materials.

To improve their strength, SGL also offers *DIABON* tubes reinforced with proprietary *CARBOGUARD* carbon fibre. Some installations where these have been fitted have shown a zero failure rate in five years of operation. *DIABON* flash tanks and columns are also available for defluorination systems.

SGL has the capability to deliver complete equipment packages for large-scale projects. Recent examples include food-grade acid and green acid revamping projects for customers, as well as delivery of complete defluorination systems. ■

The parallel mainly sulphuric acid session (Session 2) on Saturday morning included the following eight presentations*:

- **Hybrid sulphuric acid plants**
Andrés Mahecha-Botero, Noram
- **Pexgol pipe material for mineral processing – temperatures up to 230°F**
Aviv Scheinman, Pex-Industrial
- **History leads to innovation and development of major sulfuric acid plant equipment**
Leonard Friedman, Acid Engineering & Consulting
- **The next generation of sulfuric acid technology**
Garrett Palmquist, DuPont MECS
- **Advanced injector technology for increased molten sulphur injection efficiency**
Bandish Patel, Spray Solutions
- **Protecting water quality using natural treatment systems: applications of large-scale sand filters and constructed wetlands for improving mine water quality**
Mark Tumlin, Jacobs
- **A new approach to migrant iron control in industrial and power generation steam systems**
Tom Nix, Chemtreat
- **Food waste reduction and resource recovery through the USF campus food waste recovery project**
Kara Panesar, USF

*Only the presentation's lead author is listed



Chilean potassium nitrate producer SQM's Coya Sur plant.

PHOTO: SQM

The unique benefits of potassium nitrate

Potassium nitrate is a highly soluble source of two major essential plant nutrients. It has become the fertilizer of choice for high-value crops that prefer nitrate nutrition and a chloride-free source of potassium. Market demand for these fertilization properties is being met by a growing range of fertigation and foliar products.

A speciality NK fertilizer

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

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

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

Irrigation systems generally require nutrient-rich and highly-soluble fertilizers that have a low salinity index and are free of impurities and insoluble substances (*Fertilizer International* 486, p28). Potassium nitrate meets all of these requirements and has become a popular and market-leading fertigation product due to its ability to combine nitrate-nitrogen with a chloride-free source of potassium. It is also widely used in foliar applications to correct crop nutrient deficiencies.

Potassium nitrate is available in crystalline and prill form. Crystalline potassium nitrate is ideal for fertigation and foliar application, while prills are suitable for application to soil (basal and side or top dressings).

Agronomic benefits

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

- Improves tolerance to drought, frost, pests and diseases
- Increases water use efficiency
- Enhances organoleptic properties of fruit (colour, sugar content and aroma)

A key ally in quality sustainable agriculture

JW Lemons, national sales agronomist, SQM North America, explains how potassium nitrate helps improve crop quality and yield, combats plant stress and boosts plant water use efficiency.

A dual challenge

Farmers globally are facing a dual challenge. They need to make more efficient use of both available arable land and water for agriculture – at a time when both are becoming increasingly scarce. So how exactly can farmers make the best use of land and water, increasing crop yields to meet the growing demand for quality food, while contributing to sustainable agriculture?

Unique benefits

Potassium nitrate is known to produce stronger, healthier, pest- and drought-resistant crops that are more likely to recover after frost, rain and flooding. It also improves crop quality and shelf life.

Potassium nitrate offer an ideal source of potassium and nitrogen. The nitrate form of nitrogen enhances fruit retention and promotes healthier crops, while potassium maintains leaf function, improves yields and increases the sugar and soluble solids content of fruit.

Plants consume more than 80 percent of their nitrogen in nitrate form, making it the preferred nitrogen source for crops. The nitrate form of nitrogen also promotes uptake of potassium, calcium and magnesium.

Together, nitrate and potassium boost the water use efficiency of plants. This valuable property makes potassium nitrate a useful ally for farmers when water supply is restricted. Water shortages also amplify agricultural production costs, making the selection of potassium nitrate as a fertilizer an important consideration when water resources need to be conserved and optimised. Even when water supply is adequate, the use of potassium nitrate helps increase per acre crop yields.

SQM offers a portfolio of high-quality premium potassium nitrate products, including:

- KNO₃ in soluble form as *Ultrasol® K Plus*
- KNO₃ in dry prill form as *Qrop® KS*.

Water-soluble potassium nitrate for fertigation

SQM's water-soluble *Ultrasol® K Plus* product provides a source of potassium for all plant growth stages, with additional nitrate-nitrogen for quick absorption. This chloride-free potassium nitrate product is compatible with most pesticides and other water-soluble fertilizers. Importantly, it meets potassium needs without excess sulphate or chloride and has a low electrical conductivity (EC) value.

Its high purity, solubility and compatibility – and the low risk of leaf burn – make *Ultrasol® K Plus* the preferred potassium source for nursery foliar applications. When used in fertigation, *Ultrasol® K Plus* can supply potassium needs without excess salts accumulating in soils (or other growing media), while also enhancing calcium and magnesium uptake.

Prilled potassium nitrate for soil application

SQM's prilled *Qrop® KS* is a highly soluble soil-applied potassium nitrate product. It optimises yields by immediately providing nitrate and potassium in plant-available form during key growth stages, when nutrient demand is at its highest. It also function without acidifying soils. *Qrop® KS* prills are uniform in size, and their strength and abrasion resistance results in less dust and lower product losses during handling. Being compatible with other straight fertilizers, the product also offers flexibility when producing bulk or custom blends for crops.

About SQM

SQM has exclusive access to extensive high-value mineral resources in northern Chile. This enables the company to produce low-cost, natural premium fertilizers via a manufacturing process with the industry's lowest greenhouse gas emissions. The company's agronomic teams are actively engaged in comprehensive research and field studies, in collaboration with both growers and prestige research institutions. ■

- Promotes the synthesis of lycopene to create a deep red colour in fruit, for example
- Supplies nitrogen in non-volatile nitrate form, allowing easy handling, with no need for incorporation into the soil
- This avoids the soil acidification associated with the nitrification of ammonium fertilizers
- Nitrate can be readily absorbed by plants through highly efficient direct uptake from soil
- Higher nitrogen use efficiency improves yields and prevents unwanted nitrogen loss to the environment
- Nitrate promotes the uptake of other valuable plant nutrients (K, Ca, Mg)
- It also improves phosphorus and micro-nutrient availability
- Nitrate helps combat soil salinity and relieves salinity stress by counteracting the uptake of chloride
- Reduced salinity build-up also eliminates the need for additional irrigation to flush salts from the soil
- Conversion of nitrate to amino acids takes place within the leaf, an energy-efficient process that helps promote plant growth and fruit fill

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

Production and producers

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

Potassium nitrate is a high-value niche fertilizer product with a two percent share of the global potash market. World production capacity (primary and secondary) is around 1.3 million tonnes K₂O. On a product basis, the size of the global market for agriculture was estimated at 1.8 million tonnes in 2016. Production is forecast to grow at around four percent p.a. out to 2021.

Leading global producers and products include:

- **SQM:** *Ultrasol K* and *Ultrasol K plus* and *Qrop KS*
- **Haifa Group:** *Multi-K*

- **Yara International:** *UNIKA PLUS* and *KRISTA K/ULTRASOL™ K PLUS*
- **Kempaco**
- **Uralchem:** *Solar* Potassium Nitrate
- **Kingenta**
- **Wentong Group**
- **Migao Corporation.**

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

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

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

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

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

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

SQM's largest international competitor is Israel's **Haifa Group** with a potassium nitrate production capacity of around



SQM's *Ultrason® K Plus* and *Qrop® KS* potassium nitrate products.

300,000 tonnes p.a. The company is thought to have contributed about 13 percent to potassium nitrate fertilizer sales (outside China) during 2018.

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

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

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

Uralchem is Russia's only potassium nitrate producer. The product is manufactured at its Azot complex at Berezniki in the Perm region, being partly derived from the site's 1.38 million tonnes of ammonium nitrate production capacity. The company

markets *SOLAR* potassium nitrate for both greenhouse and open field fertigation of crops such as cereals, vegetables and fruits. It also targets the flower and ornamental sector.

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

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

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

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With the industry now engaging in consolidation, the fertilizers sector is gearing up for a transformative, higher value-added future. To ensure its sustainable growth, GCC fertilizer producers must innovate new products and business models. Diversifying their portfolios by developing enhanced quality products and capitalizing on opportunities that arise in key emerging markets will be crucial. Held under the theme '**Transformation: A New Era for the Agri-nutrients Industry**', the **10th GPCA Fertilizer Convention** will be held on 24-26 September 2019 at Kempinski Hotel Muscat, Oman.

The convention aims to discuss and debate subjects of great industry significance such as, disruptive technologies, digitalization, integration, future opportunities in agri-nutrients and many more which are aimed at supporting collaboration along the value chain and fostering food security. The 10th edition of this prestigious event will focus on driving value through innovation to create strong growth for the agri-nutrients industry. Workshops focused on human capital and technical sessions on environmental stewardship will provide further opportunities to learn about best practices from the region and globally at this important industry platform.



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