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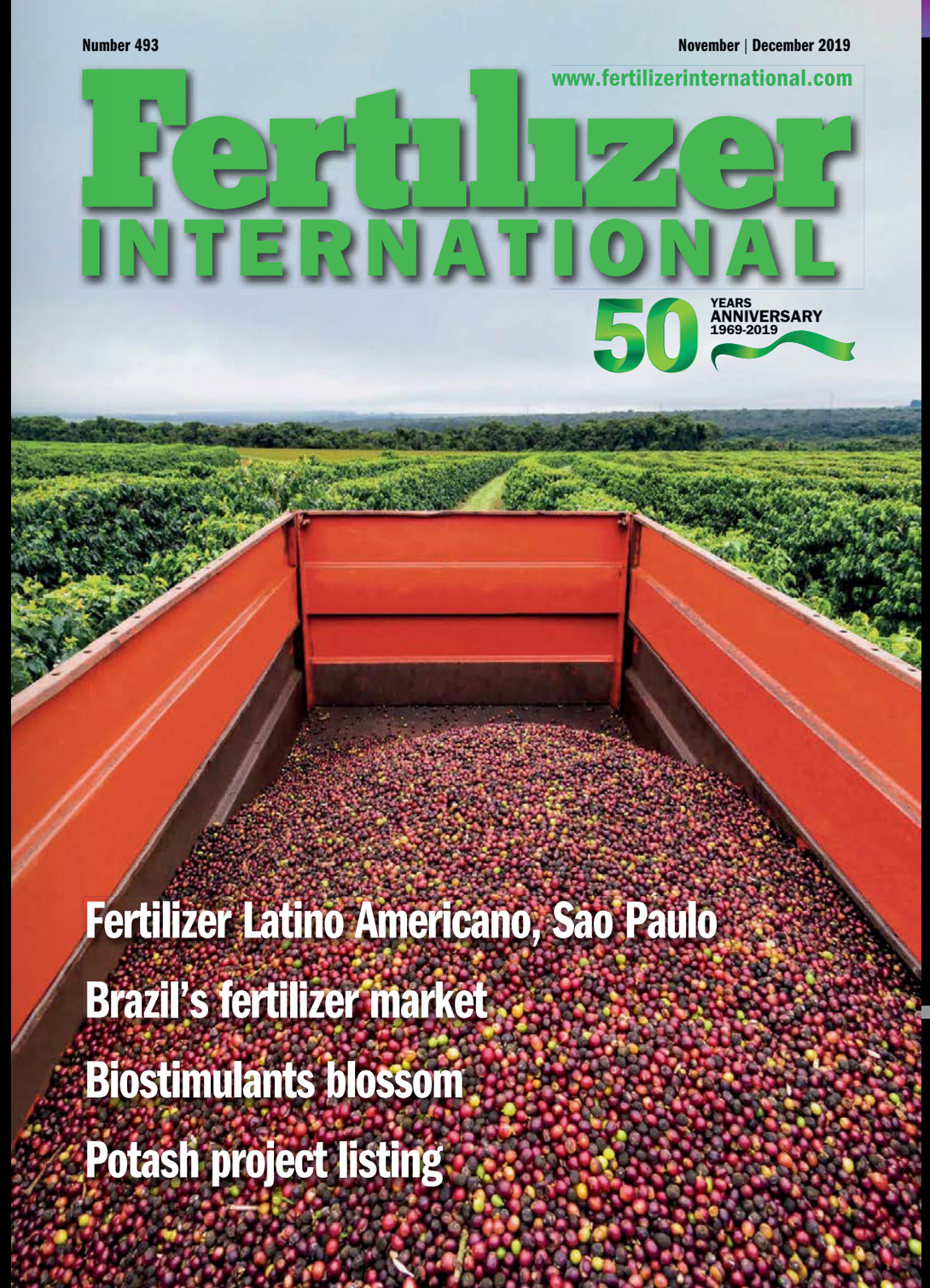
50 YEARS ANNIVERSARY 1969-2019



Fertilizer Latino Americano, Sao Paulo

Brazil's fertilizer market

Biostimulants blossom

Potash project listing

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Cover: *A crop of coffee beans, Brazil. wsfurlan/iStockPhoto.com*

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Crisis, what crisis?

"Phosphate fertiliser crisis threatens world food supply." That was the alarming headline in the UK's *Guardian* newspaper on the 6th September.

"Use of essential rock phosphate has soared, but scientists fear it could run out within a few decades," the *Guardian* went on to warn. The newspaper had this on good authority too.

"Phosphate supply is potentially a very big problem. The population is growing and we are going to need more food," commented Dr Martin Blackwell, a biogeochemist at Rothamsted Research and an expert on soil phosphorus.

In Dr Blackwell's view: "There should be a lot more effort being put in [to phosphate supply] so we are ready to deal with it. It is time to wake up. It is one of the most important issues in the world today."

> **"There should be a lot more effort being put into phosphate supply. It is time to wake up. It is one of the most important issues in the world today."**

Interestingly, Rothamsted Research and phosphate fertilizers have a shared history. The pioneer John Bennett Lawes first began manufacturing and selling superphosphate, the world's original phosphate fertilizer, in England in 1843. This was the same year that the Rothamsted Institute was founded on Lawes' Harpenden estate.

This shared tradition has continued with the publication of a new paper by Dr Blackwell and two Rothamsted colleagues. This thought-provoking paper, published in the journal *Frontiers of Agricultural Science and Engineering* in September*, explores a number of ways of using phosphorus more efficiently. It also looks at how different sources of phosphorus could be captured for soil fertilization.

The paper states: "The continued supply of phosphate fertilisers that underpin global food production is an imminent crisis."

This conclusion is based on an observed decline in the number of years remaining before global supplies of phosphate will run out. Due to rising demand, this has fallen from 300 years to 259 years of supply in the last three years. "If the estimated remaining number of years supply continues to decline at this rate, it could be argued that all supplies will be exhausted by 2040," the Rothamsted scientists write.

They add: "While this scenario is unlikely, it does highlight that imminent, fundamental changes in the global phosphorus trade, use and recycling efforts will be necessary."

The authors add one important caveat though: "It is important to recognize that these statistics oversimplify a much more complex issue of phosphate fertilizer supply, global reserves and trade dynamics."

Somewhat predictably, the observation that the exhaustion of phosphate reserves by 2040 was unlikely, and a potential oversimplification, was not reflected by newspaper and online headlines.

For those with longer memories, headlines warning of phosphorus scarcity must have provoked déjà vu – as they echo the 'peak phosphorus' controversy of a decade ago.

Thankfully, past concerns over phosphorus supply have generally evaporated when fresh appraisals revealed reserves were much larger than originally thought. Reserve estimates are notoriously fluid and can change dramatically.

So should the latest warning about a potential crisis in phosphate rock availability – linked to rising global demand – be setting off alarm bells? Well, extrapolating a three-year trend out to 2040 assumes that phosphate supply and demand are steady and predictable. That is not necessarily a valid assumption to make, particularly on the supply side of the equation.

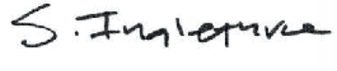
Between 2010 and 2011, for example, the USGS estimate of global phosphate rock reserves increased four-fold in a single year, changing from 16 Gt to 65 Gt. World reserves have increased slightly since then and currently stand at 70 Gt**.

China's phosphate reserves have also yo-yoed dramatically over the last 15 years. The country's reserves prior to 2003 were estimated at just 0.2 Gt. These figures were subsequently revised upwards to 6.6 Gt, making China's reserves the world's largest for several years. The USGS has since revised Chinese reserves downwards to 3.2 Gt.

It is therefore clear that any serious consideration of phosphorus scarcity needs to accept that global phosphate rock reserves are highly dynamic and have varied dramatically in recent decades – largely in an upwards direction too.

None of this undermines the key conclusion by Dr Blackwell and colleagues: "There are many opportunities for improving phosphorus use efficiency in agriculture in order to make the current sources of phosphorus fertilizer last longer, and also to prevent waste and losses to surface waters."

There are both environmental and economic imperatives for preventing phosphorus losses and capturing and recycling these instead. In a circular economy, more efficient phosphorus use has to be a priority, crisis or no crisis. ■



Simon Inglethorpe, Editor

*Blackwell, M. et al., 2019. Phosphorus use efficiency and fertilizers: future opportunities for improvements. Front. Agr. Sci. Eng., 23 September 2019.

**Gigatonnes, 1Gt = 1,000,000,000 tonnes.

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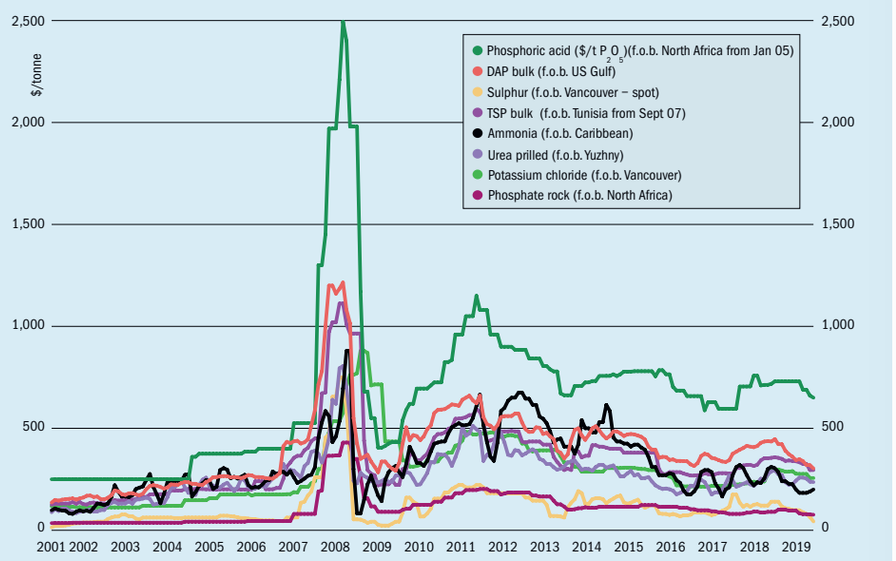
Market Insight

Historical price trends $/tonne



Source: BCInsight

Market Insight courtesy of Argus Media

PRICE TRENDS

Urea: Prices have fluctuated relatively little since August. Middle East and North African urea have been trading between $250-260/t f.o.b. and show little sign of breaking out of this range in the fourth-quarter. Demand globally, with the exception of India, has fallen short of expectations. Brazilian and European buyers have deferred purchasing, while dry weather conditions have reduced demand in other key markets. Low gas prices have enabled both Ukraine and China to export at scale during 2019. Combined, exports from these two countries are up two million tonnes year-on-year.

Phosphates: Prices have been under pressure in the Americas, driven down by import oversupply to the US market from Russia, Morocco and Saudi Arabia. DAP barges in the US have hit decade-low levels, falling to $265/st f.o.b. Nola at the end of October. US price falls also dragged down MAP prices in Brazil, these hitting $295-310/t c.fr at the time of writing.

Prices on the Indian subcontinent and elsewhere in Asia have also been on the slide since August. While Indian importers are continuing to buy DAP, high stock levels there have exerted a downward pressure on prices. Consequently, Chinese DAP fell to 310-315/t f.o.b. at the end of September. Prices did subsequently stabilise in October, however, as purchases from India and Pakistan tightened Chinese export availability.

Potash: Price levels have been dipping steadily since November last year, ending the period of strong growth that started in summer 2016. The market is currently in a period of oversupply due to pockets of lower-than-expected demand in most major potash-buying regions.

The conclusion of the first major annual supply contract of the year has, however, given suppliers some hope of a return to more stable prices. The contract between Uralkali and India's IPL, which covers the shipment of 350,000-400,000 tonnes through to the end of March, was agreed at around $280/t c.fr. Although a drop of around $10/t from last year's contract, this price was still higher than many expected.

Forward buying, high inventories, lower crop prices and new production have all chipped away at producer attempts to control prices. Granular MOP prices in Brazil, for example, have fallen to $290-305/t c.fr, down from $350-360/t c.fr in January. Standard MOP prices in Southeast Asia are currently at $278-285/t c.fr while US granular MOP barge prices are at $237-245/st f.o.b., having fallen from $300-320/t c.fr and $285-290/st f.o.b., respectively, since the start of the year.

Sulphur: It has been 12 months since spot prices first began falling and the market remains bearish. Settled fourth-quarter contracts are all down on third-quarter prices. Indeed, many prices are at their lowest levels since contracts were first introduced. Adnoc has not yet agreed any contract settlements with either Morocco's OCP or Tunisia's GCT. Neither has it agreed the delivery of tonnages to Mosaic's Brazil operations. This has left the company needing to place upwards of 750,000 tonnes of sulphur elsewhere.

On the spot market, granular sulphur prices in China are under $70/t c.fr for the first time since November 2009, with still no hope of price recovery. Poor phosphate market sentiment continues to be the number one influence on the sulphur market. The fall in China's DAP f.o.b. price to a three year low of $310/t is symptomatic of current trading conditions.

Market price summary $/tonne – End-October 2019

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	193-210	-	f.o.b. E. Europe 112-125	f.o.b. US Gulf	294-303	-	-
f.o.b. Yuzhny	225-233	225-240	-	f.o.b. N. Africa	300-330	275-315	600-700
f.o.b. Middle East	230-250	244-260**	-	c.fr India	328-330	-	625*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	236-275	-	c.fr US Gulf	70-80	f.o.b. Vancouver	40-45	-
f.o.b. Middle East	252-285	-	-	-	f.o.b. Arab Gulf	40-50	-
f.o.b. Western Europe	-	490-515	-	-	c.fr N. Africa	60-70	-
f.o.b. Baltic	213-280	-	-	-	c.fr India	60-70+	-

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

MARKET OUTLOOK

Urea: Prices will continue to drift lower until they reach a level at which marginal exporters are forced out, allowing the market to stabilise. Lack of demand will be the main market driver in the fourth-quarter. While India is enjoying a boom year due to a good monsoon, the lack of water in other Asian markets is preventing normal fertilizer consumption. In western markets, buyer caution and oversupply will combine to keep prices under pressure for the remainder of the year.

Potash: The market is experiencing oversupply linked to lower-than-expected demand in five of the top six potash-buying countries. The consequent fall in prices is expected to continue into next year. EuroChem's emergence on the potash market and the ramp-up of the Bethune mine in Canada have now started to affect key markets.

Most major potash producers have announced production cuts – due to poor demand, high inventories or planned maintenance. But these curtailments came after the market had slipped into oversupply. Even if they do rebalance the market, it will take several months for these cuts to make an impact in buying countries. In the interim, there is little to stop prices falling further.

Phosphates: The outlook for Asian DAP prices remains soft through to the year's end. Supply cuts by Chinese producers have yet to stem price falls. DAP prices there will remain under pressure should output continue at current levels. Domestic winter season demand for DAP in China is unlikely to offer producers a significant outlet for their product. Indian and Pakistan DAP demand for 2019 has now been met. Fresh demand on the subcontinent will therefore not arise again until the end of the first-quarter next year. Australia should be a useful end-destination for Chinese product during the rest of 2019 and into next year.

Elsewhere, producers have continued to push product into the US and Brazil to meet initial autumn demand. In Brazil, barter rates for soybeans and corn fell at the end of October. This may spur fertilizer buying for the *safrinha* crop in the first-quarter, following harvesting.

Sulphur: Prices look set to continue their flat-to-soft trajectory for the rest of 2019. This trend is likely to continue next year, at least until after the Chinese New Year holidays in late January. Supply and demand fundamentals are static and unlikely to provide market support until buyers return in mid-February. End-users are in no hurry to step into the market. Traders, in particular, are covered by forward selling. This has been a key strategy for cutting losses and covering positions in a bleak market. ■

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NORTH AMERICA

Market slow-down forces temporary plant shutdowns

Mosaic has temporarily curtailed production at its Esterhazy mine, Saskatchewan, Canada.

PHOTO: MOSAIC

Two of the world's largest fertilizer producers, The Mosaic Company and Nutrien, will cut North American potash and phosphates production by up to 1.8 million tonnes during the fourth-quarter of the year.

The decisions taken by both companies have been in response to poor market conditions and could lead to a combined loss of earnings of up to $300 million.

Nutrien is shutting down three of its Saskatchewan potash mines – Allan, Lanigan and Vanscoy – for up to eight weeks. Mosaic has also temporarily curtailed production at its Esterhazy mine, also in Saskatchewan.

Nutrien's inventory shutdowns, scheduled for the fourth-quarter of 2019, will cut its potash production by up to 700,000 tonnes, potentially hitting earnings (EBITDA) by $100-150 million.

The fourth-quarter production curtailment at Esterhazy, when combined with previously announced reductions, could cut Mosaic's total potash production by up to 600,000 tonnes. The negative impact on earnings (adjusted EBITDA) for Mosaic could be as high as $150 million.

Nutrien and Mosaic both said the cutbacks were in response to a "short-term slowdown" in the global potash market. The risk of a delay to the Chinese contract settlement was another factor, according to Mosaic.

"Despite the current short-term market conditions, we remain positive on potash demand for 2020, as well as the medium to long-term potash fundamentals," Nutrien said in a statement, adding: "We remain focused on a gradual ramp-up of production to meet demand and to ensure we operate the safest, most reliable and efficient potash business in the world."

Joc O'Rourke, Mosaic's president and CEO, described near-term market conditions as "challenging", although he remained bullish looking ahead. "We continue to expect a very strong application season in Brazil and North America, and a better supply and demand balance in 2020," O'Rourke said.

The curtailment should not hold up Esterhazy's K3 expansion project, Mosaic confirmed.

The market slow-down has also affected US phosphates production, with Mosaic announcing the idling of its Louisiana phosphates plant from the start of October. The decision will reduce the company's phosphate fertilizer production by around 500,000 tonnes in 2019. The cutback was made in response to excess imports and high channel inventories, a lingering consequence of the poor spring application season.

The idling of the Louisiana plant comes on top of Mosaic's decision in June to permanently close its Plant City phosphates production site in Hillsborough County, Florida. That closure alone removed around 1.3 million tonnes of US phosphates production capacity, although Plant City had been inactive since the end of 2017. The production plant was thought to be Mosaic's highest cost and least profitable US phosphates operation.

Mosaic is optimistic about a strong fall application season in North America and an improving global supply/demand balance in 2020. The precipitous drop in US phosphate fertilizer prices seen this year – by affecting production economics – will, however, weigh on US producers and their profitability.

US diammonium phosphate (DAP) prices dipped below $300/t (Tampa f.o.b.) in late October, down from $428/t a year ago. At the time of writing, DAP barge prices in the US – at $265/st Nola f.o.b. – are at a decade-low.

"Phosphate prices have declined further through the summer, with excess imports continuing to enter the US on top of high channel inventories," Joc O'Rourke said. "We expect our move to idle production to tighten supply and rebalance the market. Mosaic will prioritize shipments to meet key customer needs through the idling period."

Nutrien buys Northern Seed

Fertilizer giant Nutrien has bought Montana-based seed provider Northern Seed LLC.

The purchase was made by Nutrien Ag Solutions, the company's retail arm. It includes Northern Seed's five seed conditioning plants and its research centre in Bozeman, Montana.

Ryan Holt, Northern Seed's former vice president, said: "This is a great opportunity for our business to provide its Montana customers with a broader portfolio of products and services. Nutrien also brings a great deal of resources that will allow us to elevate to the next level in research, marketing and operational capabilities." Holt is remaining with the company as the seed manager of its Snake River division.

"The current Northern Seed team will continue to work closely with its customers to provide the highest quality certified seed and the most effective broad-spectrum seed treatments for Montana's toughest soil and seed borne diseases," Nutrien said in a statement.

The company confirmed it will continue with Northern Seed's Montana-based crop R&D programme – keeping to the goal of "supplying the highest quality and best yielding genetics for Montana farmers".

Siwertell wins new ship loader contract

Bruks Siwertell has secured a contract for a new ship loader from Martin Operating Partnership, one of its long-standing US customers.

The new rail-travelling ship loader will be installed at the company's Beaumont, Texas, terminal. It will be used to load prilled sulphur into ship holds at a capacity of up to 1,200t/h. Martin Operating Partnership handles various sulphur cargoes at its Beaumont terminal, including prilled sulphur for agricultural applications.

Siwertell's new rail-travelling loader is ideal for terminals with limited berthing space. It is capable of filling every hold on a ship without requiring the vessel to move along its berth. To ensure environmental protection, the ship loader is equipped with fully-enclosed conveyors and dust suppression systems. This is important as minimising sulphur dust emissions is a key concern for the company.

"There can be no greater endorsement than repeat business," said Ken Upchurch, Bruks Siwertell's vice president for sales and marketing in the Americas. "Martin Operating Partnership returns to Bruks Siwertell as a trusted and reliable partner, and we are delighted to renew our strong 15-year business relationship with them.

"Our proven technological capabilities and our commitment to deliver the loader within the space of nine months were all factors that secured the contract," he added.

The new machine could be delivered as early as January 2020. It will support the expansion of Martin's sulphur business in the US Gulf Coast region.

RUSSIA

Tecnimont wins initial contract for new Kingisepp plant

Maire Tecnimont has signed a memorandum of intent with EuroChem Group for a new Russian nitrogen plant.

The two companies signed an early works contract for a potential new urea-ammonia plant in October. This will be located next to EuroChem's existing Kingisepp nitrogen plant in northwest Russia, close to the Baltic Sea.

Under the terms of the agreement, Tecnimont will carry out preliminary engineering and surveying work at the industrial site. The definite go-ahead for the plant still awaits a final investment decision by EuroChem.

"We are pleased to take the next step toward considering building this world scale plant, with Maire Tecnimont, a company that we have worked with closely for many years," said Petter Østbø, EuroChem's CEO. "Expansion of production facilities is a strategic goal for us and part of the next chapter in our growth story."

"We are eager to keep on supporting a prestigious client such as EuroChem in its long-term expansion plan," said Pierroberto Folgiero, Tecnimont's CEO. "This important project reinforces our position in the fertilizer business, and confirms further our long-lasting industrial footprint in Russia."

Acron ships fertilizers through the Northeast Passage

Leading Russian fertilizer producer Acron Group has shipped its first fertilizer cargo through the Northeast Passage. It used this northern polar route to deliver 23,000 tonnes of fertilizer from the Baltic to China.

The company has become the first fertilizer manufacturer in the world to deliver fertilizers using this route.

Dmitry Khabrat, Acron's overseas vice president, said: "It is our first shipment through the Northeast Passage. This new sales route will reduce transportation costs and open new opportunities

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for delivering our products to Asia-Pacific, by significantly shortening the freight transit time".

Acron operates its own distribution network, Beijing Yong Sheng Feng, in China, the world's single largest fertilizer market. It also ships fertilizers overseas through three dedicated Baltic seaport terminals.

AUSTRALIA

Perdaman chooses Topsoe technology

Haldor Topsoe has signed a technology licensing and engineering contract with Perdaman Chemicals and Fertilisers for a new ammonia-urea plant in Karratha, Western Australia.

The Karratha project's 3,500 t/d ammonia plant will be the largest single-train unit in the world, when completed. Construction is due to start next year, although go ahead is still subject to a final investment decision. This is expected before the end of March 2020.

The four billion dollar (AUD) project, which has a guaranteed gas supply, has made significant progress over the last 12 months. SNC-Lavalin was named as the project's engineering, procurement and construction (EPC) contractor in November 2018. Stamicarbon has also come on board as the project's urea technology licensor.

Topsoe is licensing its *SynCOR Ammonia*™ technology for the project. This is company's latest technology for large-scale ammonia production. It incorporates single-step autothermal reforming and is capable of reducing steam throughput by 80 percent.

According to Topsoe, *SynCOR Ammonia*™ technology will deliver major economic and operational benefits for Karratha's large-scale ammonia plant.

"This is a significant step forward for the Karratha urea project. We are now full steam ahead on this important project that will use the latest and best technologies available. We expect Haldor Topsoe's innovative technology to deliver significant economies of scale that will contribute to making this world-scale plant exceptionally competitive," said Vikas Rambal, founding chairman and managing director, Perdaman Group.


PHOTO: HALDOR TOPSOE

Topsoe's SynCOR Ammonia™ technology is capable of reducing steam throughput by 80 percent.


PHOTO: URALCHEM

Dmitry Konyaev, (centre right) UralChem's deputy chairman, and Agostinho Kapaia (centre left), Grupo Opaia's president, at the signing ceremony in October.

ANGOLA

Uralchem to build African urea complex

Russian nitrogen producer Uralchem and Grupo Opaia have agreed to jointly develop an ammonia-urea production complex in Angola. This could enter production as early as 2023.

A memorandum of understanding was signed by both companies at the Russia-Africa Economic Forum in Angola in October. The ceremony was attended by Dmitry Konyaev, UralChem's deputy chairman and Agostinho Kapaia, Grupo Opaia's president.

Under the terms of the collaboration, Uralchem will be responsible for attracting bank financing, plant design, construction and product marketing for the project. Grupo Opaia, in contrast, will be responsible for obtaining the necessary project approvals, gas supply and finding a suitable site for the complex.

UralChem's Dmitry Konyaev said: "The planned production capacity of the complex is 1.2 million tons of urea. For the construction of the plant, we estimate from 4 to 5 years. We hope that our cooperation with Grupo Opaia will be fruitful and we will be able to provide Angola and bordering countries with quality fertilizers."

EGYPT

Tecnimont wins ammonia plant contract

Maire Tecnimont SpA has signed an engineering, procurement and construction (EPC) contract for a new ammonia plant at Ain Sokhna, near Suez.

The contract for the new 1,320 t/d ammonia plant was awarded by Egypt Hydrocarbon Corporation, a subsidiary of Carbon Holdings. The plant will operate using KBR-licensed technology. Ammonium nitrate is already being produced at the site.

Egypt Hydrocarbon Corporation is currently working to complete the project financing, with the support of US EXIM Bank and SACE. The new ammonia plant should be completed within three years, once formal go-ahead is given.

Pierroberto Folgiero, Maire Tecnimont Group CEO, said: "We are very happy to expand our footprint in Egypt in our fertilizers core business, leveraging our long-term relationships with the Egypt Hydrocarbon Corporation."

TUNISIA

Veolia supplies water-soluble fertilizer technology

Veolia is providing Alkimia Group with the crystallisation technology required for a new water-soluble phosphate plant in Gabes, Tunisia.

The *HPD*® crystallisation technology supplied by Veolia will be an integral part of Alkimia's new 25,000 t/a capacity monoammonium phosphate (MAP) plant. This will manufacture high-value fertilizers for the regional export market. The water-soluble phosphates produced will be suitable for fertigation and foliar applications. These need to be free of impurities to prevent the clogging of spraying and irrigation equipment.

Veolia has designed a production process that manufactures high-quality MAP via a double crystallisation route using the company's proprietary *HPD*® *PIC*™ technology. The process minimises waste and maximises production yields.

The plant's production line will also include solid-liquid centrifugal separation, drying, cooling, and screening systems. The plant will manufacture large MAP crystals. These will be more than 99 percent pure and highly soluble, having less than 0.2 percent impurities.

Veolia demonstrated the plant's crystallisation process and confirmed its technical feasibility using simulations and bench-scale laboratory tests. This reduced technical and commercial risks and provided Alkimia with the confidence that the proposed process was both straightforward and scalable.

"We are pleased to help Alkimia diversify its product portfolio into higher-value products. This project at Gabes reflects the confidence of leading MAP producers in Veolia's crystallisation know-how. This will deliver fully-soluble phosphate fertilizers to a market hungry for sustaining crop yields amid increased water scarcity," said Jim Brown, CEO of Veolia Water Technologies Americas.

INDIA

Wuhuan to build Talcher urea plant

China's Wuhuan Engineering Co has been awarded the contract to build a coal-based urea plant at Talcher in Odisha state.

The lump sum turnkey contract commits the company to building the $1.85 billion urea plant by September 2023.

The Talcher plant will convert 2.5 million t/a of coal and 0.35 million t/a of petcoke into syngas. This intermediary will then be used to manufacture ammonia and ultimately 1.27 million t/a of urea.

Attending the contract signing ceremony, oil minister Dharmendra Pradhan said: "The Talcher fertilizer plant was shut down in 1999 due to financial losses. Twenty years later, we have handed over work order for revival of the same."

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PHOTO: SIRIUS MINERALS

Construction slows at Sirius Minerals' Woodsmith mine in Yorkshire.

The Talcher project is essentially a plant re-opening rather than a completely new venture. The Indian government wants to boost domestic urea capacity by reviving the previously-closed fertilizer operations of Fertilizer Corporation of India Ltd (FCIL). As part of these efforts, it has placed joint venture company Talcher Fertilizers Ltd (TFL) in charge of the Talcher project.

TFL has been allotted the northern part of North Arkhapal mine as a captive source of coal for the project. Petcoke will be sourced from the Indian Oil Corporation's Paradip refinery.

The successful implementation of coal-based urea technology at Talcher should have benefits for the Indian coal industry, if it demonstrates the suitability of high-ash Indian coal in areas other than conventional power production.

IRAQ

Badra starts sulphur shipments

In a landmark moment, Iraq's Badra crude oil treatment plant has made its first granulated sulphur delivery.

Gazpromneft-Badra – a subsidiary of Gazprom Neft – delivered 1,000 tonnes of sulphur granules to Iraqi customer Ard as Sakhlya by truck in September. This was followed by a 3,000 tonne shipment.

The 72,000 tonnes of sulphur produced by Badra to date has been placed in storage. These tonnages are now ready to be shipped to Iraqi customers as orders are received.

The Badra oil field is located in Wasit province, eastern Iraq. It is estimated to hold three billion barrels of crude oil. Operator Gazprom Neft owns a 30 percent stake in the project. Other partners include Korean Gas, Petronas, TPAO and the Iraqi Oil Exploration Company. Oil production began in 2013 and is running at 170,000 bbl/d.

The gas processing plant installed at Badra has allowed Gazprom to diversify and increase gas utilisation at the field to 98 percent, according to the operator. The 1.6 bcm per year gas processing plant provides a sulphur production capacity of 110,000 t/a. The site also has 136,000 t/a of sulphur granulation capacity.

Vadim Yakovlev, first deputy CEO, Gazprom Neft, said: "We have, in Badra, created a modern industrial complex, unique in the variety of its output, producing not only oil and gas but also granulated sulphur and electricity. Cutting-edge technological solutions have allowed us to monetise all hydrocarbons produced, as well as ensuring optimum environmental friendliness on this project."

UNITED KINGDOM

Sirius launches strategic review

Sirius Minerals has launched a six-month strategic review of its UK polyhalite project.

The root-and-branch review was announced in mid-September. It coincided with the company's decision not to proceed with its 'stage 2' financing plan. This has been postponed indefinitely due to adverse bond market conditions.

Sirius was committed to issuing at least $500 million of senior secured notes by the 29 October 2019. This was agreed in April as part of a $2.5 billion 'revolving credit facility' (RCF). However, the plan to issue these notes has now been abandoned and the RCF commitment terminated. In addition, $400 million in convertible bonds issued in May, plus proceeds, will be redeemed and returned to investors.

Sirius will now slow the rate of construction at its Woodsmith polyhalite mine in North Yorkshire while it carries out the comprehensive six-month review. The company had cash reserves of around £180 million, as of the end of August, including over £117 million of uncommitted capital.

Chris Fraser, managing director and CEO of Sirius, said: "Due to the ongoing poor bond market conditions for an issuer like Sirius we have not been able to deliver our stage 2 financing plan. As a result, we have taken the decision to reduce the rate of development across the project in order to preserve funding. [This will] allow more time to develop alternatives and preserve the significant amount of inherent value in this world-class project."

Fraser called the strategic review "the most prudent decision" for the company. He said it would provide Sirius with the time it needs to assess and optimise its project development plan, as well as prepare fresh options for stage 2 funding. The review is likely to cover several areas, including:

- Financing alternatives
- Revision/optimisation of the project development plan
- Strategic partnerships.

Sirius says it will now talk to potential credit providers about the project's construction risks as part of the review process. Chris Fraser also confirmed that Sirius would be "seeking a major strategic partner for the project" as part of these discussions. Indeed, the company says it has already identified strategic partners who could bring capital into the project. ■

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Corrine Ricard and **Rick McLellan** are exchanging senior vice president (SVP) roles at The Mosaic Company. Corinne has been appointed SVP – Brazil, replacing Rick McLellan. She was previously Mosaic's SVP – Commercial. In a direct switch, Rick McLellan will return to the US to replace Corinne as SVP – Commercial.

Corrine has enjoyed a long career with Mosaic and its predecessor companies since joining in 1986. Ms Ricard has served in a variety of leadership roles in commercial, supply chain, human resources, international sales, distribution, business development and risk management. Rick has been with Mosaic and its predecessors since 1978. He has served in leadership roles in Brazil, commercial, sales, distribution, import and production.

"Corrine and Rick are experienced and respected leaders, and they are well-positioned to continue to drive growth in our business – and help Mosaic achieve its strategic vision," said Joc O'Rourke, Mosaic's president and CEO. "Rick has led remarkable work to transform Mosaic Fertilizantes, and I have every confidence that Corrine will build on our momentum in Brazil."

Burkhard Lohr will remain as chairman of K+S Aktiengesellschaft until June 2025. His current tenure, which runs until the end of May 2020, has been extended for another five years by the company's supervisory board.

At the same meeting, the supervisory board also approved a five-year extension to the tenure of chief financial officer (CFO) **Thorsten Boeckers**. His appointment, which was due to expire in mid-May 2020, has now been extended until May 2025.

"We are very much looking forward to continuing the great cooperation. K+S is developing excellently in a demanding market environment and, to some extent, under difficult conditions. The implementation of the new *Shaping 2030* strategy is being rigorously pursued and gives the company clear guidance with ambitious goals. We are convinced that the board of executive directors will continue to drive the successful development of K+S forward," said Andreas Kreimeyer, chairman of the supervisory board of K+S.

The International Fertilizer Association (IFA) presented the 2019 Norman Borlaug Award to **Dr Andrew Sharpley** in October. The award was made on 13th October to coincide with Global Fertilizer Day.

IFA said the award recognised the huge impact of Andrew's work on preventing phosphorus losses – by helping farmers to effectively manage phosphate fertilizers.

Dr Sharpley, who is based at the University of Arkansas, pioneered the development of new environmental risk assessment tools. These have been used throughout the world to protect water quality and conserve water resources. The outcomes of Andrew's research have been adopted by farmers, agronomists, environmental regulators and government agencies.

In particular, the *P Index* tool developed by Dr Sharpley is able to identify those areas on a farm which are most susceptible to phosphorus losses. The index has enabled farmers to target and use fertilizers more efficiently. Use of the *P Index* has helped reduce the amount of phosphorus lost to the environment in the United States by an estimated 25,000 tonnes.

The *P Index* has proved so successful it has been adopted by the federal National Resources Conservation Service (NRCS) in the US. It is now the cornerstone of their nutrient management planning at concentrated animal feeding operations (CAFOs) in 49 US states. The US Environmental Protection Agency and the NRCS also use the index to prioritise and target conservation measures across the United States.

Dr Sharpley has also been a vital contributor to the success of the Arkansas Discovery Farm Program, a renowned and internationally-recognised farm research and demonstration project. Twelve discovery farms currently operate across Arkansas. The project aims to minimise nutrient run-off from land to water. It evaluates conservation methods, such as reduced tillage and cover crops. It also highlights the role of nutrient stewardship in protecting soils and reducing nutrient run-off. The program has enabled farmers to produce safe and affordable food supplies by improving their nutrient management and water conservation practices.

"I am honoured and humbled to receive this award. We need to better manage phosphorus for future generations. Transferring scientific research on the subject to the field enables more sustainable farming that benefits the farmers, society and the environment," said Dr Sharpley.

"We are delighted to distinguish someone who has worked so tirelessly to ensure that farmers have the right tools and techniques to manage phosphorus properly to grow more crops while minimising their environmental footprint," said Charlotte Hebebrand, IFA's director-general. ■

Calendar 2019/2020

DECEMBER 2019

4-5
European Mineral Fertilizer Summit,
BRUSSELS, Belgium
Contact: Mado Lampropoulou, ACI
Tel: +44 (0)20 3141 0607
Email: mlampropoulou@acieu.net

JANUARY 2020

20-22
Fertilizer Latino Americano,
SAO PAOLO, Brazil
Contact: Argus Media
Tel: +44 (0)20 7780 4340
Email: fertconferences@argusmedia.com

FEBRUARY

4-7
IFA Global Stewardship Conference,
NEW YORK, United States
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

11-13
26th AFA Annual Forum & Exhibition,
SHARM EL SHEIKH, Egypt
Contact: Arab Fertilizer Association
Tel: +20 2 23054464
Email: afa@arabfertilizer.org

17-19
Nitrogen+Syngas 2020,
THE HAGUE, Netherlands
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

MARCH

3-5
IFA Market Intelligence Conference,
DUBAI, UAE
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

PICTURE THIS...

The US fertilizer industry

The US fertilizer industry contributes more than $155 billion to the domestic economy and provides nearly half a million US jobs, with nearly 90,000 of these directly employed in the sector.

Collectively, leading US fertilizer sector companies employ more than 25,500 staff and pay out in excess of $1 billion in wages annually. Employees at these companies make, on average, $67,500 each year. These economic benefits were revealed by the fourth annual *State of The Industry* report published by The Fertilizer Institute (TFI) in February.

The latest report provides a comprehensive snapshot of almost the entire US fertilizer industry. The 28 participating companies account for 89 percent of fertilizer production capacity in the United States and, additionally, 30 percent of the country's fertilizer retail sector.

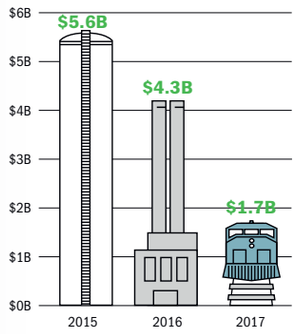
The publication of this highly accessible report – which is partly aimed at the general public – reaffirms the US fertilizer industry's commitment to transparency and openness. The report covers the 2017 calendar year and provides hard facts and figures for a wide range of economic, environmental and social indicators. On average, participating companies:

- Invested a total of $3.8 billion in capital projects annually, 2015-2017. New production capacity, plant upgrades and sustainability improvements were the main priorities.
- Captured and reused 24 percent of their greenhouse gas (GHG) emissions, a saving equivalent to the annual carbon emissions of a coal-fired power station. GHG capture has risen dramatically since the nine percent level reported in 2013.
- Recovered over 100 million gigajoules (GJ) of waste heat to generate on-site energy or return to the grid. This is equivalent to more than 50 percent of total energy use.
- Recycled 516 billion gallons of treated wastewater. Water usage per ton of fertilizer has decreased significantly since reporting began in 2013, particularly in nitrogen production.

The US fertilizer industry is becoming safer too. Between 2013 and 2017, the sector's overall lost time incident rate has dropped from 1.1 to 0.6 cases per 100 full time equivalent employees. The US fertilizer sector, as a whole, is already two times safer than its other industry peers. TFI is also encouraging fertilizer best management practices on the nation's farms and is playing its role in reducing nutrient loss. The $1.1 million the US fertilizer industry invested in the 4R nutrient stewardship research fund in 2017 being just one example. ■

Source: The Fertilizer Institute

CAPITAL INVESTMENTS



CO_2 CAPTURE

7.5 million
metric tons of CO_2

1,605,995
cars a year

WATER RECYCLED

516 billion
gallons of water

enough water to fill over
781,500
olympic-sized swimming pools

EMPLOYEE SAFETY

	Blender and wholesaler employees	Mining employees	Manufacturing employees
Lost-time incident rate	0.65	0.58	0.58
Industry benchmark	2.6	1.6	1.2

WASTE HEAT

101.8 million GJ

51%
total energy use

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Brazil's fertilizer market

Fertilizer deliveries in Brazil reached record levels in 2019. **Débora Simoes** of Agroconsult examines what's driving the market currently, and looks at prospects for the coming year.

An unexpectedly excellent outcome

Fertilizer deliveries in Brazil should reach 36.63 million tonnes this year, Agroconsult estimates, setting a new record high. This annual volume represents a 1.13 million tonne increase (3.2%) on 2018 – making 2019 one of the best years so far for Brazil's fertilizer market.

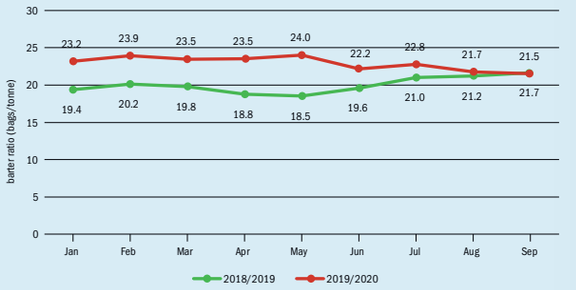
This positive upturn has been a surprise, though, given the domestic uncertainties and external factors affecting Brazil's agricultural sector currently. These had been expected to hit farmer confidence, with negative market consequences.

Indeed, the year started with a delay in fertilizer purchases. Farmers lacked confidence in commodity prices due to the uncertainty surrounding the US-China trade war and the deepening swine fever outbreak in China. The domestic agenda was also dominated by discussions about the government's freight price policy and social security reforms.

At that time, prevailing price forecasts for leading agricultural commodities – and hence for agricultural profitability in Brazil – were distinctly unfavourable. Moreover, the barter ratio (the amount of harvested crop necessary to buy one tonne of fertilizer) was also unattractive. In the case of soybean, the chief driver of fertilizer demand, the average ratio for May, for example, was 24.0 bags/tonne, much worse than in May 2018 (Figure 1). The barter situation was similarly unfavourable for corn, sugarcane and coffee.

Despite the negative fundamentals earlier in 2019, a combination of two factors dramatically improved matters for Brazilian farmers – by fate or luck – from May onwards. First, negotiations between China and the United States to resolve their trade dispute suffered a setback. Second, the record spring rainfall in North America damaged and delayed soybean and corn plantings, negatively affecting US crop output after several successive record years.

Fig. 1: **Brazil's average monthly soybean barter ratio (Sorriso, Mato Grosso state): 2019 vs 2018**



Source: Agroconsult

This mid-year bad news for North America was good news for Brazil, and the outcome of these developments was:

- **Higher corn prices** that supported a 789,150 hectare increase in Brazil's winter corn plantings
- **Better Brazil soybean premiums** which prompted a 700,000 hectare expansion in soybean plantings and a slight rise in average fertilizer use.

With soybean and corn prices returning to attractive levels, there was still time for farmers to negotiate and close fertilizer purchases. A weakening dollar and a fall in the barter ratio for grains in June also significantly favoured farmers. For soybeans, the average ratio improved from 24.0 bags/tonne in May to 22.2 bags/tonne for June. The dollar's depreciation and a price drop in fertilizer production raw materials also made nitrogen and phosphate fertilizers cheaper. Under this more encouraging agricultural scenario, with profitability improving, fertilizer trading deals progressed and fertilizer demand rebounded to record levels.

Even with a tight calendar, bumper fertilizer deliveries were still possible in the second-half of 2019 – thanks to high inventory levels and an imports surge – and are on course to achieve a new record of 29.0 million tonnes. Port and supply chain efficiency also improved compared to 2018. Fertilizer deliveries might even be extended into December.

The rise in fertilizer deliveries seen in 2019 was a result of both crop expansions and higher fertilizer application rates (Figure 2). The volume of deliveries is expected to increase in almost every state. The exceptions being Minas Gerais and Espírito Santo, where the tough state of the coffee market has led producers to cut back on their fertilizer use. The forecast in São Paulo is for a slight increase in deliveries – largely due to an upward pull by grains – as conditions in the sugarcane market are not very favourable either.

On a crop basis, the increase in fertilizer consumption in 2019 can be attributed to extra demand from winter corn followed by soybean and cotton (Figure 3).

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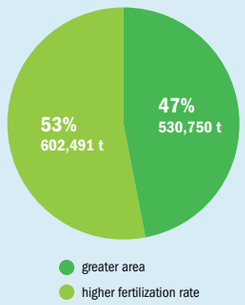
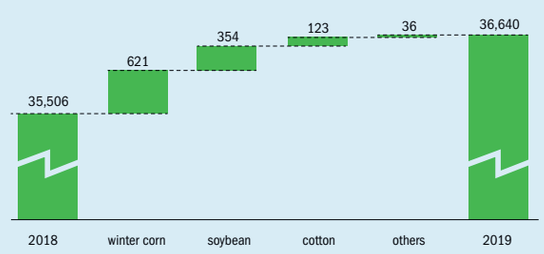
Fig. 2: **Factors driving the year-on–year increase in Brazil's fertilizer deliveries in 2019: increase in land area vs higher application rates**



Source: Agroconsult

Fig. 3: **Brazil's fertilizer demand growth, 2019 vs 2018: increase in consumption by crop ('000 t)**



Source: Agroconsult

Table 1: **Initial and final in-country fertilizer stock levels for Brazil, 2018-2020 ('000 t)**

Year	Initial stocks	Production*	Imports	Exports and loss	Consumption	Final stocks
2018	5,534	8,903	27,497	378	35,506	6,049
2019	6,049	7,816	29,000	382	36,633	5,900
2020*	5,900	8,316	29,496	383	37,279	6,050

** Forecast* *Source: Agroconsult*

Projected in-country fertilizer stocks for the end of 2019 are estimated at 5.4 million tonnes, equivalent to around 60 days of consumption this year (Table 1). This projection is slightly below the 6.0 million tonne stock level at the end of 2018, equivalent to around 62 days of consumption.

2020: Another record expected

Agroconsult is forecasting that fertilizer demand in Brazil will grow to 37.3 million tonnes in 2020. That represents a 701,918 tonne increase (1.8%) over 2019. The demand increase is expected to be driven by soybean, winter corn and sugarcane, with expansions in planted area (70%) rather than higher fertilizer application rates being mainly responsible (Table 2).

Advantageously, the barter ratio is expected to fall further next year, although it is likely to remain higher than in 2018. This should help offset the prediction that Brazil's farmers will experience falling financial returns for their main crops next season. Overall, market conditions for 2020 should sustain a reasonably positive outlook for fertilizer demand, based on current forecasts, albeit not positive enough to encourage rises in fertilizer application rates.

On the downside, extra to the usual risks associated with the weather and fertilizer prices/affordability, external and domestic factors pose a particular risk to Brazil's fertilizer market in 2020. Foremost among these remains the US-China trade dispute. Were this trade war to end, Brazilian farmers could face short-term difficulties due to a dip in soybean prices and lower exports to China. Currency appreciation against the dollar is also a risk for Brazilian farmers, especially if they are forced to sell untraded crops after a rise in the Brazilian real (BRL). This would negatively affect both export revenues and profitability – especially if farm inputs were mainly purchased while the dollar was still strong.

The second factor relates to domestic economic reforms being implemented by the Brazilian government, especially those relating to fiscal matters. Currently, the government is reviewing tax breaks on agricultural inputs. This includes the possible ending of Convenio 100/97 (Agreement 100/97). This agreement covers the taxes applied on goods and services moved within and between states (see box).

Table 2: **Brazil's fertilizer consumption, land area and fertilizer application rates by crop: 2019 vs 2020 forecast**

Crop	Consumption ('000 tonne)			Area ('000 ha)			Fertilizer use (kg/ha)		
	2019	2020	Δ	2019	2020	Δ	2019	2020	Δ
Soybean	16,285	16,609	324	36,745	37,446	701	443	444	0
Summer corn	2,191	2,189	-2	4,867	4,841	-26	450	452	2
Winter corn	4,102	4,304	201	13,181	13,571	391	311	317	5
Sugarcane	4,352	4,481	129	11,802	11,939	136	369	375	6
Cotton	2,156	2,065	-91	1,661	1,572	-89	1,298	1,313	20
Coffee	1,499	1,569	70	2,065	2,044	-21	726	768	29
Forest	1,193	1,217	24	8,529	8,645	116	140	141	1
Others	4,860	4,908	48	16,463	16,438	-25	295	299	3
Total	**36,640**	**37,341**	**702**	**95,313**	**96,497**	**1,184**	**384**	**387**	**2**

Source: Agroconsult

The end of Convenio 100/97?

Tax benefits for pesticides, seeds and fertilizers

Convenio 100/97 is an agreement signed by Brazilian states at the National Council of Political Policy (CONFAZ). It was established 22 year ago and has operated through a series of extensions since then.

The agreement provides tax breaks on sales of agricultural inputs such as pesticides, seeds and fertilizers. It covers two types of tax benefits for these agricultural inputs:

- Reductions to the sales tax calculation for interstate (ICMS) transactions – selling and buying between states
- Exemptions, deferrals and reductions to the tax calculation for internal state transactions – selling and buying within states.

The current 100/97 agreement is due to expire in April 2020. A new extension requires the unanimous approval from the representatives of every state. Some states, such as Santa Catarina, have already come out in favour of ending the current arrangements – making it unlikely that the existing agreement will extend beyond April 2020.

The end of the agreement would automatically lead to the collection in full of the interstate ICMS on agricultural inputs. States would also be obliged to revoke the tax benefits on internal transactions.

It is possible that transitional arrangements could be negotiated through CONFAZ. Alternatively, some states may insist on maintaining tax benefits on agricultural inputs. This would create great uncertainty and potentially result in legal disputes over tax collection (fiscal warfare) on inputs between the destination state and the state of origin.

Agroconsult has analysed the market impact of revoking the tax benefits of Convenio 100/97 on fertilizers – as this is the most likely outcome of the current review of Brazilian legislation in our view.

Impacts of ending the agreement

The ending of the 100/97 agreement will increase taxation rates (ICMS) on the sale of fertilizers. Current interstate rates range between 4.9-8.4 percent depending on the target state. These will rise to 7-12 percent without the current Convenio 100/97 benefits. The tax on internal state transaction, currently zero rated, will also rise to 17-18 percent, depending on the state.

Indirect effects of ending the agreement will also increase fertilizer costs. Fertilizer companies are expected to reorganise their logistics in a less efficient way as a result of the difference between the interstate and internal taxation rates. This development would not be surprising, given existing market distortions from Brazil's tax system.

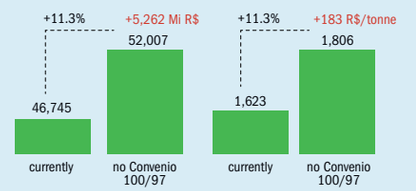
Currently, the main fertilizer consuming regions are supplied by nearby distribution centres and blending plants, mostly located within the same state, reducing logistics costs. But without the 100/97 agreement, the higher tax rates on internal state transactions make it financially more rewarding to bring in fertilizers from outside the state, even if the transportation costs are higher. Agroconsult calculates that such a reorganisation would increase average fertilizer transportation distances – between the distribution centre and the final destination – by around 22 percent. This change would obviously have a direct and negative impact on costs (Figure 4).

Importantly, the resulting re-routing of fertilizer products would create more undesirable pressure on Brazil's transport infrastructure, which already faces major efficiency and logistics difficulties currently. The reorganisation in transport routes would be particularly negative for inland distribution centres that are furthest away from seaports.

Fertilizers import arrangements at Brazilian ports would also face upheaval and reorganisation due to the shift to different fertilizer blending plants and distribution centres, if the 100/97 agreement was ended.

When combined together, these effects will change assumptions about the future investment necessary to expand Brazil's fertilizer sector. The possible end of the 100/97 agreement is likely to have a major impact on fertilizer companies too, given that their profit margins are usually very low.

Fig. 4: **Ending Convenio 100/97: the impact on fertilizer costs* (2019)**



** Note: cost includes raw materials price, logistics costs, road costs, mixer margin and ICMS tax when applicable.*

Source: Agroconsult

BRAZIL REPORT

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Biostimulants blossom

Biostimulants can enhance nutrient uptake and efficiency, improve crop quality and boost tolerance to abiotic stress. The sector's future prospects depend on tighter regulation and more definitive evidence on their beneficial effects, argues **Sajjad Awan** of the UK's Agricultural and Horticultural Development Board (AHDB).

PHOTO: ID-VIDEO/SHUTTERSTOCK.COM

Oilseed rape offers a potential market for biostimulants.

As growers strive for ever greater yields and crop quality improvements, the promised benefits of biostimulant products look increasingly tempting. These include helping plants to tolerate stress and take up more nutrients to deliver better crop yields. These are just some of the marketing claims made by biostimulant manufacturers. Yet knowing which biostimulants to choose – and knowing when, how and if they will work for a particular crop – can be confusing for growers.

At the end of the day, all inputs – "everything that goes into the tank" – need to be justifiable, according to Paul Fogg, crop agronomist with Frontier Agriculture in the UK[1]. "We're entering an era of marginal gains and as a result, interest in nutritional and biostimulant products is increasing as a possible means of making them. The problem is that,

New EU regulation: positive impacts?

Regulatory patchwork

In Europe, the regulation of biostimulants has previously been a matter for individual member states. In the UK, manufacturers are not required to prove the claims made for biostimulants. Manufacturers in other EU countries, in contrast, particularly France, Italy and Hungary – where the biostimulant market is more established and better regulated – are required to provide some empirical evidence in support of product claims together with a list of product ingredients.

New EU-wide common standards

This patchwork of different regulation across Europe is about to change, however, following the approval of new fertilizer legislation in the form of Regulation (EU) 2019/1009. This new regulation finally became law over the summer and will allow the first CE-marked biostimulants to be placed on the single market from mid-July 2022 onwards.

The regulation includes its own legal definition of biostimulants, as follows:

"Plant biostimulant means a product stimulating plant nutrition processes independently of the product's nutrient content with the sole aim of improving one or more of the following characteristics of the plant or the plant rhizosphere: (a) nutrient use efficiency; (b) tolerance to abiotic stress; (c) quality traits; (d) availability of confined nutrients in soil or rhizosphere."

The above definition, formulated by EU legislators, is very close to the industry's (EBIC's) existing definition.

The new EU regulation also sets out a new procedure for the authorisation of biostimulants. Products will now have to undergo a rigorous assessment process by an accredited body within each member state. This will ensure conformity and guarantee that biostimulants available to the growers comply with certain legal requirements. By setting a level playing field, this should increase competition between manufacturers and, valuably, improve customer confidence in the efficacy of products.

Boost to European biostimulant manufacturers

The new regulation should have a positive impact on the European biostimulants market. It recognises biostimulants in law for the first time, for example. It also introduces certification and health, safety and environmental protection standards for all biostimulants placed on the single market. These measures, which are designed to create the right conditions for Europe's biostimulants industry to innovate, prosper and grow, have been broadly welcomed by manufacturers. ■

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to recommend a product confidently, it has to have a technological benefit and we need to understand how it works," he comments.

Defined by function

Biostimulants are certainly different from other agricultural inputs in terms of how they are classified. Most products are usually defined by both their content and function. Yet biostimulants – due to the enormous variability in their chemical composition and physical properties – are solely defined by their function.

Even drawing up a definition of biostimulants based on function has not been easy. Indeed, it took a wide-ranging, year-long consultation for the European Biostimulants Industry Council (EBIC) to agree on the following functional definition:

"Plant biostimulant means a material which contains substance(s) and/or microorganisms whose function when applied to plants or the rhizosphere [soil] is to stimulate natural processes to benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and/or crop quality, independently of its nutrient content."

EBIC has argued for this practical definition of biostimulants because, in its view, this corresponds closely to manufacturers' claims about how they function and how farmers wish to use them.

Although this is now beginning to change, previously, the absence of an agreed definition and a lack of consensus has undoubtedly held back the regulation of the biostimulants sector in the EU, United States and other countries.

Importantly – as the EBIC definition suggests – the main function of biostimulants, despite their enhancing effects, is not to act directly as pesticides or fertilizers. This distinction means that biostimulants have generally fallen outside of regulation or have been regulated differently to other agricultural inputs. In the UK, for example, any pesticide placed on the market, unlike a biostimulant, must have a ministerially-approved pesticide product (MAPP) number.

Interest in biostimulants has increased significantly over the past few years. In the UK market, this has been partly due to the reduced availability of pesticides as well as the increased disease resistance of some crops. Biostimulant use is well established in higher value crops such as fruits, vegetables and potatoes. Increasingly, they are also being considered for other broad acre crops – such as winter cereals and oilseed rape – although uptake remains limited.

Table 1: **Main types of non-microbial biostimulants**

Product type	Description
Seaweed extracts	Extracts include compounds such as polysaccharides and plant growth regulators (PGRs).
Humic substances	Humic or fulvic acid compounds extracted from decayed plant or animal material.
Phosphites	Inorganic salt including phosphite (PO_3).
Chitin and chitosan derivatives	Chitin is an abundant natural polysaccharide obtained from crustaceans. Chitosan is derived from chitin.
Anti-transpirants	Compounds such as abscisic acid and waxes which reduce transpiration by plants.
Protein hydrolysates and free amino acids	Protein hydrolysates are sourced from animal and plant residues. Free amino acids are obtained from the breakdown of agro-industrial by-products with enzymes.

Source: AHDB

Table 2: **Biostimulant effects on plant nutrition, growth/yield and stress tolerance: summary of the evidence base for cereals and oilseed rape**

	Promote plant nutrition?			Improve plant growth and yield?			Promote biotic stress tolerance?	
Product type	Nitrogen	Phosphorus	Other nutrients	Hormonal	Growth	Yield	Pathogen	Pest
Seaweed extracts	●	●	●	●	●	●	●	●
Humic substances	●	●	●	●	●	●	○	○
Phosphite and other inorganic salts	○	○	○	●	●	●	●	○
Chitin and chitosan derivatives	○	○	○	●	●	●	●	●
Anti-transpirants	○	○	○	●	○	●	○	○
Protein hydrolysates and free amino acids	●	○	●	○	●	●	○	○

KEY

● *Good evidence base (including multiple field-based experiments on cereals or oilseed rape).*

● *Moderate evidence base (good number of experiments, including some field-based experiments on cereals or oilseed rape).*

● *Low evidence base (principally laboratory-based experiments with little or no data on cereals or oilseed rape).*

○ *No evidence base (not enough evidence available).*

Source: Storer et al. (2016). AHDB Research Review No. RR89

What can biostimulants do?

The main types of biostimulants are listed in Table 1. Biostimulants are particularly associated with:

- Increased crop nutrient uptake
- Improved tolerance to abiotic stress, e.g. water stress
- Improved tolerance to biotic stress, e.g. pests.

The research evidence on the benefits of biostimulants is summarised in Table 2. (Note: this is specific to broad acre crops such as cereals and oilseed rape.) While there is moderate evidence that many biostimulants *can* increase plant growth and yield, Table 2 shows that definitive proof about other beneficial effects is often limited or incomplete. Because of this, clear and concrete guidelines on how to maximise benefits and achieve consistent results from biostimulants are generally lacking.

Agronomic understanding is better for some biostimulant products than for others. Seaweed extracts are probably the most familiar biostimulant, as these algal products have been available on the market for many years. Phosphites are also relatively widely used and well-known to agronomists and growers[1].

Other biostimulants compounds hold promise but are less familiar, making their use more speculative.

"Biostimulant products can have a range of uses; some support crop growth, some help plants withstand stress and increase resilience in these situations, further products help plants access nutrients better and others (e.g. seaweeds) are more often considered as nutritional-type products," comments Paul Fogg[1].

The UK's Agriculture and Horticulture Development Board (AHDB) recently carried out a review on the function and efficacy of biostimulants[2]. The review's main conclusions for **non-microbial products** are summarised below.

Although the AHDB's review – and the information summarised in Table 2 – was specifically aimed at UK farmers, its conclusions could be applicable to other countries around the world.

Seaweeds extracts

Seaweeds are macroscopic, multicellular marine algae. Extracts can be applied to soils, as foliar treatments to plants, or added to hydroponic solutions[3].

There is moderate evidence of seaweed extracts having a beneficial effect on plant hormones, growth and yield. Three species, *Ascophyllum nodosum, Ecklonia maxima* and *Kappaphycus alvarezii*, have been most frequently studied. Of these, the brown seaweed *Ascophyllum nodosum* is most commonly used as a source of extracts. This species contain alginate, a cell wall polysaccharide, and storage carbohydrates such as laminaran, mannitol and fucans.

The demonstrated biostimulant effects of seaweed extracts on plants are wide-ranging and include:

- Higher yield and crop biomass (root and shoot)
- Increases in nutrient uptake (N, P, K and often Mg)
- Larger numbers of chloroplasts
- Prevention of chlorophyll degradation.

Seaweed extracts have been reported to improve:

- Crop yield
- Root structures
- Flowering and leaf development
- Fruit set
- Plant disease tolerance
- Tolerance of abiotic stresses such as cold and drought
- Soil structure, soil water holding capacity and soil microbiology

These effects, although not well understood, are linked to the following components of seaweed extracts:

- Plant growth regulators (PGRs) such as cytokinins, auxins, and abscisic acid (ABA)
- Gibberellic acids
- Betaine and proline which buffer against osmotic changes
- Alginate and polysaccharides which promote root growth and activate plant defence mechanisms
- Minerals and trace elements.

Biostimulants sourced from seaweeds are compositionally variable, despite the limited number of species used. This is because extracts reflect different growing environments, are derived using different extraction methods and have different stabilities.

Humic substances

Humic substances are produced by the natural decomposition of plant, animal and microbial residues[3]. They can constitute up to 80 percent of soil organic matter. Humic substances are complex mixtures but can be split into three main categories: humic acids, fulvic acids or humin.

The role of humic substances in soil fertility and sustaining plant growth is well recognised. They are known to increase macro- and micro-nutrient uptake, for example, by increasing the cation exchange capacity (CEC) of soil[3]. This is generating increasing interest in their use as a soil amendment and biostimulant.

There is moderate evidence of humic substances having positive impacts on nitrogen uptake/assimilation, plant growth and crop yield. The demonstrated effects of humic substances on plants include:

- Acting as plant hormone-like substances, e.g. acting like cytokinin, auxin and gibberellin
- Increasing above- and below-ground growth
- The emergence of lateral roots
- Increasing root hair length density and root cell proliferation
- Improved nutrient use efficiency
- Influencing primary metabolism and photosynthesis
- Alleviation of salinity stress in beans and maize.

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High doses of humic substances can, however, have negative effects on plant growth and nutrient uptake.

Phosphites

Phosphite is the reduced form of phosphate. It is often applied to soils in the form of phosphorus acid (H_3PO_3), although it can also be applied as the potassium, sodium or ammonium form of either phosphite (PO_3), hydrogen phosphite (HPO_3) or dihydrogen phosphite (H_2PO_3). Potassium dihydrogen phosphite (KH_2PO_3) and dipotassium hydrogen phosphite (K_2HPO_3) are both common phosphite products.

Phosphite has been applied to soils as a pesticide, biostimulant and supplementary source of phosphorus – although its benefits as a P fertilizer are thought to be negligible or limited. Despite this, there is evidence of phosphites having positive biostimulant (growth and yield) and fungicidal effects.

Phosphites are most commonly applied as a foliar spray, although there is also a risk of phytotoxicity when applied at high rates (above 5 g/l or 36 kg/ha).

Chitin and chitosan derivatives

There is moderate evidence that chitin and chitosan derivatives can boost plant growth and yield. Encouragingly, there is also good evidence on their pathogen control abilities.

Chitin (β-(1-4)-N-acetyl-D-glucosamine) is an abundant natural polysaccharide. It is the second most abundant polymer in nature after cellulose, being commonly found in the exoskeletons of crustaceans and insects and the cell walls of fungi.

The waste products of shellfish provide the main sources of chitin and chitosan derivatives. Worldwide crustacean production – which exceeds 10 million tonnes – provides a large potential source of shell waste for chitin production

Chitin has been found to have significant anti-microbial effects, while the demonstrated effects of chitosan on plants include:

- Direct reduction of bacteria, fungi and nematode pests
- Activation of plant defences
- Improved tolerance to abiotic stress, including drought stress
- Stimulating beneficial microorganism activity
- Regulation of plant growth.

Trials of chitin products on wheat crops reported significant yield increases (94-134 percent of the control) with no significantly negative effects. Above-ground growth increases have also been reported in wheat and maize trials, with no significant negative effects.

Anti-transpirants

The evidence on the plant hormone effects of anti-transpirants is good. There is also moderate evidence of a yield effect.

Anti-transpirants are applied to plant leaves to reduce transpiration (water loss). There are two types:

- Film anti-transpirants, such as oils, waxes or phenyl mercuric acetate, which form a colourless film over the leaf surface
- Metabolic inhibitors, such as abscisic acid and chitosan, which reduce stomatal opening.

> **The use of biostimulants to deliver yield gains – above and beyond what can be achieved through conventional crop management – is another potential opportunity... Marginal gains could be substantial if aggregated.**

There is evidence of significant yield increases for wheat under drought stress in response to film anti-transpirants. Recent research suggests that the benefits of anti-transpirants may outweigh the costs if they are targeted at key growth stages where drought sensitivity is highest, e.g. just before booting in wheat.

Protein-based products

Protein-based products can be split into two main categories:

- Protein hydrolysates – a mixture of peptides and amino acids of animal or plant origin
- Individual amino acids such as glutamate and proline.

Hydrolysates are produced by enzymatic, chemical or thermal hydrolysis of animal and plant residues. Sources include:

- Animal epithelial or connective tissues
- Animal collagen and elastine
- Arobgerm protein
- Alfalfa plants.

Individual amino acids include the 20 structural amino acids involved in protein synthesis, as well as the non-protein amino acids found in abundance in specific plant species.

There is abundant evidence supporting a role for protein hydrolysates and specific amino acids in abiotic stress tolerance. There is also evidence to suggest that protein hydrolysates may promote nitrogen assimilation in plants, via the regulation of carbon and nitrogen metabolism. Trials of alfalfa-derived protein hydrolysates on hydroponically-grown maize plants have shown enhanced shoot biomass, soluble sugar accumulation and nitrogen assimilation.

Demonstrated effects on plants include:

- Stimulation of root and leaf biomass
- Improved abiotic stress tolerance, including salinity, drought, extreme temperature and oxidative conditions
- Increased nutrient uptake
- Higher water use and nutrient use efficiencies, both for major nutrients (especially nitrogen) and micronutrients.

The mechanisms responsible for higher nutrient uptake are not fully understood but may be connected too:

- Increases in soil microbial and enzyme activity
- Improved micronutrient mobility and solubility
- Modifications to plant root architecture
- Higher nutrient-acquiring enzyme activity, e.g. nitrate reductase, glutamine synthase and Fe(III)-chelate reductase.

However, there remains very limited evidence for any of these effects on cereals and oilseed rape.

Conclusions

Biostimulants are an emerging sector. For the UK market, greater use of biostimulants on arable crops is likely to require a more substantial evidence base. Application rates and timings are still being optimised for many biostimulants. These often vary between products – making manufacturers' guidelines essential.

The potential economic benefits of different types of biostimulants available on the market need to be demonstrated and clearly understood. This is not always possible in the UK at present due to the lack of field-based data. In particular, a better understanding of those factors – growing conditions, crop growth stage, crop characteristics etc. – that maximise the positive effects of biostimulants will be essential for building a stronger economic case for their adoption. Knowing how to incorporate biostimulant products within integrated crop management systems will also be necessary.

In future, growers and agronomists are going to require more evidence if they are to improve their understanding and fully exploit biostimulants. However, the rise in independent research and new European legislation (see box), by improving knowledge and product reliability, should increase confidence in biofertilizers and their efficacy.

"No two products appear to be the same and work needs to be done to understand what each one brings to the table and how they interact with one another. We need to understand inter-season and inter-crop effects and above all, biostimulant products should pay for themselves. They have the potential to increase our ability to extract the genetic potential from crops but their adoption must be evidence led," concludes UK agronomist Paul Hogg[1].

The AHDB's review of crop biostimulants for the UK market identified three key potential benefits for cereals and oilseed rape – provided their efficacy can be reliably demonstrated:

- Firstly, in integrated management schemes, biostimulants could have a role to play by complimenting N, P and K fertilizers and improving their use efficiency.
- Secondly, the use of biostimulants to deliver yield gains – above and beyond what can be achieved through conventional crop management – is another potential opportunity. This is worth investigating as even marginal gains could be substantial if aggregated.
- Finally, it is important to recognise that some biostimulants are not designed to increase yields in a 'good' year. Instead, their real value comes from their ability to prevent yield losses in a 'bad' year when crops are suffering abiotic stress during drought, saline or cold conditions.

The risk of abiotic stress is obviously much higher in low rainfall or drought-stricken countries such as Australia or South Africa than in more temperate ones such as the UK and Germany. Even in temperate regions, however, biostimulants could have potential benefits as an insurance against poor seasons, provided they are cost-effective enough to warrant regular use in crop rotation systems. ■

Acknowledgements

Additional reporting by Simon Inglethorpe.

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Greener urea granulation

We look at recent 'green' innovations in urea finishing that reduce or eliminate biuret and formaldehyde content, and/or dust and ammonia emissions.

Fig. 1: **Process flow diagram of dry flash finishing**

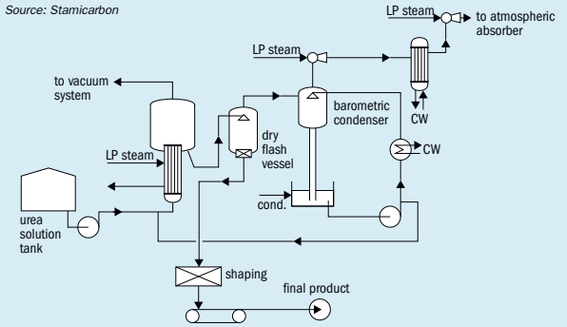
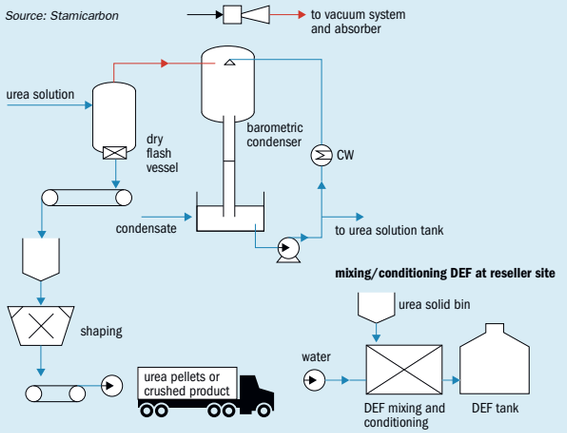


Fig. 2: **Dry flash process for DEF production**



Incremental change?

Urea granulation is generally regarded as a well-understood, mature technology. Because of this, there is a view that only incremental enhancements and marginal improvements to conventional urea finishing are possible (*Nitrogen+Syngas* 348, p40). For example:

- **Emissions:** Although dust emissions from urea finishing remain a problem, these have largely been addressed and reduced to around five parts per million. But will further emissions reductions be necessary in future?
- **Operational efficiency:** Great advances have already been made in reducing downtime. The intervals between cleaning for Stamicarbon's granulation process, for example, are already three times longer than those of some rival processes.
- **Purity:** Biuret is an issue in both prilled and granulated products. The conventional view is that little that can be done about its presence – as it is simply a consequence of urea reaction chemistry in the evaporation section.

The situation urea finishing finds itself in, according to leading technology provider Stamicarbon, is very similar to that of conventional urea melt technology back in the 1960s. Incremental innovation alone will not change the fundamentals of finishing technologies, and neither will it dramatically reduce opex or capex. Incremental improvements to the urea finishing process can even have undesirable consequences by adding to the complexity of installations.

Similar to the 1960s, therefore, what is really needed is major innovation and technological breakthrough – dry flash finishing being one example.

Dry flash finishing

The novel dry finishing technology recently developed by Stamicarbon represents a major step forward in urea granulation. The new concept, which incorporates flash drying, gets rid of dust and ammonia emissions, dramatically reduces utility consumption and halves biuret content (*Nitrogen+Syngas* 348, p40). It also offers production flexibility by allowing final products to be manufactured in a range of different sizes and forms.

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Process design

Stamicarbon's process design for dry flashing finishing is shown in Figure 1. The urea solution (typically 78 weight-percent water) is firstly concentrated in a pressure- and temperature-controlled evaporator. The concentrated solution from the evaporation step is then introduced into the flash vessel to form solid urea. Solid urea is extracted from the flash vessel through a vacuum lock and transported onwards for further processing.

A dedicated vacuum system keeps the flash vessel well below atmospheric pressure. This vacuum is created by a combination of ejectors and condensers including a contact condenser, all typical equipment for a urea plant. The contact condenser is needed to deal with entrained urea particles present in water vapour leaving the flash vessel. The overhead vapours generated by the vacuum systems of both the evaporator and dry-flash vessel are combined and then processed in the urea melt plant's atmospheric absorber.

Dry flash production of DEF (*AdBlue*®)

The low biuret content urea particles generated by the dry flashing process are perfect for the production of diesel engine fluid (DEF), a fuel additive used in the automotive industry (Figure 2). DEF is a 32.5 wt-% solution of urea in water. The ability to directly supply DEF resellers or distribution centres with solid urea is a particular advantage of the dry flash process, as it avoids transporting the large amounts of water present in dilute DEF solution. Creating the final DEF product is simple. All the DEF distribution centre needs to do is dissolve the solid urea in water at the desired concentration.

Dry flash production of 'super granules'

Farmers in some regions use large-sized urea 'super granules' – also known as *Guti* urea (Figure 3). These are conventionally produced by compacting the crushed fragments of urea prills. Super granules improve fertilizer use efficiency as they release nitrogen more slowly when added to soil because of their higher volume/surface area ratio.

Dry flashing offers a more cost-effective approach to *Guti* urea production as it makes prilling and then crushing unnecessary (Figure 4). The resulting super granules also have a lower biuret content than those made from crushed prills. The urea obtained from dry flashing is formed into super granules in a compacting machine which compresses the powder into a chosen shape (Figure 5).

PHOTO: STAMICARBON

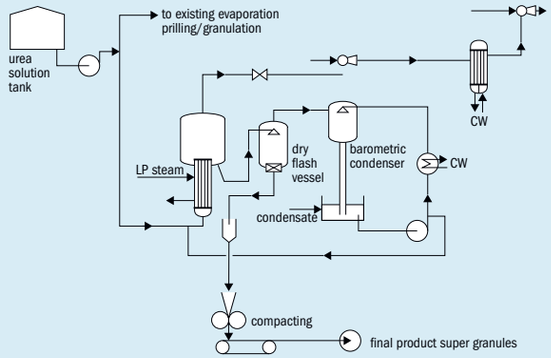
Fig. 3: Urea super granules.

The future of finishing

The relative simplicity of the dry flashing technology, *vis à vis* conventional granulation, is a key advantage. Simplicity also means low capex, with the investment requirements for a full-scale dry flashing plant likely to be just a fraction of the capital costs of a granulation plant. Once low utility consumption, zero emissions and significantly higher product quality (low biuret) are also factored in, it is clear why Stamicarbon believes that dry finishing may revolutionise fertilizer finishing.

Indeed, Stamicarbon's ultimate goal is to produce fertilizer-grade urea with dry flashing technology. The quality of the urea generated should be comparable or superior to currently-available granulated products – in terms of caking tendency, crushing strength, composition, etc. Also, in the dry flashing process, urea finishing consists of a single shaping step, avoiding the need for additional cleaning steps to minimise emissions. On top of that, it should be possible to manufacture fertilizer-grade urea by dry flashing at significantly higher output per production unit.

Fig. 4: **Dry flash process for production of super granules**



Source: Stamicarbon

Dry flashing technology

- Dry flashing opens up the possibility of a zero-emission (dust and ammonia) finishing technology for fertilizer-grade urea
- The product of the dry flashing technology can already be used for the production of DEF (*AdBlue*®) and other applications such as super granules (*Guti*)
- The dry flashing technology is ideal for capacity expansions at urea plants where the existing finishing section is operating at maximum output, or where emission legislation does not permit further conventional production expansion
- Dry-flashed urea contains very low concentrations of biuret, allowing it to be used in other applications outside of the traditional fertilizer market
- Dry flashing reduces capex requirements for urea production
- Dry flashing opens up new possibilities by allowing the shape, size and properties of urea particles to be precisely tailored to match specific end-use requirements. ■

SOURCE: STAMICARBON

Fig. 5: Example compacting equipment for production of super granules.

Table 1: **Permissible exposure limits as defined by different authorities**

	Specification	mg/m³ (ppm)
USA (Occupational Safety and Health Administration – OSHA)	PEL	0.92 (0.75)
EU / Germany (TRGS 900)	PEL	0.37 (0.3)
USA (National Institute for Occupational Safety and Health – NIOSH)	REL	0.02 (0.016) *(10h-TWA)*
	IDLH	24.56 (20)
	CREL	0.12 (0.1)
USA (American Conference of Governmental Industrial Hygienists – ACGIH)	TLV-C	0.37 (0.3)

TWA: eight-hours time weighted average
REL: recommended exposure limit
CREL: ceiling recommended exposure limit
PEL: permissible exposure limit
IDLH: immediately dangerous to life and health
TLV-C: threshold limit value ceiling

Source: thyssenkrupp

Table 2: **Comparison of product quality for urea granules treated with urea formaldehyde versus thyssenkrupp Fertilizer Technology's alternative additive**

	Treated with UFC (UF80)	Treated with alternative additive
Total nitrogen, wt-%	> 46.2	> 46.2
Biuret content, wt-%	0.7-0.8	0.7-0.8
Formaldehyde, wt-&	0.4	0
Alternative additive, wt-%	0	~ 0.2
Moisture, wt-%	0.2-0.3	0.2-0.3
Crushing strength, kg	4.1 on ∅ 3.15 mm	>4.1 on ∅ 3.15 mm
Caking tendency		same or less
Dust, %		same or less
Application	fertilizer	fertilizer, DeNOx, technical, cattle feed

Source: thyssenkrupp

Formaldehyde-free urea granules

Fertilizer use accounts for more than 80 percent of urea production, which currently exceeds 180 million t/a. Fertilizer-grade urea, in the form of granules and prills, is generally treated with formaldehyde. This is mostly introduced as a urea-formaldehyde additive, such as *UF80* and *UF85*.

These urea-formaldehyde additives maintain granulation process stability. They act to:

- **Control process parameters** such as granule growth rate and limit dust formation during production
- **Ensure good product quality**, including high crushing strength, low dust content and resistance to caking.

Using formaldehyde as a process aid is potentially problematic, however, as it has been a suspected carcinogen for more than three decades. Although the formaldehyde applied during granulation is a pre-condensate – in which most of the formaldehyde has already been reacted to form methylol urea – this still contains a substantial amount of free formaldehyde (23 wt-% or more). Extensive precautions are therefore required to ensure safe handling.

Formaldehyde's risk classification was increased in 2011 from "suspected of causing cancer" to "may cause cancer" by the International Agency for Research on Cancer (IARC), part of the World Health Organisation (WHO). The European Union (EU) also includes formaldehyde on its list of "substances of very high concern". The EU wants such compounds to be replaced as soon as possible and has placed them on its "substitute it now" list (www.sinlist.org).

Despite difficulties in defining an appropriate threshold value, authorities in the US and EU have set permissible exposure limits for formaldehyde based on the latest research evidence (Table 1).

An alternative additive

thyssenkrupp Fertilizer Technology (formerly Uhde Fertilizer Technology, UFT) has developed a new formaldehyde-free urea granulation additive with a performance that is comparable or superior to urea-formaldehyde (*Nitrogen+Syngas* 348, p36). This opens up new opportunities for extending the range of applications for urea products.

Lower dose, greater effect

thyssenkrupp tested potential new additives in different combinations and dosages, benchmarking these against urea-formaldehyde. From the results obtained, the company was able to identify an alternative additive which is at least as effective as urea-formaldehyde.

This newly-developed alternative is composed of different functional polymers in combination with a carboxylic acid. Unlike formaldehyde, all these constituents are classed as non-hazardous, and also hold several US Food and Drug Administration (FDA) approvals for direct and/or indirect food contact. As well as this, the functional

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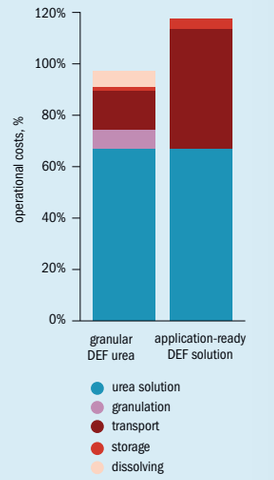
Table 3: **Requirements for automotive grade urea and values achieved with thyssenkrupp Fertilizer Technology's new alternative additive**

	Minimum	Maximum	Alternative additive
Urea content, wt-%	31.8	33.2	32.5
Density at 20°C, g/cm³	1.0870	1.0930	1.0903
Refracting at 20°C	1.3814	1.3843	1.3828
Alkalinity as NH_3, %		0.2	0.2
Biuret, %		0.3	<0.3
Aldehyde, mg/kg		5	<5
Insolubles, mg/kg		20	<20
Phosphate (PO_4), mg/kg		0.5	<0.5
Ca, Fe, mg/kg		0.5	<0.5
Cu, Zn, Cr, Ni, Al, mg/kg		0.2	<0.2
Mg, Na, K, mg/kg		0.5	<0.5

Source: thyssenkrupp

Fig. 6: **Production costs for DEF via granular urea and DEF solution**



Source: thyssenkrupp

polymers are generally exempted from the EU's REACH scheme. The carboxylic acid is also classified as non-hazardous under European regulations.

Valuably, the alternative additive can deliver granular urea products of a quality that is comparable to that obtained with formaldehyde at less than half the dosage (Table 2). Furthermore, the absence of formaldehyde means the products are suitable for additional end-uses and not solely restricted to the fertilizer market.

Industrial applications

The industrial market for urea is growing at a faster rate than fertilizer-grade urea demand. Indeed, looking ahead, industrial demand is expected to account for almost half of the total rise in global urea demand over the short-term. This is mainly due to the rising urea usage in UF resins and DeNOx applications.

In particular, demand for diesel exhaust fluid (DEF), also known as *AdBlue®*, has exploded in recent years, with stricter nitrogen oxide emission for diesel vehicles being the main driver. The size of the global market for DEF is currently around 2.3 million tonnes. This strongly-growing market is expected to exceed four million tonnes by 2020.

Product quality is a key factor for current producers of fertilizer-grade urea who also wish to enter the DEF market. Urea used to produce DEF must meet the requirements of ISO 22241 or DIN 70070. Manufacturing a product containing no more than 5 ppm of aldehydes can be the main obstacle that producers need to overcome. The new alternative additive developed by thyssenkrupp Fertilizer Technology helps producers meets this and other DEF quality criteria as it is completely free of aldehydes (Table 3).

Delivering DEF in solid form

The alternative additive can be introduced during urea finishing simply by substituting the contents of the urea-formaldehyde tank. No additional equipment or mechanical modifications to the existing plant are necessary.

The production of urea in DEF-compliant solid form is another major advantage. The tonnages that need to be stored and transported are two-thirds less than for an application-ready DEF solution. There is a need to dissolve urea in deionised water subsequently to obtain the final DEF blend. But the transport cost savings for solid urea far outweigh the very low costs ($0.05-0.07/gallon) of dissolving it prior to sale (Figure 6).

Summary: formaldehyde-free urea

The case for substituting and eliminating formaldehyde in urea finishing is stronger than ever, due to its classification as a substance of very high concern that may cause cancer. Indeed, urea producers are already facing difficulties securing formaldehyde supplies due to stricter regulations. The newly-developed non-hazardous additive from thyssenkrupp Fertilizer Technology provides urea granulation plants with a safer alternative to formaldehyde. It also offers added-value by extending the range of urea applications beyond the fertilizer market. Furthermore, by eliminating formaldehyde, the new additive should turn urea plants into much healthier working places for operators.

Cold recycle granulation (CRG)

Green Granulation Technology (GGT), a leading Chinese fertilizer technology company, offers the cold recycle granulation (CRG) process (*Nitrogen+Syngas* 335, p47). The company's innovative proprietary granulation technology combines energy savings with a low investment cost (see box). To date, GCT has commissioned eight CRG plants across China, with a further four units under construction or in design, according to its website.

An enhancement to the CRG process – deep vacuum granulation – was introduced by GCT in 2016 (*Nitrogen+Syngas* 342, p56). This is designed to produce low biuret, formaldehyde-free urea granules for the DEF market. GCT is pursuing plans to design and build an industrial-scale deep vacuum plant, having successfully commissioned a mobile pilot plant previously. ■

Cold recycle granulation (CRG)

The CRG process

The cold recycle granulation (CRG) process comprises a fluidised bed granulator, containing hydraulic urea sprayers, operating in-line with a fluidised bed cooler (Figure 7). The granulator and cooler both function at the same bed thickness.

The cooler is divided into two sections. An air sieve incorporated in the first section removes hot fines. The remaining product is then cooled to final product temperature in the second section. The installation of water-cooled plates minimises the cooler's overall size.

On leaving the cooler, the oversize material and any remaining fines are removed by a screener to leave the final product. The cold oversize is crushed and recycled to the granulator, alongside the cold fines from the screener, together with the hot fines generated by the air sieve. Granulator air and cooler air is cleaned in two separate low pressure drop wet scrubbers. Dust emissions in the stack are reduced to 20 mg/Nm³ thanks to patented double-temperature scrubbing.

Innovative fluidised bed granulation

For the CRG process, GGT has been able to optimise the movement of material within the fluidised bed granulator. This allows more product to be handled without overloading the spray zone. Importantly, the patented spray system allows the granulator to operate at a lower-than-normal bed thickness. The sprayers are also able to use urea melt feed containing 4-5 percent water (95-96 percent urea). The acceptance of higher water content melt avoids the need for a second evaporation section upstream in the urea synthesis plant. This avoids additional construction costs and reduces power consumption (*Nitrogen+Syngas* 335, p47).

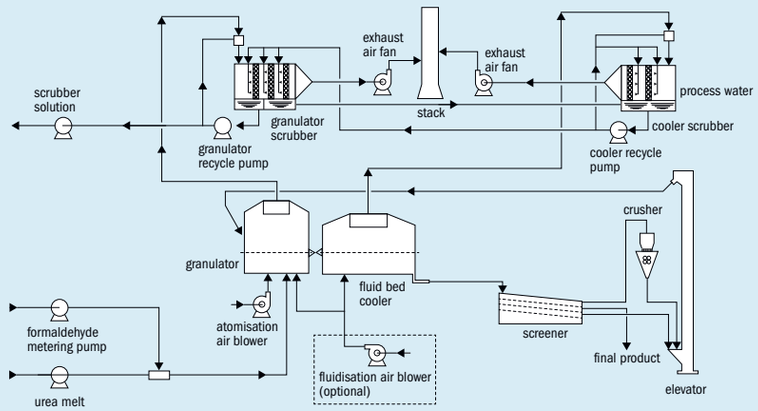
Low energy consumption

- The thinner product layer in the fluidised bed reduces the heating requirements of the fluidisation fan and the amount of air needed
- The granulator's high performance hydraulic urea sprayers operate at lower pressure and reduce the amount of air needed for atomisation
- The low pressure drop scrubbers also reduce power consumption.

Low investment cost

- Build height of the CRG unit is much lower (typically 27 metres) than a conventional urea granulation plant
- High construction strength is also only required in the lower part of the building
- The highest load bearing floor is needed at 17 metres to support the granulator with heavy vibrating screens located beneath this
- The granulator and cooler both have low strength requirements as they operate at low pressure
- The bucket elevator is smaller than usual, only 30 percent of standard capacity, as it only needs to lift fines and crushed oversize
- Less air ducting is required, as the scrubbers are designed and configured so that air enters from the top and leaves from the side ■

Fig. 7: **The coldy recycle granulation (CRG) process**



Source: Green Granulation Technology

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PHOTO: AGRA GROUP

Agra Group manufactures speciality fertilizers for the European and wider global market. The company, as one of the leading suppliers in the Czech Republic, offers a novel and innovative urease inhibitor, *StabilureN*®, as part of its product portfolio.

Agra Group, the Czech innovator

Agra Group a.s. was established in 1992 and is headquartered in Střelské Hoštice in the Czech Republic. The company manufactures and markets speciality fertilizers and is one of the leading suppliers to the Czech market. In recent years, it has diversified and expanded into international markets.

Agra collaborates closely with a number of research institutes and university agricultural departments. This has enabled the company to develop and fully-commercialise new plant nutrient technologies and products.

StabilureN®, an NBPT-based inhibitor developed by Agra, is one example of the company's approach to R&D. This product can be used with granular urea, as well as liquid urea ammonium nitrate (UAN) and urea ammonium sulphate (UAS), to increase the use efficiency of soil-applied nitrogen.

StabilureN® is offered by Agra in two forms. *StabilureN*® *TS25*, a formulation containing 25 percent NBPT, is used to coat granular or prilled urea, while *StabilureN*® 30, a formulation with 30 percent NBPT, is designed for liquid UAN and UAS fertilizers.

Agra markets urea coated and stabilised with *StabilureN*® under the brand name *UREA*$^{stabil®}$. Numerous experiments have shown that *StabilureN*® distributes NBPT extremely uniformly when applied to urea. As well as coating urea granules and prills efficiently and with ease, *StabilureN*® has excellent miscibility with UAN and UAS.

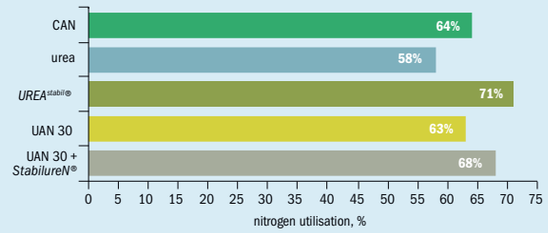
NBPT (N-(n-butyl) thiophosphoric triamide) is widely used as an urease inhibitor additive. What makes *StabilureN*® different is the incorporation of a novel patented solvent. This has the ability to transform waxy NBPT into a clear solution. The solvent, which is organic-based and covered by a worldwide patent, provides *StabilureN*® with significant advantages over other NBPT-based products, according to Agra.

The addition of *StabilureN*® to urea-based fertilizers significantly decreases soil urease enzyme activity. This prevents nitrogen losses by postponing the conversion of NH_2 in soil for several weeks. This protects nitrogen until it can percolate deeper into the soil profile, either through irrigation or during the first effective rainfall after application (i.e. precipitation of least 5 mm).

Essentially, *StabilureN*® preserves and protects nitrogen, allowing much more of the fertilizer's original nutrient content to be taken up by plants – either directly as NH_2 or after hydrolysis to NH_4^+ – or be held in the soil by sorption for later uptake.

It is always difficult to predict how soon rainfall will occur after fertilizer application. However, the use of *StabilureN*® should ensure that soil-applied urea remains unchanged until rain or irrigation helps nitrogen enter the root zone. The resulting reduction in nitrogen losses improves the economics of urea application, making fertilizer inputs more cost-effective for the farmer. Improved nitrogen management and higher nitrogen use efficiency also provide higher and more stable crop yields, as well as reducing environmental pollution.

Fig. 1: **Nitrogen utilisation by winter wheat: Czech field trial results 2016***



Source: Crop Research Institute

European winter wheat trials

The effectiveness of *StabilureN*® as an urease inhibitor for urea and UAN has been demonstrated by European trials on winter wheat. These were carried out by the Czech Crop Research Institute at Ruzyně near Prague in 2016. The trials compared the percentage nitrogen utilisation for standard urea and UAN 30 versus the same two products treated with an urease inhibitor, *UREA*$^{stabil®}$ and UAN 30 + *StabilureN*®. To provide a reference, trial results were also recorded for calcium ammonium nitrate (CAN), a popular but more expensive nitrogen fertilizer.

> **The effectiveness of *StabilureN*® as an urease inhibitor for urea and UAN has been demonstrated by European trials on winter wheat.**

All five nitrogen fertilizers were applied to winter wheat at an identical rate (60 kg N/ha) at the beginning of flowering, this timing being ideal for rainfall which arrived 6-9 days after fertilizer application. Nitrogen utilisation by the wheat grain was then determined by stable isotope (^{15}N) labelling.

The urease inhibitor *StabilureN*® improved the percentage nitrogen utilisation of winter wheat for both urea and UAN 30, trial results show (Figure 1). The two *StabilureN*®-treated products were also found to have a beneficial effect on winter wheat grain yields.

Ethiopian crop trials

Agra has a long-standing collaboration with the Ethiopian Institute of Agricultural Research (EIAR). The EIAR tested the effects of *UREA*$^{stabil®}$ on crops under field conditions between 2015 and 2018. These included field trials on wheat, barley, maize, rice and teff. A variety of different application rates and timings for *UREA*$^{stabil®}$ were investigated. Results obtained were compared to those for standard urea under identical conditions.

Findings to date have shown that *UREA*$^{stabil®}$ applications delivers higher grain yields and better economic returns in Ethiopia's farming regions, where soils typically suffer from a moisture deficit. In south Tigray, for example, *UREA*$^{stabil®}$ at an application rate of 96 kg N/ha provided the highest wheat grain yields. This was achieved by applying *UREA*$^{stabil®}$ at planting and through later split applications. ■

COMPANY PROFILE

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Young professionals

The International Fertilizer Association (IFA) is helping to fully develop the career potential of younger employees through its Young Professionals initiative. This is providing a new generation of industry professionals with access to mentoring and career development advice. It also gives individuals a chance to network with their peers, as well as subsidising attendance and participation at international conferences.

To support IFA's new initiative, *Fertilizer International* magazine is running a series of profiles featuring industry young professionals. These highlight the wide range of attractive and rewarding career options available to young people in the fertilizer sector. In this issue, Maria Antip of International Raw Materials talks to us about her career.

PHOTO: IFA

Maria Antip, 30, market research analyst

How did your career in the industry start?
Well, you could say I joined the fertilizer industry by accident! I became a policy analyst for the International Fertilizer Association (IFA) back in 2013. At the time, I was simply a young economics graduate with an interest in sustainable development wishing to get on an international career path.

What achievement are you most proud of?
Increasing ammonium sulphate sales in Madagascar by 133 percent last year is a great source of pride. That's a real accomplishment in a small market where ammonium sulphate is the only domestically-produced fertilizer. Getting people to choose a cheaper, local source of nitrogen over costlier imported urea took a lot of persuasion. We needed to educate everyone – regulators, wholesalers, retailers and farmers – and put together a small sales team with an agronomist to pull this off.

What do you find most rewarding about your job?
So far, I'd single out my role in helping develop the fertilizer market in sub-Saharan Africa. As a region, Africa will continue to be the biggest opportunity for this industry – given population growth trends and the availability of arable land etc.

I also enjoy the human development aspect of my job too. The fertilizers we provide are an essential input. They enable farmers to grow their incomes, educate their children and improve their livelihoods. That really appeals to me.

What hurdles have you had to overcome?
I guess the biggest hurdle was moving from IFA to the commercial side of the business. My focus at IFA was on macro policy trends. So having to hone-in on operations and logistics instead – with the ultimate goal of moving tonnages into the market – was a difficult switchover at first.

But, after a steep learning curve, I have grown into my current role. I'm now comfortable with cost structure mapping and all the other commercial tools of the job.

How do you get the best from yourself and your colleagues?
I enjoy travelling and doing site and customer visits. So that's what motivates me. These visits allow me to demonstrate the value of a project. Plus they also give me the chance to show how my participation can add value too.

As for motivating others, giving credit is incredibly important. Saying a simple 'thank you' often suffices. But putting that in writing in a short note also goes a long way – both with my peers and the small team I manage.

Has mentoring been important to you?
I was lucky to join the industry at a time when younger people and women were coming to prominence. At IFA, it was a particular pleasure to serve under Esin Mete, the fertilizer industry's first female president. She has been instrumental in my learning. It was Esin who give me the confidence to aim high in my career and earn a seat at the table. In my current role at International Raw Materials, I've also been fortunate to work across the business and travel widely. That's given me the chance to draw on the experience of the many professionals I've encountered.

Will your job and the industry change in future?
The fertilizer industry is becoming increasingly digitised. That's a trend across all industries. While the sector is currently lagging, I still expect to see a dramatic shift and the widespread adoption of smart tools in the next decade. Companies that can capitalise on this by offering bundled services to customers – not just a commodity or a technology – will find more success in my opinion. In terms of future changes to the workplace, I expect employees with multiple competencies to have the upper hand – an agronomist with good programming skills might be one example.

Would you recommend a career in the sector to others?
Yes, but you need to network and build strong relationships. That would be my key advice, as everyone knows everyone in this industry. What will help get that next business deal or career move? It's about good rapport and not burning bridges in my view.

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phosphates & potash INSIGHT

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Phosphoric acid purification

Phosphoric acid can be purified by chemical methods, by solvent extraction or through ion exchange. Selecting the right purification technique depends on the end application and the level of acid purity required, as Prayon process engineer, **Sébastien Havelange**, explains.

Phosphoric acid is typically produced commercially by the wet process route. This involves reacting phosphate rock with concentrated sulphuric acid and water. The 'green' phosphoric acid (ex-filter) initially obtained has a P_2O_5 concentration between 25-42 percent, depending on the exact process route (dihydrate, hemihydrate, double crystallization etc.), and an SO_3 content of around 1-2 percent.

Classically, green acid is subsequently concentrated (up to 54 percent P_2O_5) to obtain merchant grade acid (MGA). Even higher acid concentrations are necessary (70 percent P_2O_5) for production of ammonium polyphosphates.

Phosphate rock is a naturally-occurring and therefore variable raw material. Each ore deposit has its own mineral and chemical fingerprint, possessing an almost unique set of impurities at different concentrations. These impurities will – to a greater or lesser extent – persist throughout mining, beneficiation and chemical processing. After the separation of calcium sulphate, for example, they will remain present in the green phosphoric acid (ex-filter), and will also be found in higher concentration phosphoric acid such as MGA.

The purification of green phosphoric acid is not usually necessary for the production of most phosphate fertilizers. Some companies are, however, partially purifying MGA.

Reducing impurities in MGA prior to shipping can be worthwhile, for example, as it prevents undesirable sludge from forming in transportation containers. In most merchant acids, these sludges contain so-called 'X-compounds' (formula $(Fe,Al)_3H_{14}(PO_4)_8.2H_2O$), gypsum and fluosilicates.

In contrast, phosphoric acid purification is generally universal and mandatory when higher-end fertilizer products, feed or food additives are being manufactured.

In this article, we describe the following three purification techniques:
- Chemical purification for sodium tripolyphosphate (STPP) and diammonium phosphate/monoammonium phosphate (DAP/MAP) production
- Solvent extraction
- Purification by ion exchange.

In all three techniques, the impurities introduced with the acid are separated between a final purified product and liquid and/or solid secondary flow(s) containing all the non-desirable elements. These secondary flows are generally of low value or no value but can be valorised by incorporating into the feed of a low-grade fertilizer plant.

Whichever technique is selected, the purification process is divided into the following 2-3 stages:
- **Acid pre-treatment:** acid is treated to bring it up to specification for the next step. Solids, sulphate, fluorine and sometimes arsenic are usually removed from the acid.
- **Core purification:** most of the impurities are removed at this stage.
- **Post-treatment:** acid is adjusted to the final technical specification.

Chemical purification – STPP production

Sodium tripolyphosphate (STPP, $Na_5P_3O_{10}$) was traditionally produced using phosphoric acid derived from the thermal decomposition of phosphate rock. The following chemical purification method is an alternative wet production route.

Pre-treatment: The technique requires two-stages of pre-treatment to reduce the acid's sulphate and arsenic content (Figure 1). Their removal during pre-treatment as gypsum and sulphide improves settling rates and slurry filterability during the main chemical purification stage.

Sulphate is firstly removed by adding phosphate rock (or lime, chalk or barium) to warm phosphoric acid in a mixing tank. Gypsum or barium sulphate precipitates via a reaction with free sulphate:

$$3SO_4^{2-}(l) + Ca_3PO_4(s) \rightarrow 3CaSO_4(s) + 2PO_4^{3-}(l)$$

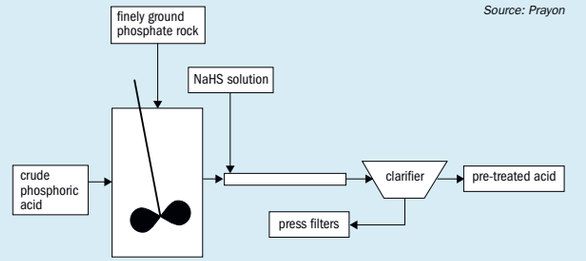
Arsenic is then removed by adding sodium hydrosulphide (NaHS) to precipitate arsenic sulphide:

$$2As^{3+} + 3NaHS \rightarrow As_2S_3 + 3Na^{+} + 3H^{+}$$

A clarifier recovers the precipitated solids generated by both pre-treatment steps. A concentrated slurry containing impurities is removed from the bottom of the clarifier and filtered to recover P_2O_5.

Fig. 1: **Phosphoric acid pre-treatment for chemical purification**

Source: Prayon



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Prayon's solvent purification

This process is one of the most widely-applied commercial solvent purification methods. The use of a set of proprietary extraction columns provides good flexibility as it allows different quality acids to be purified (Figure 2).

Pre-treatment

The acid needs to be pre-treated before solvent extraction takes place. Pre-treatment includes the removal of arsenic by sodium hydrosulphide, sulphate removal using phosphate rock, as well as a rough fluorine removal step. The acid also has to be pre-filtered through activated carbon to prevent solvent contamination.

Purification

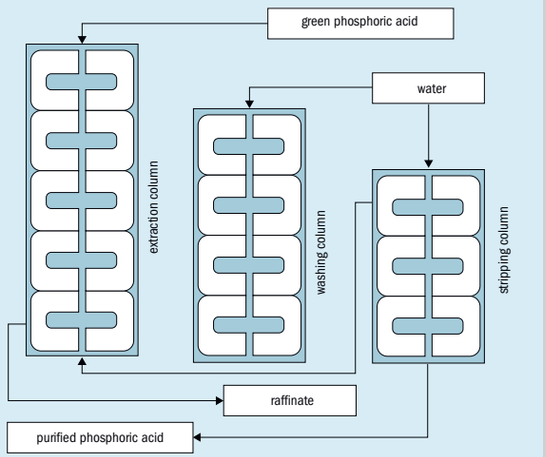
Pre-treated acid is cooled to 10-15°C and fed to the extraction column. The initial extraction occurs within this column when the solvent comes into contact with acid, flowing counter-currently, at a volume ratio of about five to one, respectively.

For a 50,000 t/a capacity plant, the extraction column is about 2.5 metres by 8 metres in size and is divided into five equilibrium stages. Each stage extracts into the solvent between 50-80 percent of the P_2O_5 present in the acid, the exact percentage depending on the quality of the green phosphoric acid.

After exiting the extraction column, the organic solvent passes through a washing column to liberate the phosphoric acid it contains. Purified acid is released inside the column by washing the solvent with a counter-current flow of water. The purified acid then passes through a stripping column to recover any solvent present. After this, the purified acid is filtered using activated carbon to remove any organic matter. It is finally concentrated to 61-62% P_2O_5 in a steam-powered vacuum evaporator to produce a technical-grade acid. A further defluorination step is necessary if the final product needs to meet food-grade acid quality requirements.

The process leaves behind a depleted acid containing most of the impurities. This is generally stripped to recover solvent before being sent to a fertilizer production plant where it is incorporated as part of the feed. ■

Fig. 2: **Prayon's solvent extraction purification process**



Source: Prayon

> **Phosphate salts used as food additives need to have extremely low impurity levels.**

Purification: The general principle is to precipitate out impurities through acid neutralisation using sodium hydroxide or sodium carbonate. The purified liquor obtained is then dried and calcined to obtain STPP:

$$NaH_2PO_4 + 2Na_2HPO_4 \rightarrow Na_5P_3O_{10} + 2H_2O$$

Dosing with sodium precipitates a wide range of compounds. Fluorine is removed first by fluosilicate precipitation (Na_2SiF_6 mainly, but also K_2SiF_6 and $MgSiF_6$). Active silica may need to be added at this stage to achieve the desired F/Si ratio of six. Silica is a natural constituent of the acid, with the amount present mainly depending on the phosphate rock type used.

Other impurities are then removed through a second addition of sodium carbonate or hydroxide. This precipitates impurities in phosphate and/or hydroxide form. The Na/P ratio during this step reaches 5/3. That compares to a target Na/P ratio of 0.15 in the final liquor.

By this stage, the purification process is almost finished, with the destruction of organic compounds being the only remaining step. This can be achieved using various oxidising agents such as hydrogen peroxide, sodium chlorate or sodium nitrate. Any residual organics still present are absorbed with activated carbon. A typical analysis of the final liquor obtained after solid/liquid separation is shown in Table 1.

The last stage in STPP production involves concentrating the sodium phosphate solution to the solids content required by the atomiser unit.

Chemical purification – DAP/MAP production

Chemical purification for diammonium phosphate (DAP) and monoammonium phosphate (MAP) production is similar to that for STPP, although ammonia is used for acid neutralisation instead of sodium carbonate or sodium hydroxide. Ammonium phosphate is then crystallised from the purified liquor obtained.

Pre-treatment: the sulphate and arsenic removal steps are identical to those for STPP production described above.

Table 1: **Typical analysis of chemically purified sodium phosphate liquor for STPP production**

Al	3.9 ppm	Fe	7.7 ppm	Na/P	1.67
Ca	25.4 ppm	K	298 ppm	P_2O_5	20.4%
F	2170 ppm	Mg	12.4 ppm	SiO_2	650 ppm

Source: Prayon

Purification: In the core purification step, dosing with ammonia neutralises phosphoric acid to precipitate a wide range of salts. As with STTP production, fluorine precipitation can be optimised if necessary by adding sodium and active silica. Organic matter is removed by the same methods used in STPP production.

The clear acid obtained is concentrated further. Water-soluble MAP or DAP are then crystallised directly from the solution and separated and recovered using centrifuges.

The quality of DAP or MAP obtained is largely determined by the total phosphate in the final product and, importantly, the proportion that is water-soluble. Water-soluble phosphate content is mainly influenced by the iron, aluminium and magnesium content of the finished product. In ammoniated products, these elements lock-up phosphate by forming insoluble salts. These are similar in composition to 'X-compounds' (formula $(Al,Fe)NH_4H_{14}(PO_4)_8.4H_2O$) and struvite ($MgNH_4PO_4.6H_2O$).

Purification by solvent extraction

Phosphate salts used as food additives need to have extremely low impurity levels. Specific impurities such as arsenic, fluorine and heavy metals may need to fall below certain threshold values. Other requirements, including colour of products and the levels of other elements (e.g. sodium and potassium), can also be specified by food industry customers for products such as sodium polyphosphate.

Solvent extraction is the only proven purification technique able to meet such stringent purity requirements. The most commonly-applied method for purifying phosphoric acid involves liquid/liquid extraction using organic solvents.

The general principles of solvent extraction are the same, despite the existence of many different patents, each of which use their own specific solvent or mix of solvents. Generally, phosphoric acid is firstly extracted from a feed flowing in one direction by a flow of solvent moving in the opposite direction and is later re-extracted from the solvent using water.

Extraction efficiency is improved if the acid is highly concentrated. Phosphoric acid feed concentration is usually kept in the range 48-60 percent P_2O_5 because of this. The selection of the right solvent is influenced by factors such as:

- Loading capacity
- Volatility, stability and reactivity
- Density and viscosity
- Selectivity – with respect to both phosphoric acid and impurities.

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Ion Exchange Resin

The key advantage of using ion exchange resins for purification is their selectivity. The process can be adjusted and tailored to reflect the impurities present by choosing a particular resin type to remove the unwanted element or elements.

In ammonium polyphosphate manufacture, for example, magnesium is the key contaminant. This is because the precipitation of magnesium pyrophosphate affects the quality of the end product. This problem can be solved by using an ion exchange resin to selectively remove magnesium present in the raw phosphoric acid.

Valuably, ion exchange resins, due to their ability to isolate undesirable cations, can allow the production of the required grade of phosphoric acid from less pure – and correspondingly cheaper – phosphate rock sources.

Acid purification via the ion exchange resin route is suitable for both weak and concentrated acids. Some technology suppliers, however, prefer to work with weak acid (25-30 percent P_2O_5). This is because weak acid is:

- Less viscous and easier to pump, compared to concentrated acid
- Phosphoric acid losses are lower
- Dilution from regeneration/washing can be easily compensated for by using downstream concentration units.

In any case, purification of weak acid is a necessary first step if this is very impure – i.e. the minor element ratio (MER) is greater than > 0.15 – to allow subsequent concentration, maturation and clarification.

Pre-treatment: For ion exchange resins, this step consists of maturation (to desaturate the acid) and clarification of the phosphoric acid. Resins are very sensitive to clogging – making clarification necessary to avoid rapid and significant falls in column performance. Acid temperature is also raised before it enters the purification column as an extra measure to prevent the clogging of resins.

Purification: An acidic type of extraction resin loaded with positive hydrogen ions is needed for effective purification. These hydrogen ions (H+) are progressively exchanged with elemental impurities (Al^{3+}, Fe^{3+} and Mg^{2+}) present in the acid as the purification process proceeds. This allows the dissolved phosphate associated with the elements to convert to phosphoric acid, as follows:

$$3\text{resin}\bullet H^+ + \text{impurity}\bullet PO_4 \rightarrow 3\text{resin}\bullet\text{impurity} + H_3PO_4$$

Beneficially, the treated acid contains fewer impurities, more phosphoric acid and also has a greater ammoniation potential. On leaving the ion exchange purification system, the treated acid can therefore be returned to its normal processing route – typically acid concentration followed by further downstream processing.

The resins eventually lose their purification abilities when they become fully loaded and need flushing and washing. The diluted phosphoric acid produced at this stage can either be routed for downstream processing, alongside the purified end-product, or be recycled back to the phosphoric acid production plant.

After washing, the resin needs to be regenerated with a strongly acid solution as it is still loaded with impurities. Sulphuric acid is generally used, as it is readily available at phosphoric acid plants, at a concentration of between 10-30 percent, depending on the resin loading and impurities. Regeneration proceeds as follows:

$$\text{resin}\bullet\text{impurity} + H_2SO_4 \rightarrow \text{resin}\bullet 2H^+ + \text{impurity}\bullet SO_4^{2-}$$

> **The key advantage of using ion exchange resins for purification is their selectivity. The process can be adjusted and tailored to reflect the impurities present.**

The sulphuric acid takes the ions extracted by the resin and transfers these back into solution as soluble (Al, Fe, Mg) sulphate salts.

The columns need to be flushed and washed again after regeneration. The resulting regeneration solution is either disposed of or sent for further processing, as the sulphate salts present may have value as a source of secondary/tertiary nutrients in fertilizers.

Ion exchange was initially a batch process – so-called fixed-bed or batch ion exchange (IX). Individual process steps needed to be carried out back-to-back, in a start-stop manner, using a series of complex valves and manifolds. This greatly limited process flexibility and the ability of ion exchange resins to process large volumes of phosphoric acid efficiently, quickly and economically. Thankfully, the development of continuous ion exchange (CIX) in recent times has allowed all of the above stages (loading, washing, regeneration, air purging, washing, etc.) to be carried out simultaneously. This has increased purification capacity exponentially compared to older batch IX processes.

Florida-based K-Technologies, in collaboration with Prayon Technologies, are currently implementing its patented CIX process as part of the El Wady phosphate project in Egypt. This will incorporate purification technology, based on conventional, currently-available ion exchange resins, into the project's new phosphoric acid production lines to reduce the minor element (Fe_2O_3, Al_2O_3, and MgO) content of the raw acid.

Conclusion

This article briefly describes several different approaches to the purification of phosphoric acid. How suitable these will be for a particular end application depends on the level of purity that needs to be attained. The high purity achieved by solvent extraction, for example, makes it suitable for feed or food phosphate production. Chemical purification, using sodium hydroxide or ammonia neutralisation, in contrast, is well suited to the preparation and production of technical-grade phosphates (STPP, MAP or DAP). Finally, ion exchange resins, being more selective, can effectively target and remove magnesium (and other undesirable elements) during the production of fertilizer-grade DAP and superphosphoric acid (SPA) used to manufacture ammonium polyphosphate fertilizers.

All four processes – despite having fundamental differences – require a pre-treatment step to prepare the green acid for purification. Further post-treatment steps may also be necessary, such as defluorination, to meet the technical specifications of downstream processes and products. ■

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Great granulation

PHOTO: FEECO

Granulated phosphate fertilizer produced by FEECO equipment.

Quality equipment holds the key when it comes to fertilizer granulation, says **Shane Le Capitaine**, FEECO International process sales engineer. He explains the importance of granulation drums, pipe reactors, pug mills, rotary dryers/coolers, hammer mills and coating drums in the granulation process.

Equipment quality: the key factor

Phosphorus is an essential and irreplaceable nutrient in crop production. The combination of dwindling finite resources and growing demand for higher-quality products makes the production of granular fertilizers from phosphates a critical endeavour.

Phosphorus resources need to be utilised to the fullest extent. That applies to both the production of phosphate fertilizers from primary rock sources, and to phosphorus recovery from secondary waste sources. And while many factors will affect the overall efficiency of a given process, one aspect that should not be overlooked is the quality of equipment.

Installing high-quality equipment helps to prevent downtime, reduces maintenance, and enhances production efficiency. In this article, we provide a basic overview of the following key items of equipment used in phosphate fertilizer granulation:

- Granulation drums
- Pipe reactors
- Pug mills
- Rotary dryers
- Rotary coolers
- Hammer mills
- Coating drums.

Please note that the features of some equipment may be specific to FEECO International.

Granulation drums

Granulation drums (Figure 1) are the centrepiece of most phosphate fertilizer operations. Incredibly versatile and capable of processing a wide array of materials, granulation drums typically serve two purposes in this setting: granule formation and completing the chemical reaction.

How granulation drums work: In phosphate fertilizer production, granulation drums tumble pre-neutralised materials in a rotating drum on a bed of recycle. Phosphoric acid and ammonia are reacted together when monoammonium phosphate (MAP) or diammonium phosphate (DAP) is being produced. These reacted materials are in the form of a slurry, and as this cools and solidifies, the tumbling action forms this into granules. The drum is also set at a slight angle, allowing material to move through the unit under gravity.

Tumbler flights are commonly incorporated into the drum's design. These improve product uniformity by using a bed tumbling action to agitate materials. Ammonia spargers are another design feature that help control granulation within the drum and complete the reaction in the material bed. The use of flexible and corrosion-resistant drum liners also reduces or eliminates material build-up on drum walls, decreasing the potential for corrosion.

Pipe reactors

Pipe reactors (Figure 2) are an acid-base reaction vessel sometimes used in the production of MAP or DAP fertilizers. Although not an essential requirement in any system, pipe reactors can provide significant energy savings – by capturing the heat of the reaction to supplement some of the energy required for drying.

PHOTO: FEECO

Figure 1: FEECO Granulation drum being prepared for shipment.

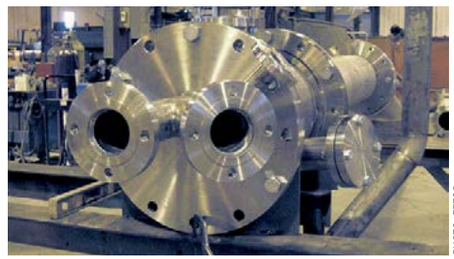

PHOTO: FEECO

Figure 2: FEECO Pipe reactor in fabrication.

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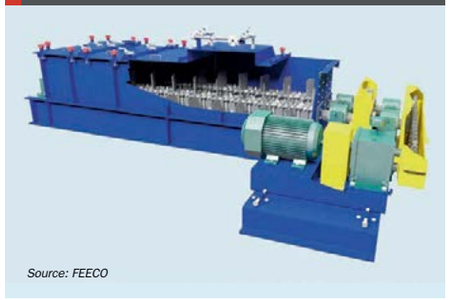
Fig. 3: **3D model of a FEECO pug mill**



Source: FEECO

Figure 4: FEECO Rotary dryer.

PHOTO: FEECO

How pipe reactors work: Pipe reactors are integrated directly into the granulation drum. Phosphoric acid is fed into one side of the reactor, with gaseous or liquid ammonia fed into the reaction chamber. The resulting hot 'melt' produced is sprayed onto a bed of recycle material in the rotary granulator. Captured reaction heat is used to help dry the material as it tumbles through the granulator and solidifies, reducing the drying burden on the post-granulation dryer.

Pug mills

Pug mills (Figure 3) are also known as paddle mixers. They are used in granular fertilizer production to mix the recycle with raw material feedstock prior to the granulation drum. Pug mills, by thoroughly mixing raw materials and recycle in advance, leave the granulation drum with the sole job of growing and polishing the granules. Indeed, in the production of ammoniated nitrates, the pug mill – often called a blunger in this setting – may serve as the sole granulation device.

How pug mills work: pug mills are a horizontal mixer featuring pitched paddles attached to dual rotating shafts. They thoroughly mix materials by using a folding and kneading action to yield a homogeneous blend – the end result being a highly uniform product.

Rotary dryers

Rotary dryers (Figure 4) are in widespread use throughout the phosphates industry, being employed to dry phosphate rock as well as granular fertilizer products.

How rotary dryers work: Rotary dryers cascade material in a rotating drum in the presence of a hot gas. Flights (lifters) – by raising the material, carrying it over and then allowing it to fall – are used to create a 'curtain' of material falling through the hot gas stream. Dryers are specifically designed around the unique process characteristics of the material being handled. The objective is to produce an optimal curtain which, in turn, maximises heat transfer efficiency.

Rotary coolers

Rotary coolers are also widely used in the processing of phosphate fertilizer products. Coolers are needed to bring down the temperature of the material after drying, allowing it to be handled or bagged. Cooling is also an essential step for preventing the caking of fertilizers during subsequent storage.

How rotary coolers work: rotary coolers have a similar action to rotary dryers. Both types cascade material in a rotating drum and use lifting flights to create a curtain that optimises heat transfer efficiency. However, rotary coolers use chilled or ambient air instead of heated air to lower the temperature of the material.

Fig. 5: **3D model of a FEECO hammer mill**

Source: FEECO

Hammer mills

Hammer mills (Figure 5) are used for crushing oversize granules so they can be returned back to the process as recycle.

How hammer mills work: Hammer mills use hammers and/or chains attached to a spinning shaft to break down oversize product. Hammer mills efficiently convert oversize agglomerates into the desired product size range (minus 4 mesh to plus 20 mesh).

Coating drums

Coating drums are sometimes used in MAP and DAP production to apply a property-enhancing coating agent to the exterior of granules. These coatings typically help prevent the dusting or caking of the fertilizer product during subsequent handling and storage.

How coating drums work: Coating drums – similar to granulation drums – operate by passing material through a rotating drum. A spray system releases the coating agent onto the material as it tumbles through the drum. Tumbler flights help to increase agitation and ensure a uniform coating.

Conclusions

The efficient granulation of phosphate fertilizers is becoming increasingly important. High-quality granulation equipment needs to be expertly designed and configured around the unique characteristics of process materials. This is essential if granulation plants are to operate at high output and maximum efficiency. ■

Potash project listing 2019

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

Plant/project	Type	Company	EPC/EPCM contractor(s)	Location	Product	Capacity ('000 t)	Status	Start-up date
AUSTRALIA								
Lake Way	G, LBE	Salt Lakes Potash		Western Australia	SOP	245	UC	2020
Beyondie	G, LBE	Kalium Lakes	DRA Global	Western Australia	SOP	82	UC	2020
BELARUS								
Petrikov	G, CM	Belaruskali		Gomel	MOP	1,500	UC	2020
Nezhinsky GOK	G, CM	Slavkaliy	China State Engineering Corp/Deilmann-Haniel	Lyuban	MOP	2,000	UC	2023
BRAZIL								
Cerrado Verde	G*, CM	Verde AgriTech		Minas Gerais	SG	500	UC	2019
CANADA								
Esterhazy K3	B, CM	Mosaic	Hatch/AMC	Saskatchewan	MOP	1,800	UC	2024
Bethune	G*, SM	K+S Canada		Saskatchewan	MOP	400	UC	2019/20
Jansen	G, CM	BHP	DMC Mining	Saskatchewan	MOP	2,000	UC	2023
Milestone	G, SM	Western Potash	Artisan Consulting/ AKITA Drilling	Saskatchewan	MOP	146	UC	2020
Wynyard	G, SM	Kamalyte Resources/ GSFC	Amec FW (Wood)	Saskatchewan	MOP	625	FS, P	N/A
Southey project	G, SM	Yancoal		Saskatchewan	MOP	2,800	P	2022
ERITREA								
Colluli	G, CM	Colluli Mining Share Company (CMSC)	DRA Global	Danakil	SOP	472	FS, P	2021/22
ETHIOPIA								
Yara Dallol	G	Yara/Liberty Metals & Mining/ XLR Capital	SNC-Lavalin	Afar	SOP	600	FS, P	N/A
Danakil Potash	G	Circum Minerals		Afar	MOP/SOP	2,000/750	FS, P	N/A
ISRAEL								
Dead Sea Works	B, LBE	ICL		Dead Sea	MOP	400	UC	2022
PERU								
SalSud	G, LBE	Salmuras Sudamericanas		Sechura desert	SOP	100	P	On hold
RUSSIA								
Volgakaliy I	G, CM	Eurochem		Volgograd	MOP	2,300	UC	2019
Volgakaliy II	G*, CM	Eurochem		Volgograd	MOP	2,000	P	2023
Usolskiy II	G*, CM	Eurochem		Perm	MOP	1,400	P	2022
Talitsky	G, CM	Acron (Verkhnekamsk Potash Company)		Perm	MOP	2,000	UC	2022/23
SPAIN								
Muga	G, CM	Highfield Resources/ Geoalcali		Navarra & Aragón	MOP	540	FS, P	N/A
UNITED KINGDOM								
Woodmsith Mine	G, CM	Sirius Minerals	DMC Mining/ STRABAG AG/Jacobs	North Yorkshire	Polyhalite	10,000	UC**	2021
UNITED STATES								
Sevier Playa	G, LBE	Cystal Peak Minerals		Utah	SOP	27.5	FS, P	2022

Notes:
Greenfield projects (G): generally, these must have reached the detailed/bankable feasibility study (FS) stage for inclusion.

Brownfield expansions (BE): capacity indicates incremental additions, not total capacity.

The following projects have not been listed as their curent status is unknown: ThaiKali, Thailand; SinoAgri, Laos; Kalium Mineracao, Brazil; Ochoa, New Mexico.

* Ramp-up/expansion ** Project under review

KEY

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

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

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

STATUS:
N/A Not available or provided

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The Williamson pit and evaporation ponds at the Lake Way project near Wiluna, Western Australia.

PHOTO: S04

Lake Way project, Western Australia

Salt Lake Potash (S04) is developing a sulphate of potash (SOP) operation at its Lake Way project near Wiluna in the northern goldfields of Western Australia (WA).

Australia has no domestic SOP producers currently. But this could be about to change with several companies now developing salt lake resources in the WA outback. Rapid progress at Lake Way this year has placed S04 at the head of the pack. This project is on-track to be the first in Australia to commercially extract SOP and bring this premium-grade fertiliser to market.

Construction of the first stage evaporation ponds (125 hectares) at Lake Way began in March. These ponds have now been completed and filled with super-saturated brine pumped out of the nearby Williamson pit, a legacy of historical gold mining. The brine, which contains high concentrations of SOP (25 kg /m^3), will be converted into solid salts by solar evaporation. The salts obtained will then be purified at Lake Way's processing plant. This is due to be commissioned towards the end of 2020.

Lake Way is expected to produce very high quality SOP. Pilot-scale tests carried out at the **Saskatchewan Research Council** in September yielded a high-grade (+53% K_2O), low chloride and highly water-soluble premium product. Importantly, total solubility and dissolution rate measurements confirmed that Lake Way SOP is suitable for use in drip irrigation systems.

The Canadian pilot plant tests consumed five tonnes of salt harvested from solar evaporation trials at Lake Way. To take advantage of the excess sulphate that occurs naturally in the Lake Way brine, potassium chloride was also added to increase the overall production of SOP.

The favourable economics of the Lake Way project were revealed by a recently completed bankable feasibility study (BFS). This confirmed that the project could be one of the lowest cost SOP operations globally. Operating costs of $205/t are projected for annual production of 245,000 tonnes over an initial 20-year period.

To achieve the premium pricing desired, the majority of Lake Way's SOP production is expected to be shipped to overseas markets, although the potential to dedicate part of the project's SOP output to supplying Australian farmers and distributors is being explored.

Constructing Lake Way will require capital investment of $173 million (including contingency), according to the BFS. The project is already well on its way to covering this capital cost. S04 has raised AUD 28 million in equity in the past 12 months, for example. In August, Australian finance house Taurus Funds Management also agreed to fund construction via a debt facility of up to $150 million.

S04 says Lake Way is an ideal site for it first SOP operation due to a number of infrastructure and logistical advantages. The project is located alongside a major regional highway and gas pipeline, for example, as well having access to the nearby Wiluna airstrip. Most of the project's tenements are granted mining leases. This allows S04 to start construction without going through a regulatory process to get these converted.

The company has ownership rights for another eight large potassium-rich salt lakes in the WA goldfields region. Its ultimate ambition is to expand SOP production beyond Lake Way's 245,000 t/a output by replicating this process and bringing additional lakes on-stream.

Tony Swiericzuk, S04's managing director, said he was extremely excited to be at the forefront of a major new export industry for Australia: "SOP produced from Western Australian salt lakes will be low cost, harnessing the Australian sun as the main energy input, and extremely viable compared to SOP produced using the Mannheim Process, which is approximately 60% of the market. We look forward to completing the steps required to bring Lake Way into production and establishing S04 as a reputable global supplier of premium grade fertilizer." ■

Muga project, Spain

The Muga potash project in Northern Spain is the flagship venture of Australian developer **Highfield Resources**. The project has an annual production target of 540,000 tonnes of muriate of potash (MOP) currently, with the potential to double output 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 $91/t (cost to port) are anticipated.

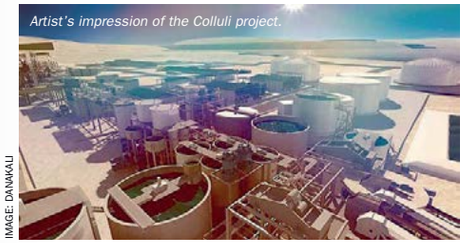
The project received its environmental permit from the Spanish government earlier this year. The DIA (Declaración de Impacto Ambiental) was granted by Spain's Ministry for Ecological Transition in May. This development is a major achievement for Highfield, as the company is now free to proceed with the project's execution and construction.

"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."

The DIA does come with conditions to minimise environmental impacts. But Highfield describes these as "standard practice in these types of environmental approvals".

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 committing to buying 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 at the start of the year. The company also renewed its memorandum of understanding (MOU) with contractor **Acciona**, who will construct the Muga mine, at the end of 2018. ■



Artist's impression of the Colluli project.

IMAGE: DANAKALI

Colluli project, Eritrea

Danakali Limited is developing the world-class Colluli potash project in the Danakil region of Eritrea, East Africa. Colluli has emerged as one of the most advanced and economically-attractive greenfield sulphate of potash (SOP) projects globally.

The project is 100 percent owned by the **Colluli Mining Share Company** (CMSC), a 50:50 joint venture between Danakali and the **Eritrean National Mining Corporation (ENAMCO)**. Colluli benefits from ore reserves of more than 1.1 billion tonnes. CMSC's initial focus is the production of SOP from this large, high-grade deposit, and marketing this as premium, chloride-free potash.

Colluli is an evaporite deposit and among the shallowest potash projects in the world. This allows for open-cut mining – a simple, low-cost and water-efficient method of potash extraction. The project is also located just 75 kilometres from the Red Sea coast.

Colluli will be developed in two stages (modules). Module I will produce 472,000 t/a of SOP, with Module II ramping-up to production of 944,000 t/a. The proposed mine is expected to have a 200-year life. Taking the project to production should take around two years, once funding is in place.

Danakali has now secured $200 million to develop the Colluli project. This was approved by the **Africa Finance Corporation** (AFC) and **African Export Import Bank** (Afreximbank) in August.

The funding announcement followed the appointment of Niels Wage as Danakali's new CEO in March. Wage – BHP's former vice president for potash – confirmed that the majority of the funding needed to construct and execute the project was now in place: "Final credit approval from leading development finance institutions AFC and Afreximbank… represents outstanding progress and a significant de-risking milestone for the Colluli project financing."

The credit approval follows the completion of a front-end engineering design (FEED) study in 2018, and the appointment of **DRA Global** as the project's engineering, procurement and construction management (EPCM) contractor. The FEED study confirmed that a post-tax net present value (NPV) of $902 million could be achieved with internal rate of return (IRR) of 29.9 percent for Modules I and II.

Danakali also signed an offtake agreement with major producer **EuroChem** last year. This guarantees cash flow for the project from future production. EuroChem will take-or-pay up to 100 percent of the production from Module 1 for ten years, with an option to extend for a further three years.

These important milestones are a sign of growing confidence in the Colluli project as it approaches the construction phase.

"With an almost 200-year mine life at an average production rate of 944,000 tonnes per annum, and the option to expand, Colluli is the largest and lowest cost SOP project currently being developed around the world," comments Niels Wage. ■

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Who's who in pumps and piping

We profile specialist suppliers of tailor-made pumps and piping systems to the phosphates and sulphur industries.

Whatever the process, fertilizer manufacturing generally involves the handling of highly abrasive and/or corrosive liquids and slurries. Industrial pumps, as vital components of any fertilizer production system, need to be robust and reliable enough to handle these.

Pumps are typically required to transfer a variety of fluids and suspensions from one stage of the production process to another. They need to cope with liquids over a wide range of temperatures, pressures and viscosities, often having to deal with different amounts and sizes of suspended solids too. Flow volumes and flow rates also vary greatly depending on the process.

The challenge for fertilizer manufacturers is choosing exactly the right pump for each step in the production process. In extremes cases, getting the pump design or specification wrong can even result in explosions – if there is insufficient flow and poor maintenance[1].

That makes selecting the correct type of pump, and ensuring pump capabilities closely match process requirements, critically important. In most cases, pump requirements are largely determined by the properties of the liquid or slurry, including:

- Temperature
- pH
- Chemical characteristics, including contaminants
- Solids content, including amount (g/l), hardness, density and particle size distribution.

Sulzer

Sulzer is a world-leader in pumping equipment and technology with a history dating back to 1834. Headquartered in Winterthur, Switzerland, the company operates from more than 180 production sites and service centres located in some 50 countries around the globe.

Sulzer manufactures and markets a wide range of pumps, mixers, and agitators for the sulphur and fertilizer industries. These durable and reliable pumps are used in the production of phosphate, potash and NPK fertilizers, acids and industrial chemicals.

Sulzer offers:

- Process pumps
- Slurry pumps
- Wear resistant pumps
- Self-priming pumps
- Gas removal pumps
- Axial flow pumps
- Vacuum pumps
- Sulphuric acid pumps
- Vertical pumps
- Submersible pumps.

These incorporate advanced materials, a wide range of shaft seals and different sealing systems. Operating efficiency is a key priority for Sulzer and the company prides itself on making extremely reliable pumps that can operate maintenance-free.

Sulzer estimates that shaft seals are responsible for around 60 percent of the operational problems with centrifugal pumps. The shaft seal is therefore a critical component when it comes to the overall lifetime costs of a pump – including capital, operating, maintenance and downtime costs.

Dynamic seals, because of their ability to improve reliability, are a notable design feature of Sulzer pumps. They work as follows:

- When the pump is operating, the expeller generates a liquid ring in the annular seal chamber and evacuates the liquid pumped from the seal cavity
- When the pump stops, the static seal tightens against the thrust ring, preventing any leakage.

By avoiding mechanical wear, leakage and the need for a sealing liquid, dynamic seals helps improve reliability and reduce the costs associated with the operation of the pump.

Sulzer pumps are widely-used in phosphate fertilizer production particularly in the wet process stages involving phosphoric acid (see box).

Weir Minerals

Weir Minerals has the capability to design and produce a wide range of engineered pumps for high wear and corrosive applications. The company operates through manufacturing sites and research centres located worldwide. These are supported by an unrivalled global service network. This ensures Weir engineers can provide customers with the assistance they require, wherever and whenever this is needed.

Weir's range of trusted and well-known brands include:

- *Warman*® centrifugal slurry pumps
- *GEHO*® positive displacement (PD) slurry pumps
- *Linatex*® rubber products
- *Vulco*® wear resistant linings
- *Cavex*® hydrocyclones
- *Enduron*® comminution equipment,
- *Delta Industrial*™ valves
- *Lewis*® pumps and valves.

PHOTO: LEWIS PUMPS

The Lewis 18HTH sulphuric acid pump.

The company's *Warman*® and *GEHO*® pumps have been successfully installed in long-distance slurry pipelines (*Fertilizer International* 491, p41).

With a history dating back to 1914, *Lewis*® pumps are a well-established brand in the sulphur, sulphuric acid and phosphoric acid industries, with equipment installed in more than 120 countries.

Lewis® pumps and valves perform very reliably in harsh sulphuric acid environments thanks to their construction from *Lewmet*® nickel-chrome alloys. *Lewmet*® provides superior erosion resistance and corrosion protection, being specifically designed to withstand long-term exposure in the extreme operating environments of sulphuric acid plants.

Lewis® acid valves – which likewise incorporate *Lewmet*® alloy – are also widely used by sulphuric acid plant operators. They offer reliable control even in severe service applications, such as acid heat exchanger/cooler bypass, and pump discharge flow regulation.

The vertical design of *Lewis*® sulphuric acid pumps, by eliminating shaft sealing issues, avoids the safety and environmental problems frequently associated with horizontal pumps in the same application. Furthermore, vertical pumps are simpler to install as they do not need the special foundations and suction piping normally required by horizontal pumps. On request, Weir can offer tailored, engineered-to-order features in response to customer requirements. These include rectangular or circular coverplates, optional suction extensions and custom lengths.

Mouvex plunger pumps

Mouvex is a leader in the design and manufacture of pumps and systems for the global energy market. Headquartered in Auxerre, France, Mouvex has representatives in more than 75 countries worldwide.

The company forms part of Illinois-headquartered PSG, the pump manufacturing arm of US conglomerate Dover Corporation. As well as Mouvex, PSG is also an umbrella for a number of other leading pump companies and brands. These include *Abaque*™, *All-Flo*, *Almatec*®, *Blackmer*®, *Ebsray*®,

Sulzer's *AHLSTAR* pump range

Sulzer manufactures the horizontally-mounted *AHLSTAR* range of self-priming pumps. These are wear-resistant and particularly suitable for pumping waste waters and slurries. They have the following characteristics:

- Single-stage end suction
- Back pull-out
- *ROTOKEY* impeller mounting
- A simplified heavy-duty bearing unit.

Sulzer's range of *AHLSTAR* pumps are designed for different kinds of chemical slurries. The wetted parts can be made from abrasion- and corrosion-resistant materials. Pump specifications and the type of pump seal can be tailored to match slurry characteristics and customer requirements.

Gypsum slurries

Relatively large volumes of gypsum slurry are generated as waste during phosphoric acid production. Pumps are generally required to transport these over distances of several kilometres or more. To do this, they need to be wear resistant, have a reliable pump seal, operate at low speed and have a high enough head. Sulzer's *AHLSTAR WPP* pump is well-suited for this application.

Although gypsum is quite soft it becomes abrasive when pumped in large amounts at speed. The following slurry characteristics are typical:

- Temperature around 40°C
- pH 4
- 300 g/l solids content
- 0.3 mm solids size
- 1,200 kg/m^3 density.

The *AHLSTAR WPP* pump is able to cope with these characteristics due to its wear-resistant hydraulics, construction from hard martensitic 4E steel, variable frequency drive, and the incorporation of a dynamic seal.

Phosphoric acid slurries

The *AHLSTAR WKP* is a heavy duty and robustly built cantilever slurry pump. This wear-resistant pump uses a maximum impeller diameter to minimise wear of the wetted parts. It also incorporates a variable frequency drive to limit the pump speed.

The pump is widely used for pumping phosphoric acid slurry to filtration. Its design, which has no seal bearing under the base frame, is well-suited for this application. Phosphoric acid slurries typically have the following characteristics:

- 37-39 percent P_2O_5 (H_3PO_4)
- Four percent sulphate (H_2SO_4)
- Two percent fluorine (HF, H_2SiF_6)
- Temperature up to 100°C
- 30 percent solids
- 1,600 kg/m^3 density.

Additionally, these slurries contain gypsum that can crystallise inside the pump. The pump's variable speed drive prevents this by ensuring it rotates constantly.

Corrosive and abrasive liquids

One of Russia's largest phosphate fertilizer manufacturers uses *AHLSTAR A* pumps for difficult-to-handle corrosive and abrasive process liquids. These are generated by the fluorine removal process during phosphoric acid manufacturing. The hot fluids (up to 70°C) obtained contain fluorosilicic acid (H_2SiF_6, up to 2.3 percent) Hydrofluoric acid (HF) and fine silica-containing solids (15 g/l, 0.1 mm size).

The *AHLSTAR A* pumps for this application incorporates super duplex 4T materials and a dynamic seal. The customer has been very satisfied with this pump design, according to Sulzer, because it does not require any maintenance. Consequently, the pumps installed have been operating reliably for more than five years without replacement of the wetted parts. ■

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EnviroGear®, *Griswold*®, *Neptune*™, *Quattroflow*™, *RedScrew*™ and *Wilden*®.

Many different types of pump have gained acceptance for the liquid transfer processes that are commonly used in fertilizer manufacturing. These include external gear, progressive cavity, screw and radial/axial piston pumps.

Yet plunger pumps can be an even better choice, according to Mouvex.

Indeed, the ability of plunger pumps to handle almost any fluid, even corrosive or hazardous types, makes them well-suited for use in fertilizer-manufacturing processes. One suitable application for plunger pumps, for example, is the ammoniation/neutralisation process during phosphate fertilizer production[1]. This application requires the injection of ammonia solution into phosphoric acid.

Plunger pumps are reciprocating positive displacement (PD) pumps. These are equipped with one or more in-line plungers. They are configured horizontally and powered by an electric motor or an engine. Plunger pumps can be:

- Single-acting – where suction occurs as the plunger ascends and discharge takes place as the plunger is depressed; or
- Double-acting – in which the suction and discharge stages take place simultaneously on opposite sides of the plunger.

Plunger pumps are designed so that the length of the plunger is longer than its stroke. They should not be confused with piston pumps, as the length of the piston in these is shorter than its stroke.

Plunger pumps are capable of creating very high discharge pressures, in some cases up to 3,000 bar (43,000 psi), although the flow rates they produce are directly proportional to pump speed, not pressure. Conversely, the discharge pressure is not speed-dependent either, being solely determined by the design of the discharge piping. This combination of operational characteristics allows plunger pumps to achieve pumping efficiencies of up to 90 percent.

Component wear is also minimised in plunger pumps. This is because the pump's packing, being situated in the sleeve surrounding the plunger, not on the plunger itself, results in more uniform wear and longer life.

Other parts including gaskets, rings, bushings, check valves and springs also experience wear. However, with proper preventive maintenance, it is not uncommon for plunger pumps to operate for 20 years without any maintenance, other than the periodic replacement of the wear parts. Plunger pumps also have a small installation footprint. This makes them ideal for operations where the available installation space is limited.

Mouvex – knowing how important proper pump selection is – offers its *API 674 Series* plunger pumps for the fertilizer manufacturing market. These pumps adhere to American Petroleum Institute (API) standard 674 for reciprocating PD pumps. This standard defines maximum and minimum operating speeds, material requirements, and testing requirements for plunger pumps used in a wide range of industries, including fertilizer production.

Mouvex plunger pumps can be used with viscous liquids (up to 100 cSt) containing solid particles (up to 0.1 mm) at high temperatures (up to 200°C/392°F). These pumps, as well as meeting API 674 specifications, can also be operated in explosive atmospheres, a critical consideration in some fertilizer plants.

The Mouvex TN-260 plunger pump.

PHOTO: MOUVEX

Rheinhütte Pumpen

Rheinhütte Pumpen has more than 150 years of experience in the design and manufacture of pumps and speciality alloys for the fertilizer, chemical and sulphur industries. Its product range includes horizontal, vertical, axial flow and liquid ring vacuum pumps. These are manufactured in various materials, including metals, thermoplastics and speciality ceramics.

For the fertilizer industry, Rheinhütte offers a range of horizontal and vertical flow pumps, including:

- The flexible *RN* horizontal pump – a reliable and efficient chemical pump for use with corrosive media that are either free of or contain low level of solids
- The robust *RCE* horizontal pump – a highly abrasion-resistant pump suitable for media with a solid contents of up to 30 percent
- The *RCEV* cantilever pump – a vertical version of the RCE pump
- The *GVSO* vertical pump – an extremely reliable submersible pump for use with solids-free media or for media with a low solids content
- The axial *R PROP* vertical pump – a propeller circulation pump used for high delivery rates and low delivery head.

These pumps are generally available in a range of wear-resistant stainless steel, nickel-based and special materials. Rheinhütte also manufactures the plastic *CPRF* horizontal vortex pump for fertilizer industry applications. This is made from extremely abrasion-resistant PE1000.

Rheinhütte also offers a wide range of horizontal and vertical centrifugal pumps for transporting molten sulphur and dilute and concentrated acids at sulphuric acid plants. The different pump designs available for molten sulphur include:

- The *GVSO* flexible use pump for molten sulphur
- The extremely robust *RCE* design for molten sulphur
- The *RMKN* seal-less magnetic drive pump for sulphur processing.

Butting Group

PHOTO: BUTTING GROUP

Butting Group headquarters, Knesebeck, Germany.

The Butting Group is a family-owned business headquartered in Knesebeck, Germany. The company is a 240-year success story, having originally started out as a coppersmiths in 1777. This long history is reflected by the company motto, *Progress by Tradition.*

Butting is a leading processor of stainless steels with more than 60 years' experience and know-how in this area. Its core competences are in forming and welding techniques and materials engineering. Products made by Butting include:

- Stainless steel welded pipes
- Clad pipes
- Customised components
- Spools and plant construction
- Vessels, tanks and apparatus
- Assemblies.

These products are manufactured to high quality standards and sold to customers all over the world.

Butting processes around 100,000 tonnes of stainless steel and clad materials annually and achieved a turnover of EUR 472 million in 2018. As well as its Knesebeck headquarters, Butting operates from two other sites in Germany at Schwedt and Könnern, and from international locations in Brazil, China and Canada. The company employs more than 1,800 people worldwide.

The company's Knesebeck headquarters stores more than 5,000 tonnes of welded pipes produced in Germany. These are manufactured in more than 140 different sizes and in 15 different material grades.

Butting surface treats its products by chemical pickling as a standard procedure after production. This guarantees optimum corrosion resistance for the pipes and components delivered to customers. The company is quality assured, operating under the DIN EN ISO 9001 management system.

Butting's primary product is high-quality, longitudinally-welded piping. Important end markets for its products include the pump and valve industry – the mechanical engineering market in particular – as well as the food and pharmaceutical industries. For many years, Butting has been producing ready-to-install components for the world's leading pump manufacturers. These are offered in a wide range of different materials, sizes and lengths.

Butting's manufacturing capability combines a range of different production processes. These include laser, welding, forming and metal cutting technologies, along with surface treatment. The company creates ready-to-install corrosion-resistant pipe components using grinding or blasting, based on optical requirements, and robot-welding.

Acid Piping Technology

Based in Arnold, Missouri, US manufacturer Acid Piping Technology (APT) specialises in engineered products for the global sulphuric and phosphoric acid industries. APT notably maintains the world's largest inventory of *MONDI*™ pipes and fittings, both for routine supply and emergency replacement.

The company stocks approximately 2,000 acid plant fittings. This includes standard elbows, tees and reducers in a full range of sizes for same day shipment. Stocks also include a wide selection of pipes (3-30 foot size range) and flanges (2-30 foot size range).

This large inventory enables APT to put together and despatch a complete set of components required by a specific project anywhere in the world as a single shipment. This saves time and costs as it avoids waiting for multiple shipments from the same or different suppliers. APT says it has sufficient inventory to replace the complete piping systems of two acid plants (3,000 t/d capacity).

APT also supplies valves and automated valve actuators. Valves stocked include gate, globe, check, plug, ball and butterfly types. These are available in iron, bronze, forged or cast steel, stainless steels (304, 316 and 310), alloy 20, hastelloys, chrome moly, titanium and Monel. These valves can also be supplied with PTFE, PFA and FEP linings. Additionally, APT stocks a range of internals for acid plant towers and converters, including ceramic packing and supports. ■

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