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Oil palm nutrient needs
China's fertilizer industry
Nitrogen projects head east
Phosphorus recovery

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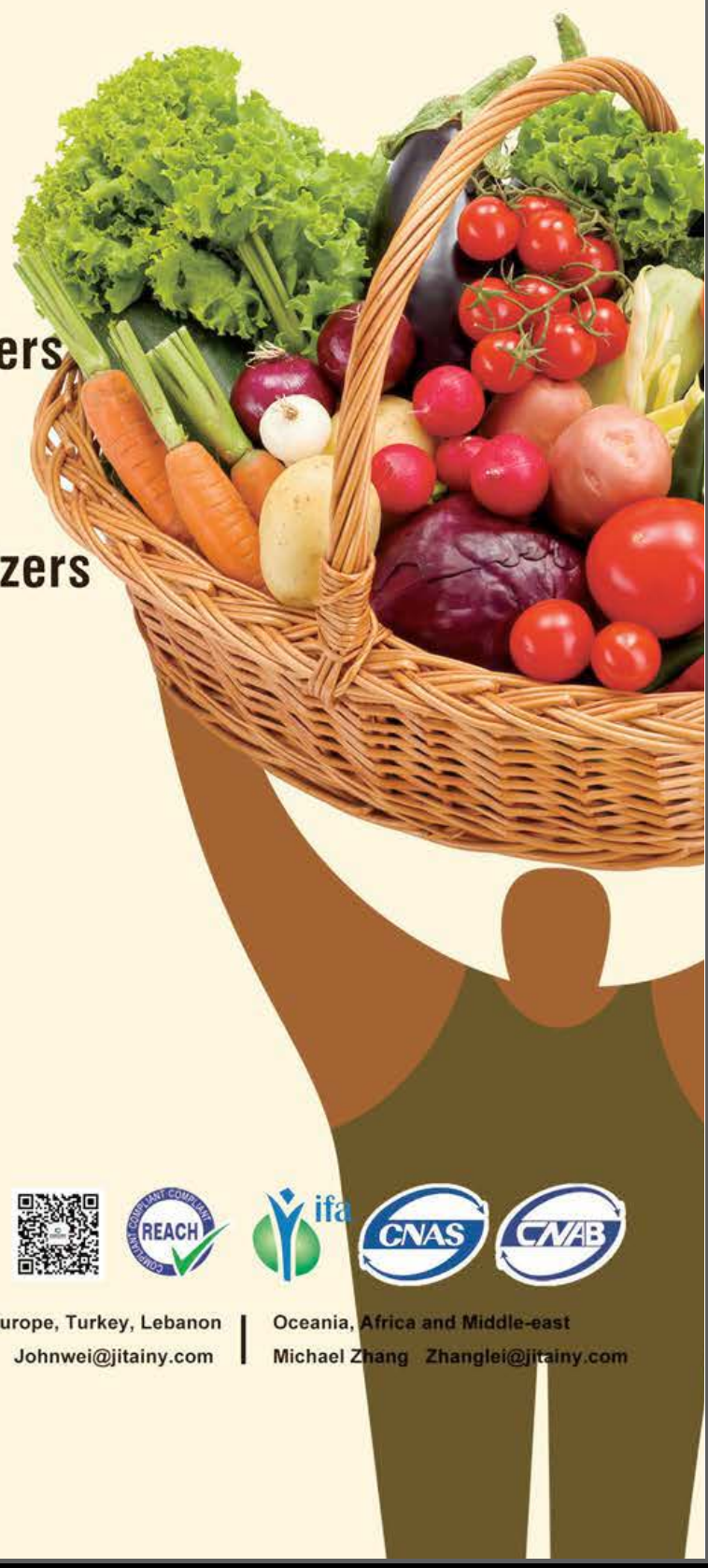

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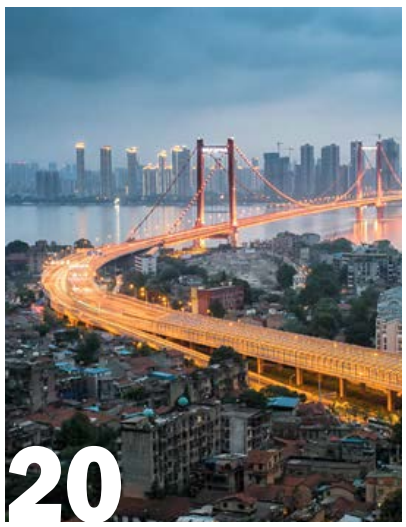

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Editorial

Fertilizer foresight

In theory, scoping future opportunities and threats is a sensible precaution for any business. Attempting to do this in practice, however, can raise more questions than it answers. The past is a notoriously unreliable guide to the future. And the further we gaze ahead, complexities multiply and the range of possibilities widen, until the future eventually becomes unknowable.

But does this mean we shouldn't look ahead and try to imagine what our world and our industry will look like in 2030?

Well, the International Fertilizer Association (IFA) has concluded that the fertilizer industry does need to plan for 2030 – and with some urgency. The Association recently embarked on an 18-month process of scenario planning as part of the new *IFA2030* initiative.

IFA's plans were revealed by Charlotte Hebebrand, its director general, at the Association's annual conference in Marrakech in May. Fittingly, Charlotte chose to unveil *IFA2030* at the conference's Young Professionals session, to an audience of individuals who are likely to be leading the industry by 2030.

Her message was a simple and compelling one: we need to make sense of a fast-changing world and identify the most significant factors affecting both the fertilizer industry and the environment in which it operates. Furthermore, scenario planning, in her view, can help IFA's member companies prepare for, help shape and ultimately thrive in whatever future eventually unfolds. Scoping the future will also help IFA ensure it remains relevant and is valued by its members.

A blizzard of change is coming our way. There is little doubt about that.

With the possible exception of Latin America and Sub-Saharan Africa, most regional fertilizer markets will have become mature by 2030-50. There is also an expectation that innovative and nutrient efficient fertilizers will prevail. Products will be crop- and site-specific, and be able respond to both plant nutrient requirements and local soil and climate conditions.

New and more affordable diagnostic tools for plants and soils will become available too. Farmers will have access to sophisticated digital services that will precisely tailor and customise nutrient delivery. Fertilizer recommendations will also make use of Big Data. Nutrient recovery and capture from waste and organic sources will become increasingly common as well. Finally, fertilizer use will become more closely integrated with other crop inputs such as seeds and biostimulants.

> **"How will the industry stay profitable in future and maintain its license to operate?**

The future of fertilizer feedstocks is also in flux. Shell, for example, foresees an "era of revolutionary transitions in the global energy system" in its scenarios out to 2050.

On the policy front, there will be a stocktake of Sustainable Development Goals (SDGs) by 2030. Globally, almost all countries are expected to submit long-term strategies for low greenhouse gas emission by 2020.

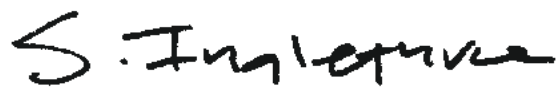
Looking ahead, the industry, together with farmers, may also have to take joint responsibility for the environmental effects of fertilizers. That's certainly what the Grantham Centre for Sustainable Futures believes: "There is a growing recognition, for a range of industrial processes, of extended producer responsibility – the producer being responsible for downstream impact, expanded to the idea of shared producer and consumer responsibility."

IFA is not alone in recognising the value of strategic foresight. Other sectors, including the paper, cement and mining industries, have already been down this road and drawn up long-term sustainability strategies. The World Economic Forum also scans the horizon by publishing a global risks report annually. Closer to our sector, UK government food and farming policy has been heavily influenced by the landmark 2011 foresight report.

What many of these types of strategic foresight have in common is that, rather than trying to predict one single, central outcome, they look at a range of possible future scenarios. This is precisely the approach IFA is taking, by placing scenario planning at the heart of its *IFA2030* initiative.

IFA is going to consult widely, both within and outside the industry, and from this develop multiple future scenarios as part of *IFA2030*. It will also identify key forces acting on the industry and then classify these by their likelihood and the magnitude of their effects. The underlying aim will be: how will the industry stay profitable in future and maintain its license to operate?

IFA is setting up an *IFA2030* Strategy Council and an *IFA2030* Strategy Task Force to guide and deliver this process. The Association is due to report back on *IFA2030* at its annual conference in Berlin next spring. The implications for IFA itself will also be discussed at its strategic forum later in 2018. ■



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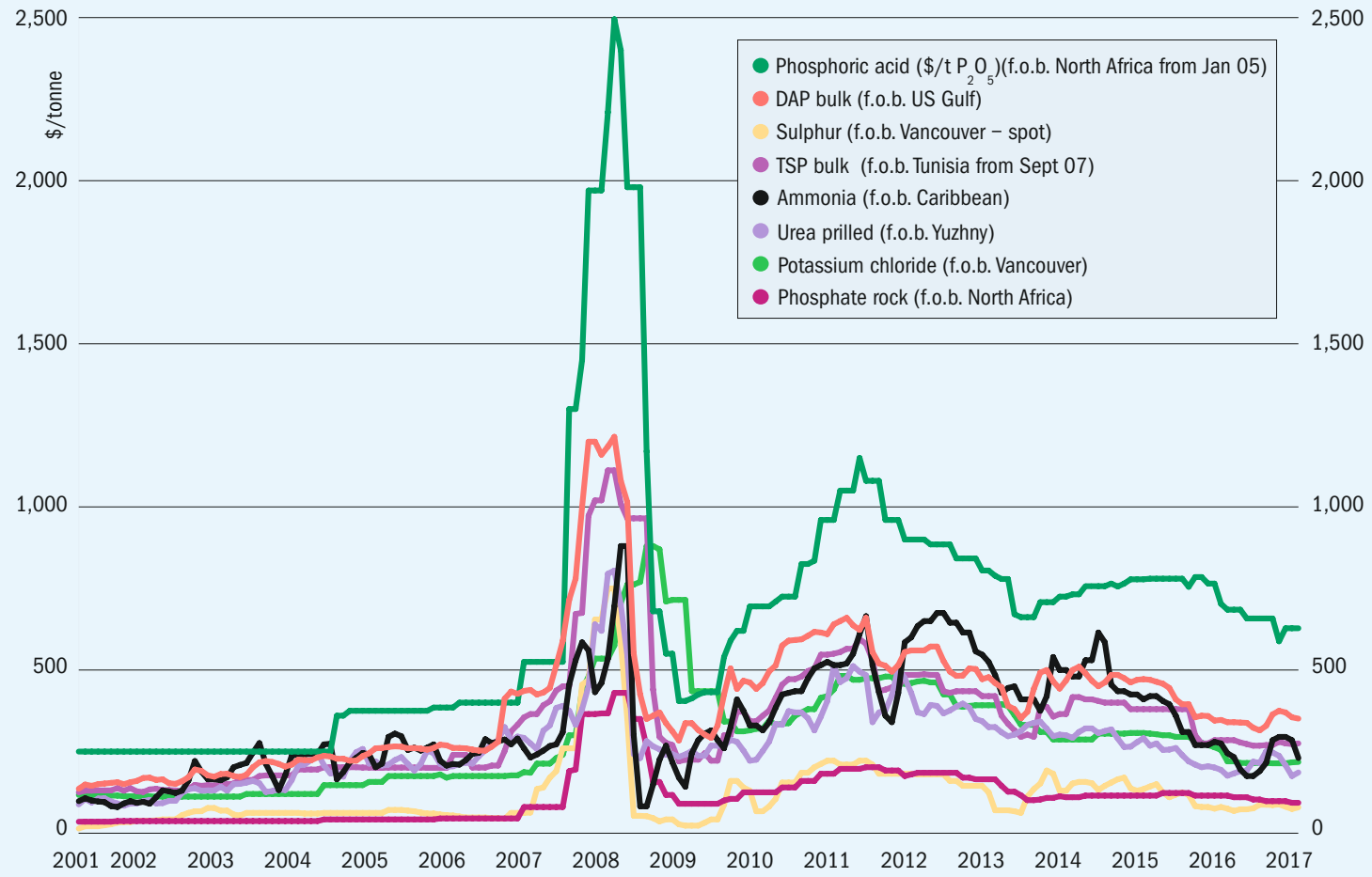
THE POWER TO MAKE THINGS GROW

Market outlook

Historical price trends $/tonne



Source: BCInsight

Market insight courtesy of Integer Research

AMMONIA

Prices softened in June in response to sluggish demand. The Yuzhny f.o.b. benchmark fell to $235/t in late June, down 25% on the March high of $315/t. A seasonal lull in the market, following strong buying activity during the US spring application period, has also aided the downward price direction. Prices have now fallen to a level where suppliers are closing capacity. Ukrainian producer OPZ, for example, announced that it would cease exporting from June, citing negative margins. In Russia, Togliatti also shut two of its ammonia plants in June, blaming a supply glut, and is not expected to restart these until August at the earliest.

UREA

Prices dropped and demand weakened in June as the market softened. The Yuzhnyy urea price declined to $186/t f.o.b. at the end of June, following a slight lift in May from the large IPL Indian market tender. Heading into the third quarter of 2017, there appears to be little upward support for prices, as the widening gap between supply and demand is likely to keep a downward pressure on all major benchmarks. China is the main source of volume adjustment in the market, and the country's January-May export volumes were down by around a half, year-on-year.

PHOSPHATE

Global sentiment in the market remains relatively downbeat. Major DAP export benchmarks outside China averaged $350-365/t f.o.b. in June, compared with the $370-385/t f.o.b. price range in March. Chinese producers are currently disadvantaged; the domestic market is in off season and DAP netbacks to South Asia are also low. Consequently, China's DAP exports to India averaged in the low $340s/t in early June.

India is reported to be well-stocked at present, although the predicted good monsoon should boost activity through July. However, the Maximum Retail Price (MRP) is expected to rise later this summer following the 12 percent increase in the Goods and Services Tax (GST) on fertilizers introduced in India at the start of July.

POTASH

A contract between Chinese buyers and suppliers has yet to be settled, at the time of writing. However, lower stocks in China point to an increasing likelihood that an agreement will be reached within a matter of weeks. Chinese sea port stocks were around 1.8 million tonnes in May, for example, compared to 2.3 million tonnes a year ago.

The absence of a big contract agreement in China does not appear to have slowed global purchasing. Global potash imports in the first quarter of 2017 reached a record 13.7 million tonnes with major increases into China, Brazil, the USA and India.

June MOP prices remain historically low, but are mostly stable. Vancouver MOP prices ($225/t f.o.b.) are at their lowest level since December 2007. Spot prices generally strengthened in the second quarter, although they were unmoved in June. Brazil and Southeast Asia MOP prices

ended the second quarter at $265/t cfr and $250/t cfr, respectively.

SULPHUR

The global market recovered towards the end of the second quarter, driven by renewed interest in China, thereby paving the way for a firmer third quarter. A combination of restocking and tighter local supply, owing to lower-than-expected refinery run rates, led to a run-up in spot pricing. Middle East producer sentiment was stable to firm in June, ranging $78-82/t f.o.b., with prices either rolling over or ticking up. Sulphur inventories at the major ports in China dropped to 1.1 million tonnes at the end of June, prompting enquiries for imported volumes. While China's January–April sulphur imports dropped by eight percent year-on-year to 3.8 million tonnes, a boost in June/July shipments is expected.

Sulphur supply has been balanced to tight in East Asia, the FSU and North America. The delay to the Barzan project in Qatar has limited sulphur supply growth in the Middle East so far this year, providing some improved price support. Vessel availability has also been hit by the diplomatic row between Qatar and other Middle Eastern countries. ■

Market price summary $/tonne – End-June 2017

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phosphoric Acid
f.o.b. Caribbean	205	n.m.	f.o.b. E. Europe 90-100	f.o.b. US Gulf	345	n.m.	n.m.
f.o.b. Yuzhny	200-220	178-186	-	f.o.b. N. Africa	351-370	265-285	515-740
f.o.b. Middle East	190-200	150-193**	-	cfr India	350-355	-	572-590*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	197-239	-	cfr US Gulf	40-50	f.o.b. Vancouver	78-84	
f.o.b. Middle East	194-236	-			f.o.b. Arab Gulf	80-85	
f.o.b. Western Europe	-	€430-460			cfr North Africa	70-85	
f.o.b. FSU	187-230				cfr India	95-100+	

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)*

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MARKET DRIVERS

- **Ammonia:** There remains limited support for upward price movement through July. The transition from strong spring demand to seasonal lull has left the market in surplus. This is unlikely to ease given seasonally weaker ammonia demand during summer months. The start-up of BASF/Yara's stand-alone 750,000 t/a ammonia plant is also on the horizon. Its start-up before the year's end adds additional downward pressure, putting a cap on significant price gains. The Yuzhnyy ammonia benchmark is expected to be in the range of $210-230/t f.o.b. in July, with no sign of the supply/demand balance tightening in the third quarter.
- **Urea:** A continuation of lower pricing levels is expected into the third quarter. The continuing gap between supply and demand is likely to maintain the downward pressure on pricing. A seasonal uptick in demand is expected towards the end of the third quarter. But this is unlikely to support a sustained recovery in pricing, as the market will remain fundamentally long. Moreover, the prospect of new US urea capacity, by reinforcing negative market sentiment, also points towards lower pricing.
- **Phosphate:** The potential for upward prices through July-August is limited. Demand is subdued in most regions with ample product available on the market. Buyers are in a strong position and can afford to be patient. In India, local buyers have already ended several tenders, having been unwilling to pay the prices offered. Indian imports could see a boost, if a strong monsoon materialises, as expected.

  Chinese DAP/MAP plants are currently operating at low rates, due to environmental inspections and low international demand and prices. China may manage output by temporary plant shutdowns, if finished phosphates prices slide further.

  North American demand has been slow during the year to date, with poor weather largely to blame. Summer fill buying should, however, materialise in the coming weeks. But we anticipate limited imminent movement in the NOLA price due to import competition. In Brazil, MAP demand should improve in July as the summer soybean season starts.
- **Potash:** The potash market has become more balanced so far in 2017. This is reflected by stable or slightly increasing price trends. It remains to be seen whether this will continue. Two new greenfield mines, the K+S Bethune mine in Canada and the Turkmen-Belarusian Garlyk mine in Lepab, Turkmenistan, have now commenced production. Several incumbent producers are also finalising brownfield expansions.

  However, supply may well be limited in the year's second half. A variety of operational factors are affecting the output of ICL's Boulby mine in the UK, K+S in Germany and Qinghai Salt Lake in China. Canpotex is also reportedly sold out until August. In addition, production at Belaruskali will be lower in the third quarter due to planned maintenance and major repairs.
- **Sulphur:** Firmer pricing is supported going into the third quarter, as the Barzan project in Qatar is not now expected online until 2018. Around 200,000 tonnes of sulphur is still expected from the long-awaited Kashagan project in Kazakhstan this year. Its first cargo is planned for September.

  Middle East producers are likely to increase monthly price postings for July/August. Activity in three key markets, China, India and Brazil, will likely determine how long this run-up in pricing will continue. While there has been a flurry of activity in China, India has remained subdued due to major buyers being covered by contract commitments. Integer expects to see a softer tone towards the end of the quarter, particularly in the absence of any meaningful recovery in downstream markets. ■

CANADA

Legacy becomes Bethune

K+S Group celebrated the grand opening of its new Canadian potash mine at Bethune, Sakatchewan, on 2 May. Around 700 guests attended, including Brad Wall, the premier of Saskatchewan. Large numbers of local government dignitaries, suppliers and employees were also present.

The mine was formally handed over to the company's operations team during the ceremony, signalling the successful completion of five years of project construction work.

"We're delighted to welcome a very good corporate citizen, K+S, back to Saskatchewan as it begins operations at a mine that will create more than 400 permanent jobs and generate taxes and royalties for years to come," said Brad Wall, speaking at the event. "The Legacy project strengthens Saskatchewan's position as the world's leading potash producer and is another indicator the province's diversified and resilient economy is weathering economic uncertainty. We're thankful for an investment that creates jobs and opportunity in Saskatchewan."

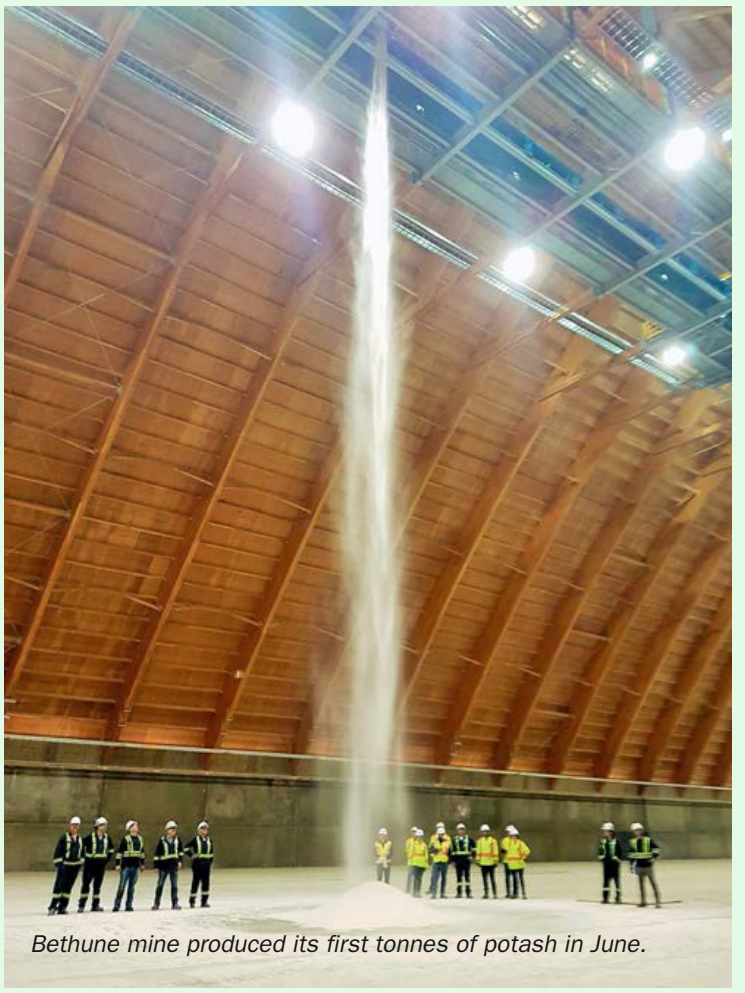
To mark the inauguration, K+S officially named the site Bethune mine, a change of title from the Legacy project name used previously. This upholds the Saskatchewan tradition of naming potash mines after nearby towns.

Ulrich Lamp, president and CEO of K+S Potash Canada (KSPC), applauded the local community for its friendliness: "We were welcomed to Saskatchewan with open arms, and we are proud to be here. The change from "Legacy" to "Bethune" honours a community that has shown our company outstanding support over the last years. I would like to thank everyone who contributed to this great project."

"With our new location, we are making a huge step forward in the internationalisation of our potash business," added Norbert Steiner, the outgoing chairman of K+S. "Bethune enables us to participate in future market growth, reduce our average production costs and strengthens our international competitiveness, which will benefit the entire K+S Group."

Following the grand opening, Bethune mine produced its first tonnes of potash in mid-June. The first rail freight delivery of potash is expected to leave the new mine during August. This will be destined for the company's new harbour terminal at Vancouver, for onward shipment to mainly South American and Asian customers.

The €3.1 billion invested in Bethune mine makes it the single largest project in the history of K+S. It also creates more than 400 permanent jobs in Canada. The mine is expected to produce 600,000-700,000 tonnes of potash in 2017, and should be up to full production capacity (two million t/a) by the end of this year.



Bethune mine produced its first tonnes of potash in June.

KSPC also took delivery of its first domestic rail cars during June. These will transport potash from Bethune mine to the company's North American customers. The cars are supplied by National Steel Car (NSC), the same manufacturer that produced the company's international delivery fleet (*Fertilizer International* 478, p14). The domestic cars have a different livery but are built to an identical specification. KSPC will receive 200 domestic rail cars from NSC from August, with more to follow during the next few years.

Martin Brown, president of K+S North America, said: "KSPC's domestic fleet is one of the cornerstones of our North American logistics network." Ulrich Lamp added: "The high-efficiency design of these cars is fit for our company's world-class facility. After producing our first tonnes of potash at Bethune mine, we are thrilled to be preparing to move our product to market." ■

POLAND

Major nitric acid investment by Grupa Azoty

Grupa Azoty is investing in a fifth nitric acid plant and modernising its four existing plants at its Puławy complex in Poland.

The company signed a major nitric acid technology contract for Pulawy with thyssenkrupp Industrial Solutions in April. The licencing deal covers the delivery of key equipment and process documentation, supervision of the plant's installation and plant start-up.

Part of the new nitric acid plant's output will be dedicated to the manufacture of a new line of speciality liquid and solid fertilizers (magnesium nitrate, calcium nitrate and potassium nitrate), with a target production capacity of 600 t/d.

The new nitric acid plant is a central part of a $190 million strategy to expand and develop Grupa Azoty's fertilizer production capabilities. The company's four existing nitric acid production lines will also be modernised as part of the company's plans. The overall aim is to increase the scale and efficiency of nitric acid production at Pulawy, and increase downstream fertilizer output.

Grupa Azoty plans to invest more than $270 million in nitrate fertilizer production

China News Round-up

Courtesy of Kcomber, owner of CCM and Tranalysis

Phosphate producers target exports

Chinese phosphate producers are focussing on more profitable diammonium phosphate (DAP) exports. The move has been prompted by weakening home demand in May, as China's domestic phosphate market entered the slack season.

The switch to exports, meanwhile, is supported by peak seasonal demand for DAP in international markets, especially India and Pakistan. Cooperation between major Chinese manufacturers has enabled the DAP f.o.b. price to be set at around $350/t.

Demand for monoammonium phosphate (MAP), on the other hand, remains low in both China and overseas markets. Comparatively high MAP prices fell slightly in May, but resulted in only a few extra orders from Chinese compound fertilizer producers. China's MAP capacity is running at just 40 percent currently, a lower operating rate than in previous years, due to the depressed state of the market.

China's phosphate fertilizer market may well remain depressed for a while longer. Domestic demand traditionally picks up again in July. But the market in China's northeast is saturated due to manufacturers overestimating regional demand. Some of this excess supply in the northeast has been redirected to Shandong and Hebei provinces. This means that traditional autumn demand in those two regions has been largely fulfilled in advance.

New HF project

Yunnan Wengfu-Yuntianhua Fluorine Chemical Technology started construction of its 30,000 t/a anhydrous hydrogen fluoride (HF) project in Kunming, China, in early April. The company is a joint venture between Yunnan Yuntianhua and Wengfu Group.

Once completed, the project will be the largest single HF production line via the fluosilicic acid route. The project incorporates Wengfu Group's in-house R&D expertise with technology acquired from Switzerland's BUSS Chem Tech. This project will fully utilise fluoride, iodine and silicon resources, promote sustainable development in the phosphate industry, and conserve resources. The project chimes with national strategies promoting the development of a circular economy in China, by turning wastes into resources.

Guizhou Kailin innovates

Guizhou Kailin Holdings Group is to collaborate on innovation with the Institute of Agricultural Resources and Regional Planning (IARRP), part of the Chinese Academy of Agricultural Sciences. The terms of the cooperation were agreed in Guizhou Province in April.

Adding value, by developing new ammonium phosphate products, and improving manufacturing efficiency by upgrading fertilizer production are some of the main aims. Supply-side structural reforms will also be implemented and a research institute promoting technological innovation in the fertilizer industry will also be set up.

Guizhou Kailin is a large industrial concern involved in mining, chemicals, trade and construction materials. The company also entered into an agreement with China COSCO Shipping Co, Ltd and Zhanjiang Port Group Co, Ltd at the end of April. The three partners will be seeking to drive down logistics, freight and storage costs and increase profitability.

New sulphuric acid joint venture

A joint venture to build a 200,000 t/a capacity sulphuric acid plant in Yunnan was announced in April. The new acid plant will consume phosphogypsum waste.

The project to build the plant, named Yunnan Huanzheng, is owned by Yunnan Yuntianhua (46%), Yunnan Ruidan (44%) and the Yunnan Chemical Design Institute (10%).

The project's $2.9 million capital cost will be invested in two phases. Yunnan Yuntianhua, Yunnan Ruidan and Yunnan Chemical Design Institute will each initially invest $670,000 million, $640,000 million and $140,000, respectively.

The project should help Yunnan Yuntianhua use more of the phosphogypsum waste generated by phosphates production. Any reduction in phosphogypsum stockpiling confers both environmental and economic benefits, by reducing waste, cutting maintenance costs and prolonging the life of storage areas. ■

by 2021, including the construction of two granulation plants. The company will also expand its product range by introducing six new fertilizers over the next four years. These new products will also support the manufacture of blended fertilizers at Grupa Azoty's Dobre Miasto plant.

Jacek Janiszek, president of Grupa Azoty Puławy, said: "This is currently the largest investment project under way in the Grupa Azoty Group's fertilizer segment – and is the Puławy plant's largest in more than a decade. The fertilizer segment is particularly important for the entire Grupa Azoty Group as it generates about 60% of its revenue."

Richard Saure, head of the nitrates and phosphates operating unit at thyssenkrupp Industrial Solutions, commented: "The technology we have purchased for the new nitric acid line at Grupa Azoty Puławy is a modern and proven solution that meets the highest environmental requirements."

GERMANY

Shell and Sandvik produce sulphur-enhanced urea

Shell and Sandvik have successfully incorporated elemental sulphur during urea granulation.

The two companies demonstrated the integration of Shell Thiogro Urea-Elemental Sulphur (ES) technology and Sandvik Rotoform equipment during a series of continuous plant trials at Sandvik's production centre at Fellbach, Germany.

The granulated speciality fertilizer obtained contains 70% finely-dispersed elemental sulphur in a matrix of urea. During the trials, an emulsion of Shell Urea-ES was fed to a Sandvik Rotoform unit and deposited as 2-4 mm diameter drops across a steel belt cooler. Water was then sprayed against the underside of this belt. This ensured no cross-contamination occurred. The liquid droplets were converted into solid pastilles as they moved along the belt. The final solid product was collected at the end of the belt for conveying, storage and bagging.

Sandvik's standard Rotoform High Speed unit can produce up to 150 t/d of Shell Urea-ES granules, making it ideal for customers looking to diversify and make speciality fertilizers. More Rotoform lines can be installed in parallel to increase capacity.

Sandvik and Shell plan to support both greenfield and brownfield installations. This will allow current and new Rotoform owners to add the production of Shell Urea-ES fertilizer to their product portfolios.

"We are pleased to collaborate with Sandvik to granulate our new Shell Urea-ES technology products on their robust Rotoform equipment. With this success, more and more fertilizer producers can granulate our urea + elemental sulphur fertilizer to potentially unlock better crop yields and improve soil health," said Michael Lumley, vice president of Shell Sulphur Solutions.

"Our collaboration with Shell for the Urea Elemental Sulphur has been a rewarding partnership," said Johan Sjögren, managing director of Sandvik Process Systems. "We believe specialty fertilizers are the future, as they promise not only a win-win situation for both farmers and fertilizer producers, but also contribute to a better environment."

INDIA

Tata Chemicals sells its urea business to Yara

Tata Chemicals Ltd has agreed to sell its urea business to Yara for $430 million. The sale will be made to Yara Fertilisers India Private Ltd, the Indian-based subsidiary of Norwegian parent Yara International AS.

The urea sell-off and move away from fertilizers is part of a strategy by Tata Chemicals to focus on higher margin, value-added products and nutritional supplements.

"We are exiting the fertilizers business, which has led to savings across the board, including in interest income," commented Tata's managing director and CEO R. Mukundan. "With this, we will not be in the fertilizer business in North India any longer. We will remain in the Eastern region, in certain markets, with the intent to maximise cash generation."

The deal is expected to go through during the next three months, pending approval from the Indian National Company Law Tribunal.

Urea bag weight cut by five kilos

The Indian government is reducing the standard size for bagged urea by five kilograms, down from the present 50 kg size to a 45 kg standard weight in future.

The government hopes the move will cut the amount of urea used by farmers, and potentially cap or reduce the spiralling subsidy budget for Indian fertilizers. The 2017/18 budget has been set at 700 billion rupees ($11.2 billion). This includes $2.2 billion set aside for urea imports during the financial year.

The fertilizer ministry calculates that the move to smaller bags could reduce consumption by 10 percent, if farmers use two 90 kg bags per acre, versus the current practice of using two 50 kg bags.

Urea application rates in India have already fallen by 4-6 percent since the switchover to neem-coated urea, according to the agriculture ministry. Yet India still needed to import eight million tonnes of urea to meet domestic demand in 2016/17, even though domestic urea production hit a record production of 24.2 million tonnes last year.

The Indian government is also hoping to reopen closed urea plants to ramp-up domestic production and reduce the country's import reliance.

JORDAN

Manaseer Group unveils fertilizer complex project

Manaseer Group and the Aqaba Development Corporation signed a land lease agreement for the development of a $1 billion fertilizer complex during the World Economic Forum in May.

The agreement covers 11 individual plants. Speciality fertilizers will be produced using Jordanian phosphate, potash and bromine raw materials. Some 90% of production will be destined for export, according to Manaseer Group.

The project to build the complex should be executed later this year with production scheduled to start early in 2020. Manaseer said the project is to be "entrusted to one of the world's largest contracting companies" and will also use the latest European equipment.

"The significance of the concerned project is based on the fact that it will be the first project in the world to produce all kinds of specialized fertilizers, which will make Jordan one of the most important fertilizer providers in the world, ranking the second place after China globally," Manaseer chairman Ziad Al Manaseer said in a statement.

Manaseer awarded WorleyParsons a management consulting services contract for the project in March. The firm will act as the project's technical advisor, supervising engineering, procurement and construction (EPC) services for the fertilizer complex over a three-year period.

SPAIN

EuroChem buys stake in Hispalense

Spain's Hispalense de Liquidos has sold a minority stake (50 percent minus one share) to Swiss-headquartered EuroChem Group.

Hispalense is a family-owned liquid NPK producer located in Seville in the south of Spain. The part-purchase will enable EuroChem to expand its premium product range, by providing extra production capabilities and new technical know-how.

Hispalense manufactures a range of customised fertilizers, mainly selling these directly to local farmers. The company's 1,500 t/d capacity plant currently produces around 50,000 t/a of liquid fertilizer blends. These are mainly based on urea ammonium nitrate (UAN), phosphoric acid, monoammonium phosphate (MAP), urea and potash. The Seville plant also has a 21,000 tonne storage capacity for liquid and solid raw materials, and, advantageously, has direct port access.

Dmitry Strezhnev, EuroChem CEO, commented: "The acquisition of a stake in Hispalense, a well-established player in the Spanish fertilizer market, reflects our intention to expand our premium product portfolio. This is an interesting growth area for us and we see it has some exciting potential. The additional technical expertise will enable us to produce a new variety of such fertilizers and further support our customers with their efforts in sustainable farming."

Juan Romero, chairman of Hispalense de Liquidos, added: "This is a win-win opportunity for us, giving us the ability to market some of EuroChem's value-added fertilizers in Spain and to further promote our liquid fertilizer technology worldwide."

The purchase price and precise terms of the deal have not been disclosed.

ISRAEL

ICL cuts phosacid production due to leak

ICL has cut phosphoric acid production at its Rotem plant in Israel's Negev region following a leak. The partial collapse of a dike on 30 June resulted in a phosphogypsum leakage from an accumulation pool, the company said in a statement.

ICL has partially ceased production at the affected unit, although, according to ICL, this is responsible for less than half of the plant's phosphoric acid output. The site, operated by ICL subsidiary ICL Rotem, manufactures phosphate fertilizers.

ICL says it took immediate action to stop phosphogypsum water from leaking out of the accumulation pool, in full coordination with the Israeli Ministry of Environmental Protection. Insurers have been notified about the Rotem spill, and the company is investigating the circumstances surrounding the incident to prevent any future recurrence. ICL says it is currently unable to fully assess the ramifications of the incident and, because of this, the environmental and financial implications are not yet clear.

After the incident, the Israeli Ministry of Environmental Protection ordered ICL Rotem to discontinue use of the three active phosphogypsum water accumulation pools (Pools 1-3). It also asked the company to submit an alternative plan for the accumulation of phosphogypsum water generated by fertilizer production. ICL Rotem has responded to this request by submitting an application for the alternative, temporary use of Pool 4.

ICL says it will update the public about further developments relating to the incident. ■

People

Rakesh Kapur is the new chair of the International Fertilizer Association (IFA). Mr Kapur, the joint managing director of the Indian Farmers Fertilizer Cooperative (IFFCO), was elected at IFA's annual conference in Marrakech in May. OCP Group's CEO **Mostafa Terrab**, a long-standing IFA executive board member, was nominated as IFA's vice-chair.

Mr Kapur is currently completing his term as chair of the Fertilizer Association of India (FAI). He has held various senior Indian government positions, including as director of the Ministry of Chemicals & Fertilizers and the Telecom Regulatory Authority of India. Latterly, he served as the additional assessor and collector at the Municipal Corporation of India, immediately prior to joining IFFCO.

Rakesh Kapur has previously chaired IFA's Production and International Trade Committee. He also joined IFA's executive board in 2015, when he was elected as vice-chair and chair of IFA's Finance Committee.

Mr Kapur said: "I am honoured and delighted to assume IFA's Presidency and will continue to further advance and expand IFA's strategic role in promoting product and nutrient stewardship initiatives around the world and delivering added value through its programs on statistics and market analysis. Under his leadership, my predecessor, Dr Jawahery, has already accomplished major advances in driving the industry's commitment to the Sustainable Development Goals. I pledge to continue this engagement in my new role, and ensure that IFA supports the industry to contribute to the important Agenda 2030 Goals. I am also delighted to oversee the development of a strategic, future oriented outlook for plant nutrition and our industry during my two year Chairmanship."

Dr Burkhard Lohr officially became chairman of K+S Group's board of executive directors in May. **Thorsten Boeckers** also joined the board as chief finance officer (CFO). Dr Lohr (54) and Mr Boeckers (42) join three other executive directors on the board: Dr Otto Lose (46), who has been responsible for the potash and magnesium products business unit since the start of 2017, personnel director, Thomas Nöcker (59), and Mark Roberts (54) who is responsible for the salt business unit.

"We look to the future with great optimism. With our two strong pillars, we have an excellent basis for further developing the company over the long term. We are also ready to explore new avenues," commented Dr Lohr.

Dr Andreas Kreimeyer was elected as chairman of the company's supervisory board in May, as previously announced (*Fertilizer International* 478, p16). He warmly welcomed the company's new chairman: "Having been CFO for five years, Burkhard Lohr is familiar with all aspects of K+S. He stands equally for continuity and for a willingness to change. I wish him and his colleagues, as well as all employees of the K+S Group, every success and all the best for the future".

Rinat Gizatulin has been appointed deputy general director of JSC Uralchem. He has been tasked with coordinating the work of a new Government Relations Directorate set up by the company in May. Additionally, Dr Gizatulin has also been appointed as an advisor to the CEO of PJSC Uralkali.

Uralchem has also announced the appointment of **Anatoly Shablinsky** as general director of Voskresensk Mineral Fertilizers (VMF), JSC. He replaces **Sergey Drinevsky**, who had held this position since 2012. During a visit to VMF, Dmitry Konyaev, Uralchem's CEO, expressed gratitude to Sergey Drinevsky for his great work during a difficult period for the company.

PhosAgro's board of directors has re-elected **Sven Ombudstvedt** as its chairman. **Andrei Guryev**, vice-president of the Russian Union of Chemists, was re-elected deputy chairman. Mr Guryev was also made chairman of PhosAgro's strategy committee.

Peter Feldhaus is the new CEO of thyssenkrupp Industrial Solutions. He was previously the CEO of the Marine Systems part of the business. Dr Feldhaus, (50), was appointed CEO and made an executive board member by the supervisory board of Industrial Solutions, effective 4 May. Guido Kerkhoff, supervisory board chairman of Industrial Solutions, wished him every success in his new role: "Peter Feldhaus has outstanding strategic skills and experience in various sectors. As CEO, he integrated Marine Systems more fully into the overall structure of the Industrial Solutions business area and linked strategy and sales closer together, and as a result was able to leverage synergies. In his former role as the Group's strategy chief, he also closely supported the realignment of Industrial Solutions."

Dr Rolf Wirtz, (53), becomes the new CEO of thyssenkrupp Marine Systems, having previously been CEO of Atlas Elektronik. The acting CEO of Industrial Solutions, **Stefan Gesing**, has returned to his duties as CFO. "Stefan Gesing has systematically driven forward the urgently needed transformation program in our plant engineering business area. We are extremely grateful to Mr Gesing for taking on this double workload," commented Kerkhoff.

Calendar 2017

SEPTEMBER

17-19

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

26-28

8th GPCA Fertilizer Convention, BAHRAIN
Contact: Ammara Shahiryar
Tel: +9714 4510666, Ext. 10
Email: ammara@gpca.org.ae

OCTOBER

9-11

East and Southern Africa Fertilizer Agribusiness Conference,
MAPUTO, Mozambique
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

10-12

30th AFA Technical Conference,
AMMAN, Jordan
Contact: Arab Fertilizer Association
Tel: +20 2 23054464
Email: afa@arabfertilizer.org

24-26

IFA Crossroads Asia-Pacific Conference,
SHANGHAI, China
Contact: IFA Conference Service
Tel: +33 1 53 93 05 25
Email: conference@fertilizer.org
Web: www.fertilizer.org

NOVEMBER

6-9

Sulphur 2017,
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Oil palm nutrient needs

PHOTO: DOLPHFYN/SHUTTERSTOCK.COM

Oil palm is grown on 18 million hectares worldwide, yielding four tonnes of oil or more per hectare, making it the world's most efficient oil crop. Indonesia and Malaysia are the main palm oil producing countries, accounting for around 85 percent of world output.

Above: Oil palm fruits.

Oil palm (*Elaeis guineensis*) is the world's highest yielding perennial oil crop. The species, once a native of west and southwest Africa, is now cultivated in Madagascar, Sri Lanka, Malaysia, Sumatra, Central America, the West Indies and several Indian and Pacific Ocean islands.

Single-stemmed mature palms grow to a height of 20 metres and produce new pinnate leaves, 3-5 metres long, every year. Palms produce a reddish colour fruit, roughly the size of a large plum, in large bunches. These take 5-6 months to mature and weigh 5-30 kg, depending on the tree's age.

Each fruit (30-35% oil content) consists of a fleshy outer layer (the pericarp) together with a single seed (the palm kernel), both of which are oil-rich. The harvested fruit yields commercially valuable palm oil (4-6 t/ha), high-quality kernel oil (0.4-0.6 t/ha) and kernel meal. Importantly, the palm oil and palm kernel oil obtained have a significantly different fatty acid composition.

The most suitable areas for oil palm cultivation are located between ten degrees north and south of the equator. Being a tropical tree, palms thrive in sunny and humid conditions, and prefer a temperature of between 24 and 32 degrees centigrade and rainfall evenly distributed throughout the year. Oil palms are now most widely cultivated in Indonesia and Malaysia, the world's two largest palm oil-producing nations.

Palm oil production

Over the last two decades, palm oil production has rocketed globally, from 15.2 million tonnes in 1995 to 62.6 million tonnes in 2015. This production volume is the highest of any vegetable oil, exceeding the second biggest oil crop, soybean, by more than 10 million tonnes.

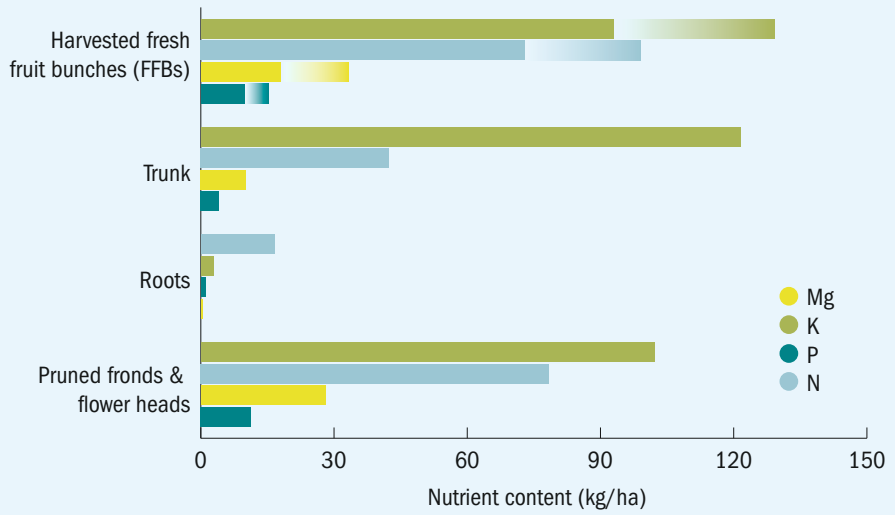
Remarkably, palm oil produced over one-third of total global vegetable oil output in 2015 (179.6 million tonnes) from just seven percent of the land dedicated to oil crop cultivation worldwide (274.4 million hectares). On average, oil palm requires less than half the land used by other oilseed crops, such as sunflower, soybean or rapeseed, to yield similar amounts of oil.

Indonesia (53%) and Malaysia (32%) account for over four-fifths of global palm oil production. However, oil palm cultivation is on the rise in other parts of the world, with Central America (3.4 million tonnes), Thailand (1.8 million tonnes) and West Africa (2.4 million tonnes) accounting for significant additional production. Although the production and consumption of sustainable palm oil is on the rise, the encroachment of oil palm plantations onto high conservation value forest (HCVF) and peatland remains a major environmental concern (*Fertilizer International* 439, p20).

Palm oil consumption and use

Global consumption rose from 14.6 million tonnes in 1995 to 61.1 million tonnes in 2015, making palm oil the most widely consumed type of vegetable oil in the world. Indonesia, China, India, and the EU are the main consuming regions and countries, the latter three accounting for 48 per cent of global imports in 2015.

Fig 1: **Oil palm: nutrients removed as harvested fresh fruit bunches (FFBs), immobilised in trunk and roots and recycled as pruned fronds and flower heads**



Assumes target FFB yield of 24-30 t/ha

Source: Comte et al. (2012)

Palm oil is used in both crude (25%) and refined form (75%). Domestic cooking in Southeast Asia, Africa and Brazil represents a major end-use for crude palm oil. In Europe and the United States, in contrast, palm oil is mostly consumed as a refined, odourless, pale yellow oil. This makes it a valuable, affordable ingredient, adding texture and taste in many food products, including margarine, chocolate, ice cream and bakery products. Refined palm oil is also widely-used in soap, candles, and cosmetics. More than half the product lines on sale in supermarkets contain palm oil, according to one estimate.

Oil palm nutrients needs

The nutrient needs of oil palm are fairly well understood. Oil palm requires particularly large quantities of potassium, supplemented by nitrogen, phosphorus, magnesium and boron. Copper and zinc fertilization is also necessary on peat soils[1].

Nutrients are required by fresh fruit bunches (FFBs), the harvested part of the plant, and are also immobilised in other biomass such as the trunk and roots (Figure 1). Nutrients can be recycled by returning pruned fronds and flower heads (male inflorescences) to the soil.

Yield responses and nutrient deficiencies

Fertilizer applications are needed to provide a balanced supply of nutrients and to replenish nutrients removed during harvesting. For harvested fresh fruit bunches, per hectare yield responses are greatest for potassium (15-19 kg/kg K) and nitrogen (0-45 kg/kg N) but less marked for phosphorus (0-20 kg/kg P). Yield increases of up to 45 percent have also been obtained with magnesium applications (kieserite) on yellow sandy loams in north Sumatra[1].

Leaf or stem measurements of N, P, K and Mg are generally necessary to determine both nutrient deficiencies and the right fertiliser recommendation. Thresholds for nutrient deficiencies are site- and soil-specific rather than generic. Leaves will show signs of deficiency if nutrient deficits are severe (Table 1)[1].

Oil palm nutrient demand

On average, fertilizer applications fall well short of crop nutrient demand in the major oil palm growing countries of Southeast Asia, with fertilizers being applied at 40-90 percent of recommended rates. A 2013 International Fertilizer Association (IFA) study found that average potassium applications for Malaysian plantations were double those of Indonesian plantations, and three times greater than those in Thailand[2]. Despite this, even Malaysian

Table 1: **Nutrient deficiency symptoms**

Nutrient	Effect of deficiency	Visual symptom
Nitrogen	● Decreased bunch weight and number ● Decreased vegetative dry matter production ● Suppressed net assimilation rate ● Increased phyllochron time	● Chlorosis in younger leaves ● Stunting
Phosphorus	● Yield decrease on some soils ● Reduced yield response to N and K fertilizers	● Conical trunk shape
Potassium	● Strongly decreased bunch weight and number ● Decreased vegetative dry matter production	● Yellow spotting in older leaves
Magnesium	● Yield decrease on some soils ● Reduced yield response to N and K fertilizers ● Reduced oil/bunch ratio	● Yellow/orange colour in older leaves exposed to sunlight
Boron	● Decreased bunch number and yield when leaf deficiency symptoms are present	● Crinkling of older leaves ● Stunting of young leaves (‘little leaf’)
Copper, zinc	● Reduced bunch number and size (Zn, Cu) ● Reduced photosynthesis (Zn) ● Decreased vegetative dry matter production (Zn)	● Yellowing and necrosis in older leaves starting at the tip

Source: Woittieza et al. (2017)

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Table 2: **N, P and K application on oil palm in Indonesia, Malaysia, and Thailand, 2010/11**

	Total application ('000 t/a)			Annual application rate (kg/ha)			Annual nutrient removal*(kg/ha)
	Indonesia	Malaysia	Thailand	Indonesia	Malaysia	Thailand	
N	548	374	41	95	91	72	146
P	61	78	9	11	19	16	19
K	643	821	39	111	199	69	248

**Assumes 30 t/ha FFB yield*

Source: Heffer (2013)

applications were insufficient to replace the N, P and K removed by a 30 t/ha fresh fruit bunch yield (Table 2).

In Indonesia, large quantities of nutrients are required to maintain yields in oil palm plantations established on the poorly fertile inland and upland soils of Sumatra and Borneo – making the use of mineral fertilizers compulsory[3]. Because of this, fertilizers can account for 50-70% of the cost of field operations and about 25% of the total cost of production. Efficient fertilizer use is therefore crucial, both to maximise yields and ensure good economic returns[3].

Application rates

Urea, triple superphosphate (TSP), rock phosphate, ammonium sulphate (AS), muriate of potash (MOP) and kieserite are the main fertilizers used on oil palm plantations in Indonesia. Blended NPK, NP, and PK fertilizers are also applied[3].

Fertilizer application rates vary according to climate, soil type, the age of the palm (immature vs mature) and target yield. Typical application rates for oil palm in Southeast Asia are shown in Figure 2.

The frequency and timing of applications depend on factors such as rainfall and soil type. More frequent fertilizer applications at lower rates are advised where there is a risk of large nutrient losses through runoff or drainage – such as on sandy soils and/or sloping land. Scheduling applications to account for rainfall helps avoid substantial nutrient losses. The general guidance is to avoid applying fertilizers during high rainfall periods[3], such as months with:

- More than 250 mm of rain overall
- High rainfall on more than 16 days
- High-intensity rainfall events of more than 25 mm in a single day

Immature palms generally require more frequent fertilizer applications. It is the practice in some plantations to apply fertilizers close to the base of palms in early years, but later extend applications to the tree avenues, once the canopy overlaps and roots become well-developed.

Fertilizer recommendation systems

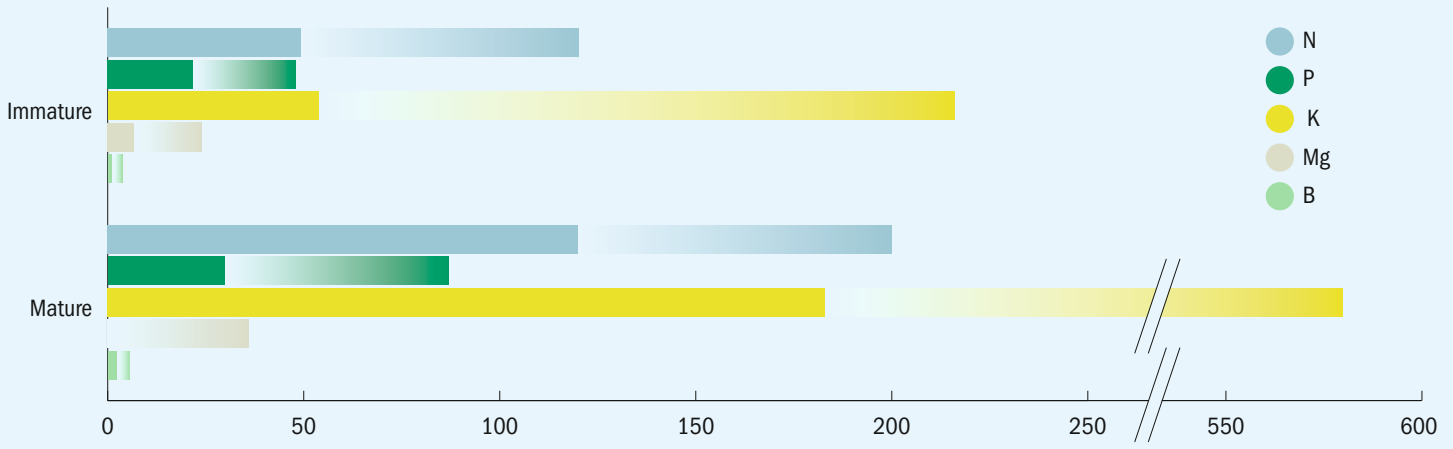
A number of fertilizer recommendation systems have been developed for oil palm. These include two systems developed by Malaysia's Applied Agriculture Research group: the site-specific yield potential (ASYP) and the integrated site-specific fertilizer recommendation system (INFERS). The Foster system, which combines leaf analysis data with site-specific characteristics, is another choice. The International Cooperation Centre in Agronomic Research for Development (CIRAD) has also developed response curves for leaf nutrient concentration versus FFB yield. These enable optimum economic fertilizer application rates to be determined, based on leaf analysis and soil type.

Their main purpose of all these systems is to ensure:

- Each palm is supplied with an adequate and balanced supply of nutrients for healthy growth and optimum economic yields
- Fertilizer applications result in the efficient uptake of nutrients
- The use of mineral fertilizers is integrated with the recycling of palm residues
- Negative environmental impacts are reduced or avoided, particularly over-fertilization, nutrient loss and land degradation

Best management practices (BMPs) have been developed by the Roundtable on Sustainable Palm Oil (RSPO) for the cultivation of

Fig 2: **Recommended fertilizer application rates for oil palm in South East Asia**



**Plantation density of 140 palms per hectare*

Source: Comte (2012)

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certified sustainable palm oil. These BMPs include detailed fertilizer management advice for oil palms grown on peat[4]. The RSPO's recommendations are summarised below.

Sustainable fertilizer use

An adequate and balanced supply of nutrients is vital for high productivity oil palm on peatland. Recycling nutrients, by placing pruned fronds between palms, can significantly reduce costs by lowering mineral fertilizer use. The RSPO also encourages greater use of palm oil mill by-products for nutrient recycling, such as decanter solids and composted empty fruit bunches.

Nitrogen and potassium fertilizer applications need to be co-ordinated to avoid N/K imbalance problems, particularly the reduced FFB yields caused by 'white-stripe' disorder. Excessive nitrogen use can also lead to undesirable nitrous oxide emissions, and should therefore also be avoided. Nitrous oxide is an aggressive greenhouse gas and its generation, especially on peatlands under wet conditions, contributes significantly to the climate impacts of oil palm plantations.

Fertilizer inputs can account for more than half of oil palm plantation costs. Because of high water infiltration rates on peat, keeping fertilizer leaching to a minimum is essential, to control costs and keep production profitable. This is especially true of growing regions with high and frequent rainfall. Sarawak, for example, experiences 3,000-5,500 mm of rain annually and 180-220 days of rain each year. Strict timing of fertilizer delivery to avoid high rainfall periods is also particularly critical when applying boron and potash fertilizers, as these easily leach.

Immature and mature palms require different fertilizer application strategies, as follows:

Fertilization of immature palms on peat: The use of controlled-release fertilizers at planting is helpful in regions short of labour, and also reduces leaching losses. The RSPO recommends the following for each palm to ensure healthy growth for 10-11 months:

- Application of 0.3 kg of controlled-release NPK fertilizer (e.g. 17:8:9:3) and 0.5 kg of rock phosphate in the planting hole at planting
- Followed by surface application of 2.5 kg of powdered limestone

Acidic peat is best limed (2.5 kg of limestone per palm annually) just outside the palm circle during the first two years of planting to avoid excessive calcium build-up, as this may antagonize potassium uptake.

Fertilization of mature palms on peat: For mature palms, the RSPO suggests fertilizer recommendations based on annual leaf analyses and nutrient trial results. Straight fertilizers (urea, MOP, rock phosphate, borate, $CuSO_4$ and $ZnSO_4$) are normally used for mature palms. High potash applications (4-6 kg MOP/palm/year, split between 2-3 applications) are typically needed to obtain high yields on peat. The use of coated urea is useful way of reducing volatilisation losses and nitrous oxide emissions.

According to the RSPO, the K_2O:N ratio of fertilizer applications needs to be increased progressively, from around three in the second year of planting to about 4.5 when the palms come into full maturity. Growing trials on peat in Riau, Indonesia, have shown that applying potash without nitrogen fertilizer lowers FFB yield. Excessive potash application rates (>6 kg MOP/palm/year)

also decrease oil-to-bunch ratio, as well as depressing both magnesium and boron uptake, so affecting yields.

In plantations with fluctuating water tables or which flood periodically, urea and MOP mixtures can be applied together in perforated plastic bags. This results in a slow release effect, thereby reducing losses. By placing two bags per palm roughly two metres from the palm base, this fertilizer application method is able to regulate fertilizer release over a 4-5 month period.

Oil palm's yield response to phosphorus is not usually significant on peat. A minor input of about 0.5 kg rock phosphate annually is normally sufficient to maintain optimum phosphorus leaf status. Higher rates of rock phosphate application (>1.0 kg/palm/year) are not advised, as this reportedly reduces copper and zinc uptake.

Copper and zinc availability can be an issue due to their fixation in peat. Fortnightly spraying of copper solution (15 g CuSO4 dissolved in 18 litres) on young palms suffering from severe copper deficiency should be carried out until new fronds turn green. For severe cases of zinc deficiency in young palms, fortnightly foliar spraying (80 g of $ZnSO_4$ dissolved in 18 litres) is beneficial. Borate application (80-120 g/palm/year) is considered important in the early stages of production. Inadequate boron will lead to significant yield declines due to leaf deformation and the impacts of deficiency on inflorescence and bunch formation.

Manufacturer fertilizer recommendations

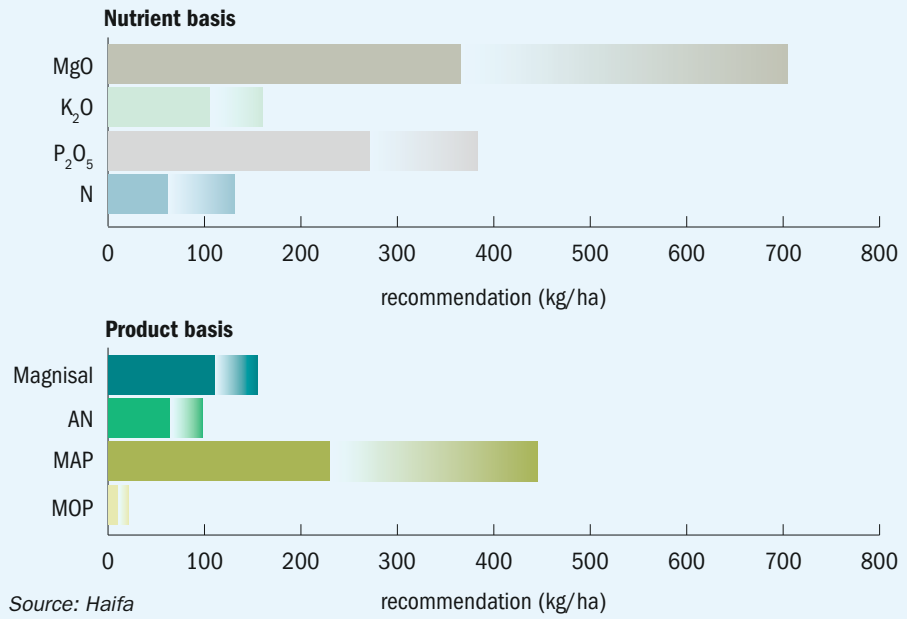
K+S KALI GmbH produces a fertilization guide for oil palm as part of its online crop advisory service. The German potash producer stresses the importance of potassium, magnesium, sulphur and boron as oil palm nutrients, mainly because:

- Potassium secures yield and quality
- Magnesium is necessary for high photosynthesis
- Sulphur is essential for oil quality
- Boron is a vital micronutrient in oil palm nutrition

Potassium is the most important nutrient, suggests K+S, as high oil yield targets cannot be achieved without adequate potash supply. Leaf potassium content is also known to correlate with fruit bunch size and bunch number.

For a target FFB yield of 30 tonnes, K+S advises a standard fertilizer recommendation of:

Fig 3: **Annual nutrient requirements and fertilizer recommendations for mature oil palms**



Source: Haifa

- 3.0-3.5 kg of MOP applied in two applications for mineral soils and up to three applications in peat soils, and
- 1.5 kg of its ESTA *Kieserite* product to supply the magnesium needs of each palm
- Alternatively, 5.5-6.0 kg of *Korn-Kali+B* is recommended, split into three applications, to supply essential potassium, magnesium and boron simultaneously

Haifa Group also provides nutritional recommendation for oil palm. These are based on a plantation density of 128-148 trees/ha, an expected FFB yield of 10-18 t/ha, and a first harvest 32-38 months after planting.

Potassium deficiency is very common, and is the major yield constraint in sandy or peaty soils, advises Haifa. Whereas nitrogen deficiency is usually associated with waterlogging, heavy weed infestation and topsoil erosion. Leaves become shorter in phosphorus-deficient palms and fruit bunch size and trunk diameters are also reduced.

Haifa recommends supplying mature oil palms with sufficient N, P, K, and Mg through the application of MOP, monoammonium phosphate (MAP), ammonium nitrate (AN) and *Magnisal* (magnesium nitrate). It provides average fertilizer application rates for mature oil palms aged six years and over (Figure 3). Haifa advises that:

- Nitrogen should be split into several dressings, the last application timed at least 3-4 months before the start of the dry season in regions with an extended dry period
- Water-soluble phosphate sources are preferrable during the palm's immature phase
- Potash should be spread over the circle around young palms but later broadcast between rows when these mature

Concluding remarks

Yield gaps in commercial palm oil plantations are large. This is partly linked to insufficient fertilizer application rates, these being 40-90% below recommendations in Southeast Asia. Potential oil yields of up to 8 t/ha are achievable in most oil palm growing regions, whereas average actual oil yields are closer to 3.3 t/ha. Encouragingly, there is much scope for closing this yield gap and simultaneously improving plantation sustainability. However, yield responses to micronutrient fertilizers – and attendant issues in mature plantations such as waterlogging, drainage, and plant stress – remain poorly understood[1].

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4. Lim, K. et al., 2012. *RSPO Manual on Best Management Practices (BMPs) for Existing Oil Palm Cultivation on Peat*. RSPO, Kuala Lumpur.

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Parrot Island Yangtze River Bridge in Wuhan, Hubei, China.

China at the crossroads

China is the world's largest producer, consumer and exporter of urea and finished phosphate products. Yet the country's fertilizer industry is at the crossroads currently due to structural oversupply. We report on the outlook for China's nitrogen and phosphate sectors, particularly the prospects for capacity closures, diversification and restructuring.

China wields enormous influence over the global fertilizer industry. Whatever the product, from primary nutrients to speciality fertilizers, from feed phosphates to sulphate of potash (SOP), any analysis of the global marketplace inevitably returns to one key question: how will China behave?

Chinese agriculture now accounts for about one-third of overall global fertilizer consumption. Over the last two decades ago, the country has grown to become the world's largest producer, consumer and exporter of urea and finished phosphates. Having reached self-sufficiency, the country has also emerged as a major nitrogen and phosphates exporter, placing a significant share of its production on the international market[1].

This was not always the case, and China's ascendancy as a fertilizer producer and consumer has been a dramatic one. Going back to the mid-1990s, domestic fertilizer production and agricultural demand were both on a modest scale; China was still heavily import reliant at this stage – and remains so for potash – even becoming one of the largest global importers of urea at one point.

In recent decades, China has actively developed its fertilizer industry, particularly the nitrogen and phosphate sectors, as part of a concerted drive to support domestic crop production. Agricultural intensification has driven fertilizer demand – average yields in China have more than quadrupled in the last 50 years, for example. This, together with a system of subsidies and price controls, has prompted a dramatic 50-fold increase in China's fertilizer use since the 1960s[1].

The nitrogen industry: coal, not gas

The growth of China's nitrogen industry has been shaped by the distribution and abundance of fossil fuels – particularly the prevalence of coal resources versus the limited availability of natural gas. Consequently, three quarters of the country's urea production capacity consumes coal as a feedstock, with natural gas-based plants accounting for the remaining quarter. China originally invested in anthracite-based urea plants and these still account for 40 percent of production capacity. Subsequent investment has, however, increasingly switched to nitrogen plants able to accept lower-cost and lower-grade bituminous coal[1].

The importance of natural gas as a nitrogen feedstock is in decline. China's prioritisation of natural gas for other industrial sectors has tended to price out its use in nitrogen manufacture. Gas-based plants also tend

to have lower operating rates due to natural gas scarcity and availability issues[1].

Historically, China's nitrogen industry has grown up next to coalfields to minimise feedstock transport costs. Because of the way coal resources are distributed, anthracite-based plants are generally located in central or central-eastern provinces, while lower grade bituminous coal plants are typically found in northern or north-western provinces; natural gas-based plants have usually been built near stranded gas deposits.

Nitrogen production

Chinese nitrogen producers are a diverse mix of listed companies, national energy businesses and provincially-owned firms. Many of these operators manufacture nitrogen to add downstream value to their coal extraction activities[1]. The industry remains fragmented, with around 100 urea producers, both small and large, operating across the country. Although the trend is towards larger-scale manufacturing, around a quarter of the country's urea plants still have a production capacity of less than half a million tonnes per year[1].

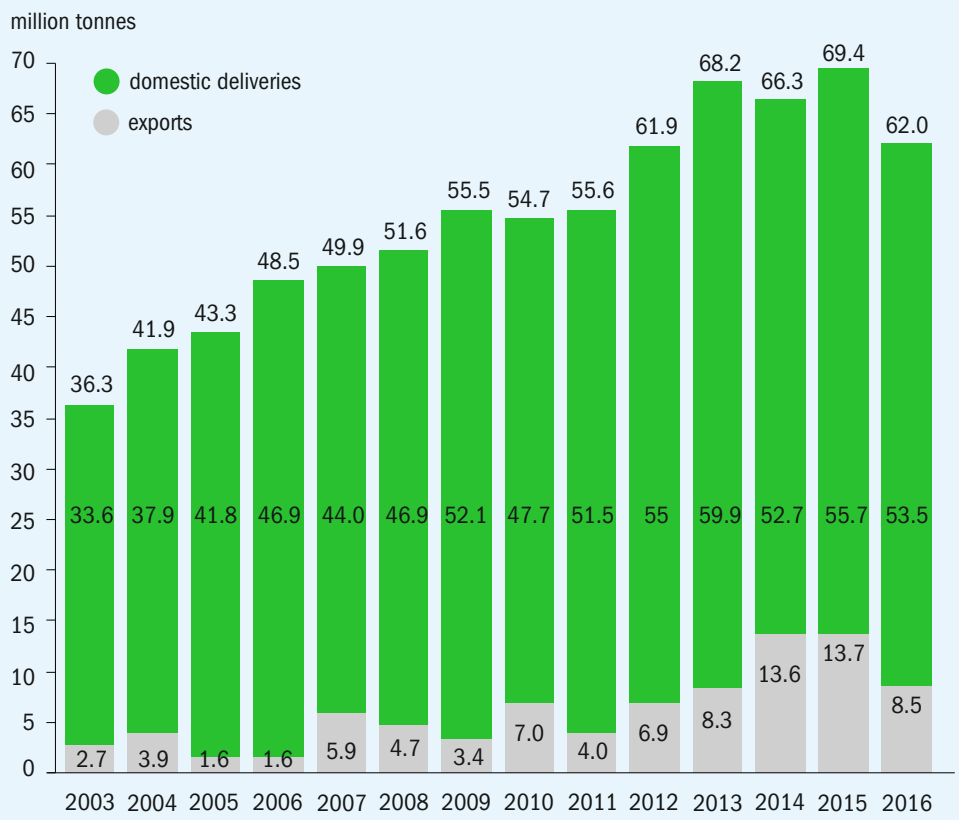
China produced 62.0 million tonnes of urea in 2016, down 7.4 million tonnes on the record levels seen in 2015 (Figure 1). Around six million tonnes of the country's capacity is currently being idled for economic reasons, a situation that is unlikely to be sustainable over the longer-term[2]. The industry is reported to be producing at an average operating rate of under 65 percent currently.

China's urea industry is coming under great pressure to rationalise and restructure in response to a range of challenges, including cost inflation, tighter air quality regulation and the need for plant closures to address overcapacity.

Feedstock price hike, production costs rise

2016 was a dynamic year for Chinese urea costs. A tightening of coal policy caused a spike in urea feedstock prices. Between January 2016 and March 2017, the ex works cost of bituminous coal-based production increased from $152/t to $208/t in Shandong and from $140/t to $190/t in Hubei. Anthracite-based ex works costs also moved upwards, rising from $211/t to $235/t in Shandong and from $196/t to $204/t in Shanxi last year. As a consequence, Chinese urea output fell to 50 percent of nameplate capacity in the final three months of last year[3].

Fig 1: **Chinese urea production, consumption and exports, 2003-16** (million tonnes)



China's share of world urea production:
- 31% 2003
- 40% 2015

China's share of world urea exports:
- 9% 2003
- 29% 2015

Source: Integer Research

Exports fall

Chinese urea exports which rose to a record 13.7 million tonnes in 2015, fell back to 8.5 million tonnes last year, a decline of almost two-fifths (Figure 1). China was effectively squeezed out of both the Indian and Atlantic markets in 2016. Exports to the Americas fell by one million tonnes and those to India were down four million tonnes year-on-year[3].

Further export falls were reported for the first four months of this year. January-April 2017 exports were 1.63 million tonnes, significantly down on the 3.67 million tonnes and 5.28 million tonnes exported over the same period in 2016 and 2015, respectively[2]. Full year Chinese urea exports of 4-5 million tonnes are currently forecast for 2017, a further year-on-year decline, with annual export levels expected to stabilise at around 3.5-4 million tonnes out to 2021.

Higher cost urea producers in China have now completely retreated from the international market. At an international urea price in the region of $200/t, more than 60% of the China urea industry was loss making in 2016, with utilisation rates falling month-on-month last year from March onwards as a consequence[2].

Closure rates

Analysts CRU have estimated that China ultimately needs to close around 15 million tonnes of urea capacity by 2020 to balance the market[4]. This is based on a number of assumptions including exports of 6.5 million t/a, incremental demand of 3.0 million t/a and an average operating rate of 85 percent over this period. While a 15 million tonne downsize in urea capacity should be achievable, the pace of plant closure remains key. Chinese urea producers have been able to resist closure and protect themselves due to factors such as:

- Their relative cost position
- The strength of their balance sheets
- Sales on long-term contacts or hedged sales

- Product premiums and value of the local market
- Government protection of local industry
- Shutdown and restart costs

Previously, the Chinese state has also delayed urea plant closures and industry rationalisation with a policy of cheap coal, state ownership and subsidised capacity. However, CRU's view is that such delaying tactics only provide a temporary reprieve – being sustainable for just 18 months or so – and cannot prevent large-scale closures over the longer-term. By 2018, China needs to close 12 million tonnes of urea capacity to move the market back into balance, suggests CRU, and prompt a return to more positive pricing[4].

China has indeed scheduled some closures in response to poor market conditions. More than seven million tonnes of Chinese urea capacity was due to close in 2016, for example. In the event, though, only 4.4 million tonnes of closures were realised. Forecasting how much Chinese urea capacity will eventually close – and when – is complicated because the market mechanisms forcing closure may be blunted by state intervention. The Chinese government has a history of propping up key sectors, including the nitrogen and coal industries, when these come under economic pressure[2].

Tackling air quality

China's ministry of environmental protection (MEP) is targeting urea production as part of efforts to improve air quality. It has asked many urea plants located near population centres to keep their operating rates low, for example. Also, as much as 28-30 million tonnes of China's urea production capacity could be affected by an MEP consultation on seasonal production cuts for energy intensive industries in North East China (Shandong, Shanxi, Hebei plus Beijing and Tianjing). **Yihua Group** has already been forced to close its Yichang plant in Hebei for environmental reasons[3]. Provincial and city administrators also look set to move against nitrogen plants on environmental grounds, suggests Integer Research[2].

Effects on pricing

The combined effect of higher coal prices in a lower operating rate environment caused urea prices to rise temporarily during the last quarter of 2016 and the first quarter of this year. Prices have since declined back to cyclical lows as 2017 has progressed. Urea prices are still expected to recover to $300/t by the end of this decade, though, as marginal costs increase in China and the market enters a demand-driven phase.

The phosphates industry

China is self-sufficient in phosphate rock with resources concentrated in south and southwest provinces. Variations in ore grade mean that a substantial proportion of domestically-produced phosphate rock concentrate is unsuitable for the manufacture of diammonium phosphate (DAP), a high analysis product. The Chinese industry has overcome this issue by producing lower-analysis monoammonium phosphate (MAP) as well. The country's phosphate industry has grown to the point that it now produces almost half of global DAP and MAP output[1].

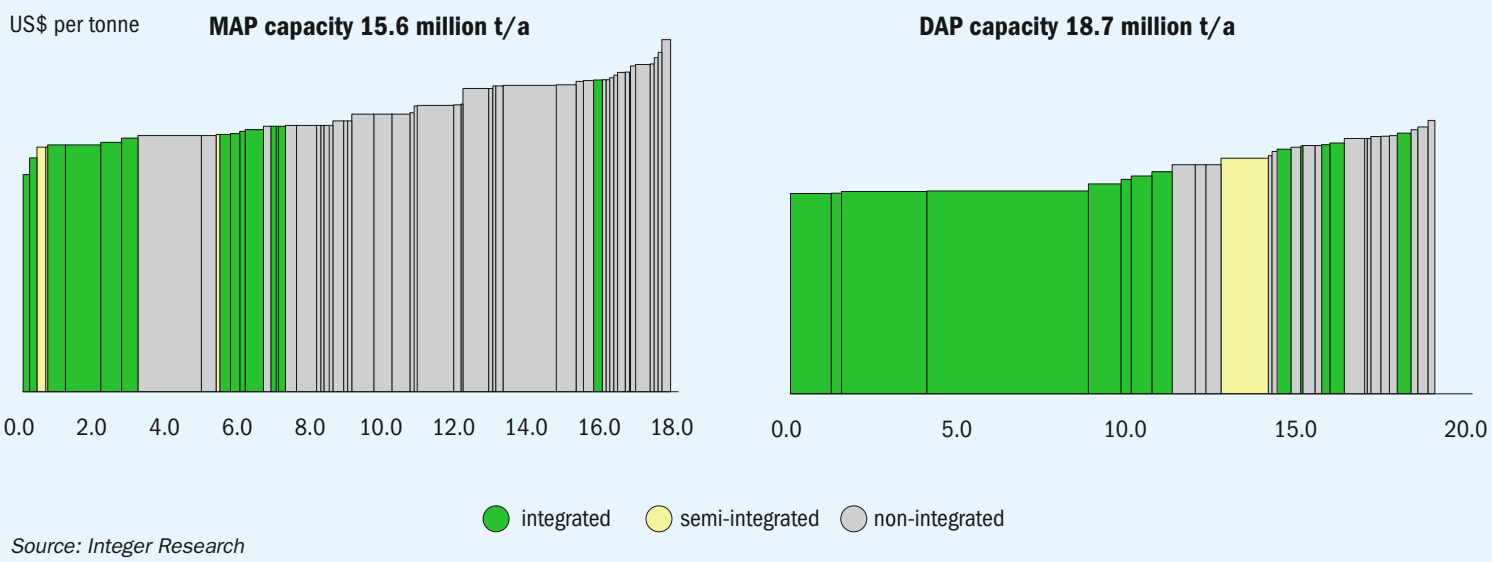
China currently has 18.7 million t/a of DAP capacity and 15.6 million t/a of MAP capacity (Figure 2). Very little of the country's MAP capacity is integrated whereas close to 15 million t/a of DAP capacity is either integrated or semi-integrated (*Fertilizer International* 477, p43). As well as being largely non-integrated, China's MAP sector is fragmented. The country's three largest MAP producers have a combined share of market capacity of less than 25 percent, for instance, whereas the three largest DAP companies account for around 40% of total capacity.

The current state of the phosphates market makes it difficult for non-integrated producers to turn a profit. Cash margins for typical Chinese non-integrated DAP producers were below zero during 2016, prior to the recent price rally (*Fertilizer International* 477, p 43).

Oversupply and declining domestic demand

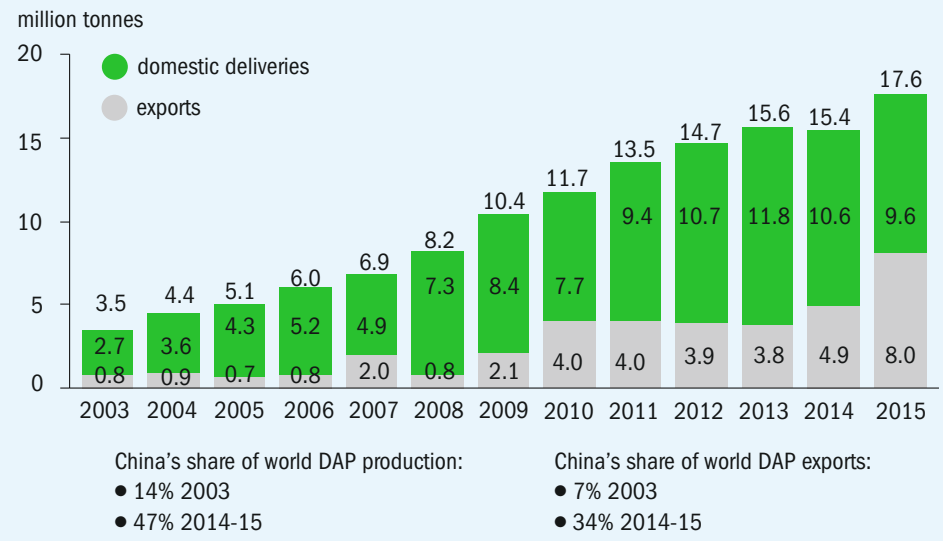
The question of how China's phosphates industry will react to oversupply and declining domestic demand was one of the main themes of CRU's 10th Phosphates International Conference in Tampa this March. Questions were also raised about the extent to which industry restructuring in China can help close the growing chasm between global phosphates capacity and demand (*Fertilizer International* 479, p53).

Fig 2: **Cost curves: Chinese MAP (left) and DAP (right) production, million t/a**



Source: Integer Research

Fig 3: **Chinese DAP production, consumption and exports, 2003-15** (milion tonnes)



Source: Integer Research

In predicting future production, export levels and pricing trends, Chinese phosphates industry observers are monitoring developments on three fronts:

- **Domestic demand:** how far will it fall?
- **Cost structures:** can provincial governments continue with bailouts?
- **Diversification:** can producers successfully enter other markets?

China triggers a price rally

An unexpected phosphates price rally at the start of this year was at least partly triggered by Chinese market developments. The fall in the Chinese DAP price to below $300/t at the end of 2016 – for the first time in four years – appears to have acted as the initial trigger[5]. Some 8-10 producers in China reacted to this news by announcing production curtailments. The Chinese industry agreed to reduce operating rates to 65-70 percent during 2017. Consequently, DAP prices (f.o.b. Tampa), which had languished at close to $310/t in December 2016, rose steadily during January-March, as impressive global demand and shiploading issues tightened availability. Rumours of a DAP subsidy increase in India also helped fuel the rise[5].

Producer discipline

China produces almost half of global DAP. Production is far in excess of domestic requirements and eight million tonnes (45%) of the 17.6 million tonnes of DAP produced in 2015 was exported (Figure 3).

Chinese DAP production is dominated by a handful of producers:

- Yuntianhua (YTH): 23% DAP market share
- Wengfu: 13% DAP market share
- Kailin: 13% DAP market share
- Yihua: 10% DAP market share
- China BlueChem: 5% DAP market share
- XiangFeng: 3% DAP market share
- Xingfa: 2% DAP market share
- Huangmailing: 2% DAP market share
- Sinochem: 2% DAP market share

Six of the largest producers, together with two main distributors, form the '6+2' group. This group, which holds over 70% of total Chinese DAP capacity, is taking action to boost industry profitability and accelerate restructuring[6]. Initiatives include:

- Setting a minimum export price
- Establishing operating rate guidelines
- Raising rock prices
- A sulphur-sourcing joint venture among some members

In January, large DAP producers, including YTH, Wengfu and Kailin, agreed to reduce production by five million tonnes in 2017. The recent price rebound, however, seems to have undermined this agreement (see below).

Loss making operators

CRU reported a $170 fall in the China DAP f.o.b. price last year, from around $460-470/t level in August 2015 to a floor price of around $290-300/t by last November.

Prices are at the floor for many Chinese producers currently, according to Integer Research. The country's production costs (ex-works) are estimated to range from $250-350/t for DAP and $240-325/t for MAP. China's average operating rate is also thought to be around 70% typically (*Fertilizer International* 477, p43).

Chinese DAP producers occupying the third quartile of the cost curve have been operating at a loss, according to CRU. Some of the country's DAP production, concentrated in Hubei, Yunnan and Guizhou regions, is therefore being idled – but could return in response to rising prices[5].

The Chinese government reported that 70 percent of the domestic industry was unprofitable last year. Even big Chinese phosphate producers posted large losses. 2016 losses at YTH and Yihua, for example, are now expected to total $465 million and $160 million, respectively[6].

Most large phosphate producers still operate on reasonable gross margins, although these have been squeezed in recent years. But many move into the red after financial, sales and administrative expenses are deducted[7]. Leading producers are now expected to speed-up the restructuring of the country's phosphates industry in a bid to restore profitability[6].

Risk of closure

Looking ahead, CRU estimates that 3.5 million tonnes (P_2O_5) of Chinese phosphoric acid capacity is at a medium-to-high risk of permanent closure over the next five years. The loss of this capacity, if it were to occur, could spur a much-needed tightening of the global market. Chinese DAP and MAP utilisation rates are also expected to fall to 65 percent and 50 percent, respectively, over this period[5].

Last May, China's National Phosphate and Compound Fertilizer Industry Annual Conference called for the permanent closure of "outdated" plants totalling 3.0 million tonnes P_2O_5 capacity by the end of the decade, equivalent to about 6.5 million tonnes of DAP production capacity[6].

The Chinese government has also embarked on environmental audits of industrial sites, and plans to close down the most serious polluters. Nearly 300 government inspectors began the crackdown with audits in six northern provinces at the end of February. Forthcoming audits in southern and eastern China will encompass phosphate producers in Hubei, Sichuan, and Chongqing provinces, a move that is expected to fuel the industry's restructuring drive[6].

In a further sign of its determination to crackdown on polluters, the Chinese government is set to impose new taxes on air and water discharges from next January. These taxes could potentially add $10-30/t to DAP and MAP production costs[6].

The Chinese fertilizer industry has previously benefited from a raft of subsidies guaranteeing favourable prices on raw materials and transportation. However, nearly all of these subsidies were removed in 2015-2016, either with immediate effect or phased out, including

- **Special rail freight rate:** cancelled since February 2015
- **VAT exemption:** 13 percent rate re-introduced September 2015
- **Low electricity price:** ended April 2016
- **Special natural gas rate:** cancelled November 2016

Lower operating rates, not closures

Despite the removal of subsidies and the ratcheting-up of cost and environmental pressures, analysts CRU are not currently forecasting a wave of plant closures, describing the current state of the Chinese phosphates industry as "a story of lower operating rates" rather than closures.

It is true that some phosphate plants have closed down in recent years. **YTH Jiangchuan Tianhu** in Yunnan closed in 2009, for example, and all plant and equipment has now gone. **Qihua Mining** in Inner Mongolia and **Lvling Group** in Jiangsu both went bankrupt in 2014 and 2015, respectively. **Ningxia Luxi Chemical** in Ningxia switched production away from fertilizers between 2010 and 2014 and is unlikely to change back again.

However, other closures have been less permanent and more difficult to predict. **Luzhai Fertilizer** in Guangxi recently closed for six months, for example, but may be reconfigured for NPK production and reopen with the help of the provincial government. **Zhanhua Group** in Guangdong also closed for three months at the end of 2016, burdened by old, inefficient plants and tight capital, but has since resumed production.

Oversupply

The Chinese phosphate market is undoubtedly facing a double challenge of long-term oversupply and declining domestic demand[7]. China's production capacity for finished phosphate fertilizers amounts to around 21-22 million tonnes P_2O_5 currently. The country's total capacity increases to around 24 million tonnes P_2O_5, once 2.5 million tonnes of additional feed phosphate and purified wet acid (PWA) capacity is factored in. This leaves China with roughly 10 million tonnes P_2O_5 of excess capacity above its domestic consumption needs[7].

Exports

Chinese phosphate fertilizer production and exports are expected to decline as a result of unprofitable economics and more stringent environmental regulation. Exports dropped to 9.5 million tonnes in 2016, a decrease of 2.1 million from the record level of 2015[6]. Although forecasts vary widely, exports look set to decline to around six million tonnes this year. Further declines in Chinese phosphates industry output and exports are expected in 2017, partly because the industry and government are united in their wish to speed-up restructuring[6]. Recent trade figures suggest, however, that production and exports are currently rising year-on-year (see below).

"The Chinese phosphate market is undoubtedly facing a double challenge of long-term oversupply and declining domestic demand."

Diversification one answer

Redirecting current excess capacity away from DAP, MAP and triple superphosphate (TSP) production will require a strategy of diversification. Indeed, China's producers are already looking to diversify, prompted by the downward pressure on DAP and MAP margins. A shift to NPK production is currently the primary choice for diversification. Other options for producers include a move into feed phosphates, purified wet acid (PWA) or value-added fertilizer markets. Overseas investment offers another way of diversifying.

Shifting to products with reasonable margins, and ensuring production methods are not environmentally damaging, will be the key to putting China's phosphates industry on a more sustainable footing, according to CRU[7].

Price signals too strong to resist

Large Chinese DAP producers, because of their dominant market share, are perfectly capable of managing supply, as Integer Research recently pointed out. But as 2017 has progressed it has become equally clear that agreements to curtail production are of little value when market signals encourage the exact opposite. Chinese DAP prices, tracking international prices, increased by $50/t to $355/t during the first quarter 2017. In response, Chinese phosphate output and exports have risen, rather than fallen, as the big producers promised at the start of the year.

Overall Chinese phosphate production reached six million tonnes (P_2O_5) during January-April, a three percent increase on the same period last year. DAP and MAP exports over the same period reached one million tonnes and 0.7 million tonnes, respectively, up 17 percent and 54 percent on 2016 levels.

Such statistics suggest that real cuts to Chinese phosphates output are going to require greater producer discipline, and will need to be accompanied by the medicine of depressed prices if they are to be sustained.

More positively, Chinese phosphate producers have taken action to diversify their product portfolios and shift away from DAP/MAP into either NPK or PWA production – in the face of tighter margins, declining domestic demand and oversupply. It will take time for this approach to work. And, for the moment, the jury remains out on how successful and profitable this strategy will be. ■

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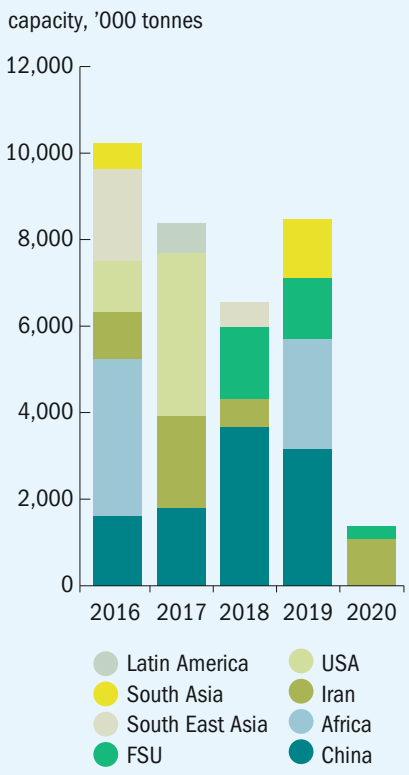
Nitrogen projects head east

We take a look at new nitrogen capacity being planned in Russia and the countries of Central Asia. The Former Soviet Union remains a regional bright spot for new nitrogen plant construction, with three million tonnes of extra ammonia capacity expected to come on-stream in Russia alone by the end of the decade.

While there has been a slowdown in nitrogen capacity building in the Middle East, and India has found it hard to get new plants started, there are still some bright spots for new construction. North America has grabbed many of the headlines (*Fertilizer International* 471, p20), with a plethora of new projects on the back of cheap shale gas availability, alongside ready-made domestic demand, but Central Asia and Russia are also seeing major new investments. While the US has led the way in new urea capacity over the last two years, the Former Soviet Union (FSU) and Africa will both make substantial capacity additions between now and the end of the decade (Figure 1).

Fig 1: **Timing of new urea capacity, 2017-18**



Source: CRU

In recent times, the rouble's depreciation has continued to make nitrogen capacity expansion in Russia a competitive proposition, even against a backdrop of global overcapacity and depressed product prices (*Fertilizer International* 476, p25). Encouraged by favourable investment conditions, both the International Fertilizer Association (IFA) and Integer Research expect Russia's ammonia capacity to increase by three million t/a by 2020. Projects coming on-stream include EuroChem's new nitrogen plant at Kingisepp and PhosAgro's new ammonia plant at Cherepovets (Table 1, Figure 2).

Substantial seaborne supply

These Russian plants are part of a select group of 11 stand-alone ammonia plants globally – out of a total of 43 scheduled for commissioning between 2016 and 2020 – not associated with urea production. IFA expects the new Kingisepp and Cherepovets ammonia plants to contribute substantially to extra seaborne supply, as will similar ammonia projects in Indonesia and Saudi Arabia.

FSU countries ship ammonia internationally from Ventspils and Sillamaë in the Baltic and Yuzhny on the Black Sea. Total seaborne ammonia exports from Baltic ports and the Black Sea amounted to almost 3.7 million tonnes in 2015.

Over the medium-term, surplus production is expected to boost Black Sea and Baltic ammonia exports to markets west of Suez. More seaborne tonnage should emerge from Kingisepp, once Eurochem's new 0.96 million t/a ammonia unit at the site is commissioned in 2018. Kingisepp has the potential to provide surplus ammonia for merchant trade, despite production being earmarked for downstream use. Acron's recently commissioned Novgorod plant and the start-up of PhosAgro Cherepovets plant later this year should also increase Russian export supply. In addition, surplus ammonia production from Nakhodka's project in Russia's Far East could eventually serve exports markets east of Suez (*Fertilizer International* 476, p22). Two other nitrogen projects in the region SOCAR's Sumgait project in Azerbaijan and Turkmenkhimiya's Garabogaz project in Turkmenistan are not expected to generate surplus ammonia, suggests IFA.

Massive increase in export-oriented urea capacity

Around three-fifths of new urea production capacity due to come on-stream globally by 2020 will be aimed at the export market. The additional urea capacity being developed in a number of countries is far in excess of local demand, providing significant surplus capacity for export. This a "key feature of virtually all projects" in Russia and Central Asia, according to IFA.

Eastern Europe and Central Asia account for 7% and 15% of world urea production and exports, respectively. With relatively low domestic use, close to 70% of regional urea production is exported, either as solid urea or as urea ammonium nitrate (UAN) solution. The construction of new urea plants in Azerbaijan, Russia and Turkmenistan is expected to add 3.3 million tonnes of extra capacity by 2020.

Russia's urea capacity is likely to expand by 17 percent between 2015 and

Table 1: **Nitrogen project listing, Russia and Central Asia**

Company	Location	Product	Capacity (t/d)	Contractor	Licensor	Status	Start-up
Azerbaijan							
SOCAR	Sumgait	Ammonia	1,200	Samsung	Haldor Topsoe	UC	2018
SOCAR	Sumgait	Urea	2,000	Samsung	Stamicarbon	UC	2018
Russia							
TogliattiAzot	Togliatti	Urea	2,200	Casale	Casale	DE	2019
EuroChem	Kingisepp	Ammonia	2,700	Tecnimont	KBR	UC	2018
EuroChem	Nevinnomyssk	Ammonia	2,700	Tecnimont	KBR	BE	On hold
Baltic Urea Plant	St Petersburg	Urea	+770	Saipem	Saipem, UFT	DE	On hold
PhosAgro	Cherepovets	Ammonia	2,200	MHI/Sojitz	Haldor Topsoe	BE	2017
PhosAgro	Cherepovets	Urea	1,500	Chemoprojekt	Stamicarbon	UC	2018
Turkmenistan							
Turkmenkhimiya	Garabogaz	Ammonia	2,000	MHI	Haldor Topsoe	CA	2018
Turkmenkhimiya	Garabogaz	Urea	3,500	MHI	Saipem/UFT	UC	2017
Uzbekistan							
NavoijAzot	Navoij	Ammonia	2,000	MHI	Haldor Topsoe	UC	2018
NavoijAzot	Navoij	Urea	1,750	MHI	Saipem/UFT	UC	2018
NavoijAzot	Navoij	Nitric acid	1,500	n/a	Casale	UC	2018

Key: BE: Basic engineering CA: Contract awarded DE: Design engineering UC: Under construction
Source: Nitrogen project listing 2017 (Nitrogen+Syngas 345, p36)

Fig 2: **Nitrogen capacity in Russia and the CIS**

Russia
1. EuroChem (Nevynnomyssk)
2. EuroChem (Novomoskovsk)
3. UralChem (Berezniki)
4. UralChem (Perm)
5. UralChem (Kirovo-Chepetsk)
6. Sibur (Kemerovo)
7. TogliattiAzot (Togliatti)
8. KuibyshevAzot (Samara)
9. JSC Acron (Novgorod)
10. JSC Acron (Dorogobuzh)
11. Minudobreniya Rossoh (Rossoh)
12. PhosAgro (Cherepovets)
13. AO Salavat (Salavat)
14. JSC Angarsk (Angarsk)

Ukraine
15. Odessa Port Plant (Odessa)
16. Concern Stirol (Gorlovka)
17. DniproAzot (Dniprodzerzhinsk)
18. RovnoAzot (Rovno)
19. Severodonetsk Azot (Severodonetsk)
20. OJSC Azot (Cherkassy)

Kazakhstan
21. KazAzot (Aktau)

Turkmenistan
22. Turkmenchimiya State Concern (Tedzhen)
23. MaryAzot (Mary)

Uzbekistan
24. UzKimyoSanoat (Navoi)
25. UzKimyoSanoat (Ferghana)
26. Maxam-Chirchik (Chirchik)

Belarus
27. GrodnoAzot (Grodno)

Tajikistan
28. TajikAzot (Sarband)

New plants
29. EuroChem (Kingisepp)
30. EuroChem (Nevynnomyssk)*
31. JSC Acron (Novgurod)
32. PhosAgro (Cherepovets)
33. Turkmenchimiya (Garabogaz)
34. Uzkimyo Sanoat (Navoi)
* currently on hold

Natural gas

Oil and natural gas are the mainstays of the economies of several FSU countries. Gas production in the region is dominated by Russia, but Uzbekistan, Turkmenistan and Kazakhstan are also major producers; Ukraine and Azerbaijan also have significant gas production. Ample natural gas availability, being a key feedstock for nitrogen production, has helped the FSU region become one of the major global centres for ammonia and urea production.

Russia

BP's annual review of natural gas shows that Russia's proven natural gas reserves stood at 32.3 trillion m^3 by the start of 2016. This represents 17.3% of the world's natural gas reserves. However, this is a significant downward revision from previous figures, and places Russia in unaccustomed second place in terms of reserves, behind Iran. Production was 573 billion cubic metres (bcm) in 2015, a 1.5% fall on the previous year. This figure is almost exactly the same as it was 10 years ago. In general Russian gas production has stagnated, in a period when global gas production has risen overall by 30%, and in Qatar, for example, has more than quadrupled.

Russia remains dependent on natural gas for the majority of its energy. Gazprom still controls much of Russia's natural gas production, owning and operating the country's entire natural gas network, and holding a monopoly on gas exports. The company also generates over one-fifth of Russian tax revenues.

Gazprom embarked upon a much-vaunted 'pivot to Asia' in order to supply gas to the hungry Chinese market. However, the 'Power of Siberia' pipeline to northeastern China is unlikely be completed before 2020. Deteriorating global gas market conditions have also left Novatek's Yamal project as the only Russian LNG project likely to produce gas before the end of the decade.

Kazakhstan

Kazakhstan's gas reserves (0.9 trillion m^3) are the third largest in the region, but most of it is associated gas in the large Tengiz and Karachaganak oil fields. Actual volumes of gas produced have tripled in a decade, but two thirds of the gas is immediately re-injected into wells to keep the oil flowing. The lack of gas processing capacity at the Karachaganak gas processing plant is the main reason for this, and considerable volumes of gas actually cross the border to the Russian Orenburg gas plant. Kazakhstan's gas, often being highly sour, also requires considerable processing to turn it into usable sales gas.

The country's major oil fields are due to be joined by another, the super-giant field at Kashagan. The field holds an estimated 38 billion barrels of crude and a trillion cubic meters of natural gas, making it the largest oil deposit outside the Middle East and the fifth largest in the world. The Kashagan project has been under development for many years and overrun its budget several times over. Oil production at Kashagan resumed in October 2016, the field having briefly produced in 2013.

Turkmenistan

Turkmenistan has seen its estimated gas reserves leap in recent years, from 2.3 tcm in 2004 to 17.5 tcm in 2015. The country now holds the second largest reserves in the region, after Russia, and the fourth largest reserves globally. Turkmenistan has struggled to monetise this huge endowment in natural gas, however, due to the absence of a domestic market and its dependence on Russian-owned pipelines for export. Despite this, the country has attracted considerable cash investments from countries such as India and China, both of whom are desperate for additional supplies of natural gas. The country's huge Galkynysh facility, which began production in 2013, is ramping up gas production and processing, and is aiming to produce 20 bcm per year by 2020.

To improve export supply, China has financed the Central Asia-China pipeline, which connects Turkmenistan and China via Uzbekistan and Kazakhstan. This pipeline consists of three lines A, B and C which between them have a total natural gas capacity of 55 bcm per year. Line C went on stream in May 2014 and has an annual capacity of 25 bcm. Turkmenistan plans to increase this to 80 bcm per year by 2020 by constructing Line D.

Plans also exist for a 33 bcm TAPI (Turkmenistan-Afghanistan-Pakistan-India pipeline) pipeline to run from Galkynysh. Although the route has been surveyed and gas offtake and supply agreements signed, the complex politics and security situation of the region make many sceptical about whether this will ever get built.

Uzbekistan

Uzbekistan is the third largest regional producer (57.7 bcm) after Russia and Turkmenistan (72.4 bcm). Its gas reserves are considerable (1.1 trillion m^3) and of a similar size to Kazakhstan's. Considerable volumes are exported via the Central Asia-China pipeline – although sizable volumes of gas are still flared in the country, and scope remains for extra production. As in Russia, Uzbekistan's ageing gas infrastructure has seen its gas production stagnate over the past decade.

Ukraine

Ukraine reserves are of a similar magnitude (0.6 trillion m^3), but its gas production, at 18.6 bcm per year, fails to meet the country's overall gas demand of 38.4 bcm. Because of this, Ukraine has traditionally relied on Russian gas, and has also acted as a gas conduit to Europe. This has given Russia considerable leverage over Ukraine in the past. Ukraine also reacted to Russia's occupation of the Crimea by cutting off energy supplies to the peninsula. Unsurprisingly, energy dealings between the two countries have been extremely fractious in recent years, making life extremely difficult for ammonia producers within Ukraine as a consequence. Ukraine halted gas purchases from Gazprom in July 2015, for example, after Ukraine and Russia failed to reach a deal on gas deliveries for the remainder of that year. ■

2020, reaching 10.3 million tonnes by the decade's end. Capacity could rise further, to 12.3 million tonnes, if NGhG's Nakhodka nitrogen projects are completed by 2020.

New production

Russia remains the dominant nitrogen producer in the region. Industry consolidation has placed more than half of production in the hands of just three companies: EuroChem, Uralchem and TogliattiAzot. Together with JSC Acron, Sibur, PhosAgro and Minudobreniya Rossoh, seven companies collectively produce more than 90 percent of Russia's ammonia currently.

The commissioning in 2015 of the $1.6 billion **Ammonii** complex at Mendeleyevsk in the Republic of Tatarstan marked the start a new wave of nitrogen project investment in Russia. The integrated ammonia, methanol and granular urea plant reached full capacity in September 2015. Symbolically, Ammonii was the first large-scale fertilizer complex to be built in the region since the collapse of Soviet Union nearly 35 years ago.

The plant has a design capacity of 717,550 t/a for ammonia, 238,000 t/a for methanol and 717,000 t/a for granular urea. Excess ammonia is used to supply the existing ammonium nitrate plant at the site which dates from 1988.

Ammonii is a joint venture between Regiongazfinans (68%) and the Tatarstan government (32%). It was built in collaboration with Russian Design Institute NIIK, engineering and procurement (EP) contractor Mitsubishi Heavy Industries (MHI) and Chinese construction company CNCEC (*Nitrogen+Syngas* 338, p46). Natural gas feedstock for the complex is supplied by Gazprom subsidiary ZAO Tatgazinvest.

Technology licensors for the complex include Haldor Topsoe's IMAP process for ammonia and methanol co-production and Saipem's Snamprogetti process for the urea melt plant. Uhde Fertilizer Technology (UFT) is used in Ammonii's urea granulation plant.

Ammonii has its own rail freight fleet, including 200 cars for methanol and 150 cars for ammonia, and began taking steps to build a similar rail fleet of dry bulk hopper cars for its urea deliveries last year.

Ammonii has plans to develop Ammonii-2, an identical capacity integrated ammonia, methanol and urea plant. It signed a memorandum of intent for this successor project with Japanese partners MHI and Sojitz Corporation in February last year.

JSC Acron also expanded its nitrogen production capacity last year by commissioning a new ammonia plant at its Veliky Novgorod site. The $420 million, 700,000 t/a capacity ammonia-4 unit is Acron's largest nitrogen project investment in several decades and uses Haldor Topsoe technology. The new plant increases Acron's ammonia capacity by 65%, allowing the firm to expand fertilizer production. The new unit will also generate ammonia export sales for Acron. Ammonia output from the new unit will be exported using capacity at the AS Baltic Chemical Terminal (BCT) at the Port of Sillamäe in Estonia.

The low gas consumption of the two existing ammonia units at Novgorod (1,070 m^3/t NH_3) means they are the most cost effective in Russia, according to Acron. Ammonia-4 is even more gas efficient (gas consumption of 927 m^3/t NH_3) – and should therefore reduce production costs at Novgorod even further.

In Russia, **EuroChem** has the most ambitious expansion programme in the

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region. The company plans to eventually build three new nitrogen plants over the next ten years, two in Russia and one near Zhanatas in Kazakhstan.

Construction work on a 2,700 t/d capacity ammonia plant at Kingisepp near St Petersburg on the Gulf of Finland is already underway. KBR is providing the technology and Maire Tecnimont is acting as the general designer and EPC contractor. Scheduled for completion in late 2018, Kingisepp will be the most advanced ammonia plant of its kind in Europe. A separate plan to integrate urea production at Kingisepp remains under consideration.

Although Maire Tecnimont has completed front-end engineering design for the proposed new Nevinnomyssk plant in Russia, EuroChem has yet to greenlight other ammonia-urea projects in the region. A final decision on whether to proceed with these is not expected until after the Kingisepp ammonia plant has been completed, and once the company's greenfield VolgaKaliy and Usolskiy potash projects enter operation.

PhosAgro began construction of a new, more energy efficient 760,000 t/a capacity ammonia plant at its Cherepovets site in 2013. Mitsubishi Heavy Industries is building the plant using Haldor Topsoe technology. Cherepovets currently has a production capacity of:

- 4.0 million t/a for MAP/DAP/NPK/NPS
- 1.19 million t/a for ammonia
- 980,000 t/a for urea
- 450,000 t/a for ammonium nitrate
- 140,000 t/a for ammonium polyphosphate

PhosAgro's overall production of nitrogen fertilizers increased by 4.3 percent last year to 1.5 million tonnes, although its nitrogen fertilizer sales were stable at 1.4 million tonnes. Output at the Cherepovets site increased by eight percent year-on-year in 2016, according to the company.

Much of PhosAgro's capital expenditure in 2016 (RUB 45.3 billion) was focused on the construction of the new ammonia plant and the associated 500,000 t/a urea granulation plant at its Cherepovets site. The construction costs of the ammonia plant and urea plant had reached RUB 34,222 million and RUB 11,925 million, respectively, by the end of 2016. Construction of the ammonia plant remains on track and it is due to be commissioned later this year.

PhosAgro is aiming to become fully self-sufficient in ammonia and significantly reduce its costs once the new ammonia and urea granulation units at Cherepovets have been launched. Ammonia purchasing accounted for seven percent of the costs of goods sold at the company in 2016. PhosAgro's natural gas consumption per tonne of product should also be reduced by 8% once the new ammonia plant is up and running.

Uralchem is expanding production via revamps. A revamp was recently completed at the Kirovo-Chepetsk ammonia plant, taking capacity to 1,750 t/d. Stamicarbon is also working on raising urea production at Uralchem's Perm site by 40% (250,000 t/a) by 2019 using *Urea2000plus* technology. **TogliattiAzot** is also revamping all its ammonia plants.

Turkmenistan has two nitrogen manufacturing sites run by state-owned **Turkmenhimiya**. The country's largest operational production site is the MaryAzot complex at Mary, which has 400,000 t/a of ammonia capacity and 635,000 t/a of urea capacity. The Tedzhen complex, completed in 2004, provides an additional 200,000 t/a of ammonia and 350,000 t/a of urea capacity.

Turkmenkhimiya is building a new nitrogen complex at Garabogaz, with 2,000 t/d of ammonia and 3,500 t/d of urea capacity. HaldorTopsoe and Saipem are the technology suppliers here, with UFT providing the urea granulation plant. Completion is set for mid-2018.

Finally in Uzbekistan, **Navoiyazat**, the chemical production arm of state-owned Uzkimyosanoat, has awarded the EPC contract for its new gas-based ammonia-urea fertilizer plant at Navoiy to Mitsubishi Heavy Industries (MHI) and Mitsubishi Corporation. The plant will produce 2,000 t/d of ammonia and 1,750 t/d of granulated urea, with a surplus of around 1,000 t/d of ammonia.

No new projects are expected in Ukraine over the medium-term. The country's nitrogen industry is mostly in the hands of **Group DF** via its Ostchem holding company. The group owns four of the country's six production sites – Rivne, Cherkassy, Severodonetsk and Stirol/Gorlovka – and also markets product on behalf of the state-owned **Odessa Port Plant** (OPZ) at Yuzhnyy. The country's third producer, **DneproAzot**, is leased to gas supplier Ukrnafta, both firms being part of the Privat Group. Although most Ukrainian plants have avoided the direct consequences of the Russian-Ukraine conflict, the two largest, Severodonetsk and Stirol, are located near to the combat zone in the east of the country.

Table 2: **Ammonia, production, consumption, imports and exports in the Russia and selected FSU countries, 2015 ('000 t)**

Country	Production	Apparent consumption	Exports	Imports
Belarus	1,103	1,097	6	0
Kazakhstan	170	182	0	12
Russia	15,153	11,521	3,632	0
Turkmenistan	578	578	0	0
Ukraine	2,673	2,203	652	182
Uzbekistan	1,360	1,354	7	0
FSU total	**22,335**	**18,329**	**4,309**	**303**

Source: IFA

Impact of new capacity

The FSU region's production, consumption and trade in ammonia are shown by country in Table 2. Russia controls more than two-thirds of regional ammonia production. Its nearest rival Ukraine has seen its normal production levels cut back by about 60 percent since 2013, due to conflict, gas shortages and cost increases. The construction of new plants, together with upgrades and revamps, will add around three million t/a to Russian ammonia capacity by 2020, about half of this being dedicated to downstream urea capacity, the rest being destined for the merchant market. Another 1.5 million t/a is under development in Turkmenistan and Uzbekistan, 80 percent of it with downstream urea capacity. Collectively, this 4-5 million tonne regional ammonia capacity addition is the largest outside of China, and promises to more than make up for losses from Ukrainian production. The FSU should therefore remain a nitrogen project investment hotspot until the decade's end. ■

Acknowledgement

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SCHADE portal reclaimer at PhosAgro's Cherepovets site in Russia.

Fertilizer handling orders and contracts

The transportation and distribution of fertilizers and associated raw materials by road, rail and sea relies on safe and efficient bulk handling and storage. We provide a round-up of major recent equipment contracts.

Custom portal reclaimer for Agrium

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

AMECO currently supplies stackers, reclaimers, blending systems and shiploaders for fertilizer, pulp, biomass and coal power plants and port terminals. It recently commissioned a 480 t/h custom portal reclaimer with a rail span of 54 metres for urea handling at **Agrium**'s Borger, Texas, plant. The innovative storage system designed and installed by AMECO drags urea from a pile to 20 degrees below ground. The extra storage capacity provided by the new state-of-the art reclaimer is 50 percent greater than other standard equipment available on the market, according to AMECO.

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

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

FLSmidth wins port construction order

Global engineering giant **FLSmidth** secured a major engineering, procurement and supervision (EPS) contract with Russian marine export terminal owner **Oteko-Portservice** last year. The €160 million contract is for fitting-out a new cargo terminal under construction at Taman on Russia's Black Sea coast. The new terminal will handle Russian fertilizer, coal, iron ore and sulphur exports once complete. Under the contract, FLSmidth will supply and install railcar unloading, screening and crushing equipment, stockyard machines, shiploaders and associated conveyor systems.

"FLSmidth and Oteko have worked jointly on this project for a long time and have now found a technically and commercially viable solution that allows this project to go ahead despite the headwind from the commodity market," said Manfred Schaffer, executive vice president of FLSmidth's minerals division, speaking last May. "This order includes supplies and services from various FLSmidth business units and is particularly valuable in times with low capital investments in the mining and minerals industry."

The contract with Oteko follows a €30 million order from Moroccan phosphate producer **OCP Group** in 2015. This covers the supply of materials handling equipment at a port and mine site. It also covers the supervision of equipment erection and commissioning. The equipment to be supplied includes:

- Three 2,000 t/h capacity bucket wheel reclaimers
- Two 2,000 t/h capacity stackers
- Two 1,000 t/h capacity stackers
- Associated yard conveyors

"OCP Group is experiencing an increase in fertilizer demand and thereby a need for capacity expansion. The Group is a well-known customer to FLSmidth and we are very happy that they have chosen to place this order with us," commented Manfred Schaffer.

Reclaimers for PhosAgro Cherepovets, Russia

SCHADE Lagertechnik GmbH, part of the global conveying and storage technology company AUMUND Group, recently suppled **PhosAgro** with three portal reclaimers for its Cherepovets fertilizer complex in Russia. It follows a previous 2014 order with PhosAgro for a 200 t/h capacity reclaimer with a 54 metre rail span for the company's urea plant. This was delivered in August last year. SCHADE says it won its latest order thanks to a similar equipment reference at OAO Ammoni in Mendeleevsk, Russia, commissioned in the summer of 2015, and another in Dakota in the United States.

Two full-portal reclaimers, each with a capacity of 100 t/h, a rail span of 44 metres and weighing 144 tonnes, were delivered to the Cherepovets complex in January. These were installed at an extension plant for potash, ammonium sulphate and NPK production. The new equipment will allow what SCHADE describes as "very aggressive material" to be reclaimed via two conveyor belts. As well as equipment, SCHADE is also supplying engineering know-how for this plant.

To complete the contract, a third large-scale full-portal reclaimer was also delivered to PhosAgro in January. This 400 t/h capacity machine with a rail span of 44 metres will be used in the three-train (10,000 t/a each) NPK production plant at Cherepovets.

Sackett and Waconia merge

A.J. Sackett & Sons Company and Waconia Manufacturing, Inc. merged at the start of 2017 to become **Sackett-Waconia**. The merged company has over 180 years of experience, combines four US manufacturing locations and brings together joint ventures in Brazil and Africa.

Sackett-Waconia specialises in complete system design for bulk blending, bulk terminals, granulation, compaction/granulation and fertilizer coating. More than 1,000 Sackett-Waconia blending plants are currently in operation, and the company has sold its technology and equipment to 65 countries globally.

Sackett-Waconia has completed a wide spectrum of fertilizer industry projects in recent years. In the US and Canada, this includes:

- Numerous bulk blending plants, notably for Helena Chemical, Wilbur-Ellis Companies, United Farmers Co-op, Star of the West Milling, CHS, Simplot and Koch
- PotashCorp's new Hammond, Indiana, regional distribution centre, one of several large North American terminal projects
- A granulation system for Anuvia Plant Nutrients

PotashCorp's massive new $90 million Hammond, Indiana, distribution centre, which opened in September 2016, can store over 100,000 tons of potash and accommodate more than 1,000 rail cars. The state-of-the-art centre unloads and loads potash at 1,200 t/h and 800 t/h, respectively, around two- to three-times faster than existing potash warehouses.

Sackett-Waconia's granulation plant for Anuvia in Zellwood, Florida, was commissioned in March last year. This creates enhanced efficiency fertilizers (EEFs) from organic materials using patented slow-release technology. Products include *SymTRX* for the agricultural market and *GreenTRX* for turf and speciality markets. "Our work with Anuvia and the creation of the Zellwood facility is one more step in Sackett's commitment to engineering and building high efficiency equipment that supports the 4R Nutrient Stewardship philosophy and the overall trend toward better nutrient stewardship," Charles Formisani, Sackett's vice president of sales, commented last March.

In Latin America, Sackett-Waconia blending projects include proprietary *Precision Fertilizer Blending* systems and soluble fertilizer blending plants. Locations range from Mexico to Chile and parts of the Caribbean.

Sackett-Waconia offers its complete product line in Brazil through Sackett do Brasil, an Araxá-based company founded 10 years ago with local partners. Sackett do Brasil currently has contracts for a number of high-capacity blending plants in Brazil. The company offers engineering, project management, and manufacturing expertise for blend plants, NPK and SSP production and other fertilizer-related technologies.

Sackett-Waconia is also active in Australasia. The firm has completed an initial *Precision Fertilizer Blending* plant for Ravensdown in New Zealand, with a second plant under contract, and has also completed systems for Summit Fertilizers and others in Australia.

Sackett-Waconia recently partnered with **Bagtech International** in the African market. Bagtech has an excellent reputation for blending and bagging throughout Africa, and the two companies are now jointly marketing and supplying fertilizer blending, handling and process systems on the continent.

Automated continuous blending machines

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

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

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

EMT also produces connecting equipment including elevator chains and belt transport conveyors. It also offers fertiliser screening, lump crushers, conditioners and coating machines as part of its equipment delivery packages. All of the company's machines are constructed in stainless streel and are easy to transport in containers. Blender lines are based on batch blending or a continuous process, as used by its *Weighcont* machines.

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

France: EMT has installed a *Weighcont* blender at a fertilizer coating and blending factory in France. The 100 t/h capacity factory treats urea with an inhibitor. A double-unit, big bag fill *Weighcont* system with a capacity of 140 t/h was supplied. EMT also installed three stainless steel dust screening lines at this French factory.

Ethiopia: EMT installed blender and bagging systems at four inland fertilizer distributor warehouses in Ethiopia for ATA last year. Each of these lines enables the customer to blend and bag fertilizers at 40 t/h.

South Africa: EMT recently delivered a complete product intake project for a customer in South Africa with screen lines and box distribution conveyors. A *Weighcont* blender line and two bagging lines were also installed for the customer as part of this project. EMT needed to ship machines in 12 containers from the Netherlands to South Africa to complete this project.

Thailand: EMT installed three *Quattro* bagging machines with six bagging lines and two robotic pallet systems at a central factory with a capacity of 240 t/h. EMT also supplied conveyors to discharge raw materials from the harbour to the bagging machines as part of this project. All machines were constructed in stainless steel.

The Netherlands: EMT installed a *Weighcont* blender line for water soluble fertilizers. Dust reducing housings needed to be placed above the intake hopper of the blender due to the dusty nature of these powdery and crystalline products.

Advances in dust suppression

DSH Systems Ltd has successfully installed its latest generation *DSH PFC Dust Suppression System* at Cargill's grain processing plant in Wahpeton, North Dakota. The system is also perfect for fertilizer loading applications, says DSH, as these often require multiple products of widely varying characteristics to be loaded via a single loading point.

The new and highly-flexible PFC system allows a single DSH hopper unit to be used with either:

- A variety of different products
- The same product with a large variation in bulk density
- A combination of both of the above

The system installed for Cargill, for example, allows two different products to be selected, and then one of four density settings to be selected for each product. However, the system is highly flexible and can be fully-customised to meet specific project needs.

The PFC system is fully compatible with any size of hopper in the DSH range. The system consists of a Steel DSH Dust Suppression Hopper (Stainless, Corten or Hardox options) resting on a Loadcell within a specialised frame design. The Loadcell is connected to a DSH-supplied PLC control system. A motor (ATEX specification, if required) and screw-jack unit are also connected to the PLC controller. The screw-jack has a DSH Hopper Plug attached.

During operation, the PLC continuously monitors the weight signal coming from the Loadcell. This allows the PLC to control the position of the hopper plug by instructing the screw-jack to action

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up or down accordingly. The PLC comes with a variety of self-test, safety over-rides and reset controls. During calibration, it is trained to look for the known optimum operating weight, based on product type and bulk density.

Many DSH customers handle products with bulk densities that vary according to humidity/temperature, or the stage of the loading process – for example, at the top or bottom of the silo or the start or end of ship unloading. The PLC allows the operator to adjust for this by simply selecting the type of product being loaded and the applicable bulk density, whether high, normal or low.

While the standard DSH Dust Suppression System meets the needs of the large majority of global customers, the addition of the latest PFC system provides even greater flexibility during loading. It also represent a major step forward in achieving the DSH company's ambition to eliminate all dust during bulk loadout – to safeguard workers' health, save companies money and protect the environment.

Bedeschi: partnering with Yara

Bedeschi Spa is a well-established turnkey supplier of crushing and handling machines for cement, steel, coal, mining and other industrial processes. The Italian industrial manufacturer moved into the marine sector 15 years ago and now offers a range of large-scale onshore and offshore shiploading equipment. It is also active in the container logistics sector.

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

Bedeschi has developed a strong partnership with Yara International over the last 13 years. A shiploader contract at the port of Sluiskil in the Netherlands is the latest of four contracts awarded by Yara to Bedeschi. Their relationship dates back to supply of a shiploader at the port of Ravenna in Italy in 2004. Bedeschi also engineered, erected and commissioned a new shiploader at Brunsbuttel, Germany, in 2012, as part of a turnkey project with Yara Germany to replace its existing shiploader at the port.

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

In January this year, Bedeschi was awarded the contract for the supply of the No 1 shiploader at Yara's Sluiskil plant in the Netherlands. Sluiskil is a major fertilizer production complex and the largest manufacturing site for ammonia and nitrate fertilizers in Europe. The complex comprises of three ammonia plants, two nitric acid plants, two nitrate granulation plants and two urea plants, one for prilling and the other for granulation. The complex is located close to Antwerp with direct access to the North Sea.

A new slewing shiploader with a 600 t/h design capacity will be installed at Sluiskil to efficiently load barges and shipping vessels under heavy duty conditions.

The shiploader is a long travel type. A towed tripper diverts material from a wharf gallery conveyor onto a sandwich belt conveyor, and then onwards to a loading boom belt. The boom will incorporate luffing and slewing movements to perform the required loading operations. The shiploader will be pre-assembled at Mammoet Multi-Purpose Terminal and then transported to the quayside at Sluiskil using barges equipped with floating cranes.

Bedeschi's R&D department is also bringing a fully automatic shiploading system to market. The highly efficient system increases overall loading rates and cuts down on the manpower needed during loading. It also incorporates extra safety features, requires less maintenance and improves turnaround during the loading of bulk carriers. The system is suitable for both manned and unmanned shiploader operations.

Key features of the new automated loading system are the 3D-laser and 2D-radar sensors mounted at the end of the boom and near the chute. The system uses data from these sensors to create a digital model of the ship prior to loading, including vessel structure, hatch layouts and hatch sizes. Additional sensors located close to the boom prevent the loader from colliding with any of the ship's structures. In future, port investment in fast, innovative, efficient and non-polluting shiploading equipment will be based on fully automated systems, predicts Bedeschi.

New sulphur unloader at Aqaba

Siwertell completed the delivery of a comprehensive dry bulk handling package to the Jordanian Port of Aqaba in 2016. Siwertell supplied the port with a state-of-the-art, rail-mounted *ST 640-M* ship unloader. The history of the project dates back 10 years. The port authorities first invited Siwertell to tender for a replacement ship unloader in 2006, following the catastrophic breakdown of a bucket unloader.

The Port of Aqaba is operated by Jordan Industrial Ports Co (JIPC), a company set up in 2009 and jointly owned by the Jordan Phosphate Mines Company (JPMC) and the Arab Potash Company (APC).

In 2014, a Spanish joint venture (JV) company formed by Técnicas Reunidas and PHB secured a contract from JIPC for a refurbished and expanded jetty at the port. These JV partners then awarded a contract to Siwertell in 2015 to supply and deliver an unloader for the port within a 12-month timeframe.

The unloader's component parts were initially delivered to Gijon in northern Spain where they were assembled by the JV company, prior to delivery of the complete unit to Jordan. The unloader was finally installed, tested and commissioned earlier this year. Siwertell has supplied a comprehensive spare parts package and provided on-site operator training as part of its contract.

The new unloader is equipped with Siwertell's 4S safety system as it will be mainly used to discharge sulphur. 4S is a two-stage system: it firstly works on preventative basis, seeking to eliminate the risk of explosions or fires by monitoring and removing ignition conditions; it also acts to contain and extinguish fires in the unlikely event of an explosion.

Environmental safeguards offered by Siwertell helped secure the contract. Aqaba's Red Sea location is renowned for its unpolluted waters, coral reefs and beaches. Zero emissions were therefore an important requirement for any bulk handling system in this sensitive marine area. The Siwertell ship unloader has a totally-enclosed conveyor system. This starts at the ship's hold, with the intake of material below the cargo level, and continues to the discharge point at the receiving belt conveyor. It is probably the only technology on the market that offers dust- and spillage-free cargo handling, according to Siwertell.

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BCInsight

Our ideas make profitable plants

World class phosphoric acid technology

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With more than 50 years' experience, Prayon Technologies has developed a unique expertise in designing phosphoric acid plants. Our mission is to optimise your plant performance and increase its profitability.

P recovery: from evolution to revolution

Full-scale deployment of phosphorus recovery technologies is on the rise. In Europe, greater interest in P recovery is directly linked to the debate surrounding the European Commission's circular economy policy package. **Christian Kabbe** and **Fabian Kraus** of Kompetenzzentrum Wasser Berlin report on the latest commercial developments in nutrient recovery technology.

Challenges remain about how to transform the circular economy from a buzzword into something more tangible and concrete. Fortunately, a growing number of nutrient recovery technologies are becoming increasingly commercial and marketable as they mature. But ultimate commercial success will not depend on pure recovery alone, as the nature of the intermediate and final products obtained also governs viability. The key challenge now is to build on progress to date, and use this as a springboard to bridge the gap between the recovery of secondary nutrients (supply) and the market for these (demand). This will require the creation of credible markets and viable value chains.

Phosphorus and nitrogen

Several new, full-scale struvite recovery units have entered commissioning recently. New projects to install the next wave of these units have also been launched. As well as the growing popularity of standard struvite recovery, a number of more advanced – so-called second generation – units are starting to enter operation. This is evidence that a broader approach to nutrient and energy recovery, one that encompasses the capture of nitrogen and carbon as well as phosphorus, is fast gaining ground.

Enhanced recovery of carbon, phosphorus and nitrogen at wastewater treatment plants (WWTPs), by combining proven technologies in a single package, is delivering added benefits and synergies. Ash-based approaches to phosphorus recovery have also matured and are poised to enter the market. Here, the focus has switched away from producing solid nutrient concentrates towards phosphoric acid production instead. Even the production of elemental phosphorus (P_4) from ash is back on the agenda.

Table 1: **Phosphorus recovery from the wastewater: operating units and those under construction**

Technology	Location and operator	Operational since	Recovered material
Onsite wastewater treatment plants			
AirPrex®	MG-Neuwerk (DE), Niersverband	2009	Struvite
	Wassmannsdorf (DE), Berliner Wasserbetriebe	2010	
	Echten (NL), Drents Overijsselse Delta	2013	
	Amsterdam-West (NL), Waternet	2014	
	Uelzen (DE), SE Uelzen	2015	
	Salzgitter Nord (DE), ASG	2015	
	Wolfsburg (DE), SE Wolfsburg	2016	
	Tianjin (CN), Tianjin CEPG	2016	
	Liverpool, OH (USA), Medina County	2017/18	
ANPHOS® (Colsen)	Odiliapeel (NL), Peka Kroef	2005	Struvite
	Kruiningen (NL), Lamb Weston Meijer	2005	
	Bergen op Zoom (NL), Lamb Weston Meijer	2007/16	
	Budrio (IT), Pizzoli	2010	
	Oosterbierum (NL), Lamb Weston Meijer	2016	
	Den Bosch (NL), Waterschap Aa en Maas	2017	
Crystalactor®	Nanjing (CN), Royal Haskoning DHV	2010	Struvite
EloPhos®	Lingen (DE), SE Lingen	2016	Struvite
EXTRAPHOS® (Budenheim)	MZ-Mombach (DE), Wirtschaftsbetrieb Mainz	2017 (pilot)	DCP
Gifhorn	Gifhorn (DE), ASG	2007	Struvite/CaP
Hitachi-Zosen (Unitika)	Matsue (JP)	1998	Struvite
	Senboku (JP), Senboku City	2009	HAP

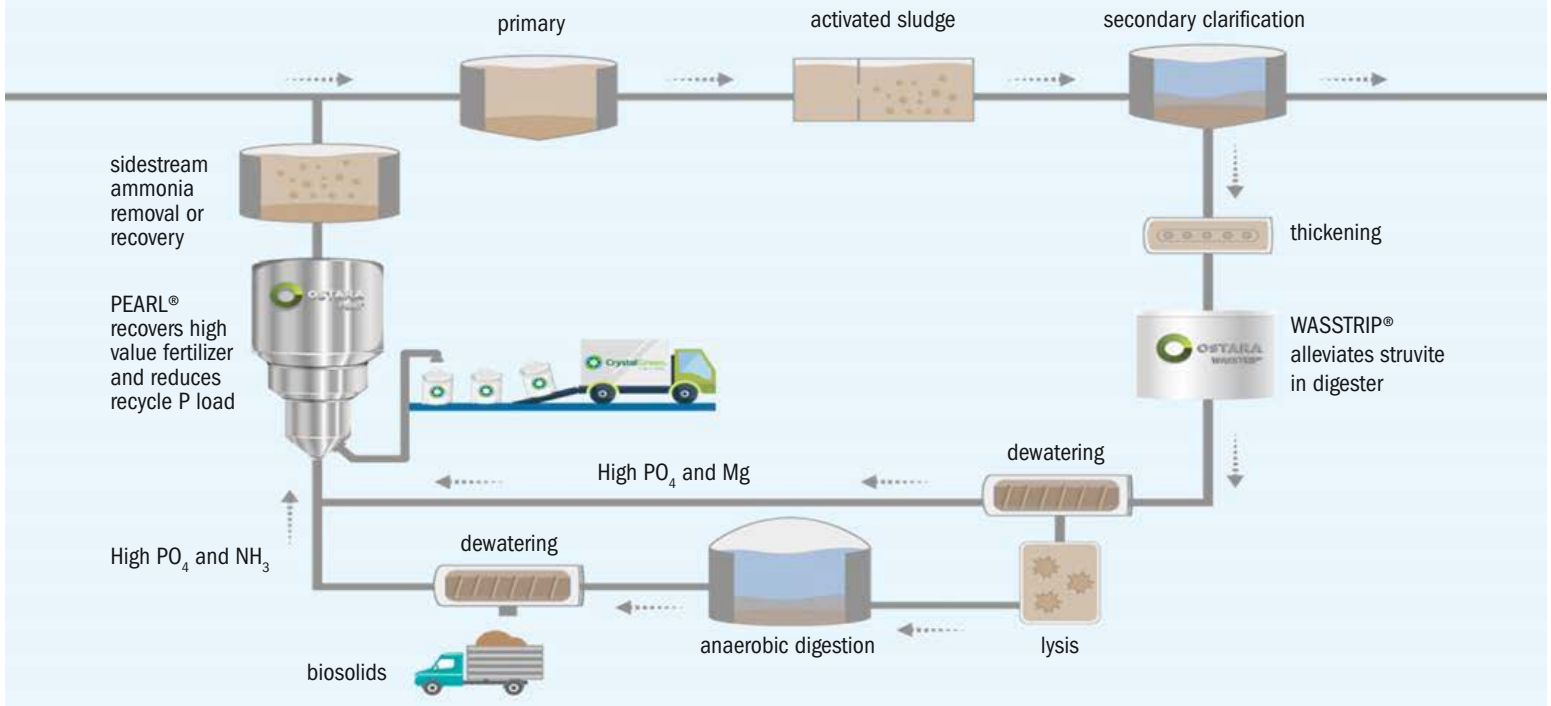
Table 1: **Phosphorus recovery from the wastewater: operating units and those under construction (continued)**

Technology	Location and operator	Operational since	Recovered material
Onsite wastewater treatment plants continued			
J-Oil	Yokohama (JP), J-Oil Mills Co.		HAP
JSA	Kawasaki (JP), Japan Synthetic Alcohol Co.	1998	HAP
KURITA	Fukuoka (JP), 3 plants	1997	Struvite
Kyowa Hakko	Hofu (JP), Kyowa Hakko Bio Corp.	2006	HAP
Multiform™	Yakima, WA (USA) Boise, ID (USA) Massey, MD (USA), Jones Family Farms (dairy) Green Bay, WI (USA)		Struvite
NASKEO	Castres (FR)	2015	Struvite
PEARL® (OSTARA)	Tigard, OR (USA), Clean Water Services Suffolk, VA (USA), Hampton Roads Sanit. District York, PA (USA), City of York Hillsboro, OR (USA), Clean Water Services Slough (UK), Thames Water Saskatoon, SK (CDN), City of Saskatoon Madison, WI (USA), Madison Metro. Sew. Distr. Burford, GA (USA), Gwinnett County Amersfoort (NL), Vallei & Veluwe Edmonton, AB (CDN), EPCOR Water Services Stickney, IL (USA), Metro. Water Recl. Chicago Reno, NV (USA), Cities of Reno and Sparks Madrid (ES), Canal de Isabel II Winchester, VA (USA), F. Winchester Service A.	2009 2010 2010 2012 2013 2013 2014 2015 2015 2015 2016 2016 2016 2016	Struvite (Crystal Green®)
PHORWater	Calahorra (ES), El Cidacos	2015 (demo)	Struvite
PHOSPAQ™	Olburgen (NL), Waterstromen Lomm (NL), Waterstromen Nottingham (UK), Severn Trent Water Tilburg (NL), Waterchap de Dommel	2006 2008 2014 2016	Struvite
PhosphoGREEN (SUEZ)	Aaby (DK), Aarhus Water Marselisborg (DK), Aarhus Water Herning (DK), Herning Water	2013 2018 2016	Struvite
REPHOS® (delivered by NuReSys)	Altentreptow (DE), Remondis Aqua (dairy)	2006	Struvite
STRUVIA™	Helsingør Southcoast (DK), Forsyning Helsingør	2015	Struvite
Stuttgart	Offenburg (DE), AZV Mobile unit – MSE Mobile Schlammentwässerungs GmbH	2011 (demo) 2015	Struvite (after acid leaching)
Swing	Kobe (JP), Swing Corp.	2012	Struvite

Technology	Location and operator	Operational since	Recovered material
Downstream wastewater treatment plants and ash treatment			
EcoPhos	Varna (BG), DecaPhos Dunkerque (FR), EcoPhos	2016 2017	H_3PO_4/DCP/ MCP
Fertilizer industry	Various companies already apply or consider use of secondary P sources	tested and intended	commercial fertilizer
MEPHREC	Nürnberg (DE), SUN	2016 (demo)	P-slag
METAWATER	Gifu (JP) Tottori (JP)	2010 2013	HAP
Nippon PA	Chiba (JP), Nippon Phosphoric Acid	2009	H_3PO_4
TetraPhos®	Hamburg (DE), Hamburg Wasser / Remondis Aqua	2015 (pilot) 2019 (full sc.)	H_3PO_4

Source: the authors

Fig 1: **Enhanced nutrient recovery technologies: process and value chain**



Source: Ostara

Combining technologies

The precipitation of struvite ($NH_4MgPO_4 6H_{20}$) from phosphate-rich sewage sludge water is becoming a well-established technology with more than 40 full-scale installations world-wide, be it for municipal or industrial wastewaters. These first generation struvite recovery units are limited to recovery rates of between 5-25% of the P load entering the WWTP. Second generation units, in contrast, have the potential to double these rates.

The combination of three technologies at a WWTP site in Amersfoort in the Netherlands (Waterboard Vallei en Veluwe), namely Ostara's WASSTRIP and PEARL processes together with the LYSOTHERM thermal sludge process, is an excellent example of second generation nutrient recovery with enhanced carbon management. The operational benefits include improved biodegradation and increased biogas yield. Higher orthophosphate concentration in the aqueous phase also delivers improved recovery rates and reduces the amount of sludge solids requiring disposal. These enhancements strengthen the economic case for implementing the nutrient recovery technology at those WWTPs with enhanced biological phosphorus removal (EBPR) and anaerobic digestion (AD). Operational costs can be reduced by several hundreds of thousands euros per year, even before selling the struvite. Ostara's second WASSTRIP and PEARL combination in Europe has just started operation in Madrid.

Energy-efficient nutrient recovery is certainly a growing trend. More technology providers are now jumping on this bandwagon in an attempt to realise the synergies between enhanced sludge treatment and nutrient recovery.

Another second generation project is currently underway in at Steinhof WWTP in Brunswick, Germany (Abwasserverband Braunschweig AVB, SEIBS). Commissioning is expected in 2018. This project will be the first full-scale enhanced carbon, phosphorus and nitrogen recovery facility in Europe. It combines thermal hydrolysis for enhanced sludge disintegration with struvite recovery and ammonia stripping. The recovered struvite and ammonium sulphate will be valorised locally.

The ability to valorise products is vital, yet has often been ignored in the past. While it is relatively easy to recover materials, it is much harder to valorise these. Firstly, for nutrient recycling, there are regulatory obstacles in the EU to be faced, such as REACH and the fertilizer regulation, but logistics and distribution also play a decisive role. WWTP operators do not have a track record or experience in producing fertilizers or providing raw materials for fertilizer manufacture. Neither do they have the distribution networks and logistical expertise needed to bring such products to market. That raises the question: what is the point of nutrient recovery if the nutrients cannot be effectively marketed and reused?

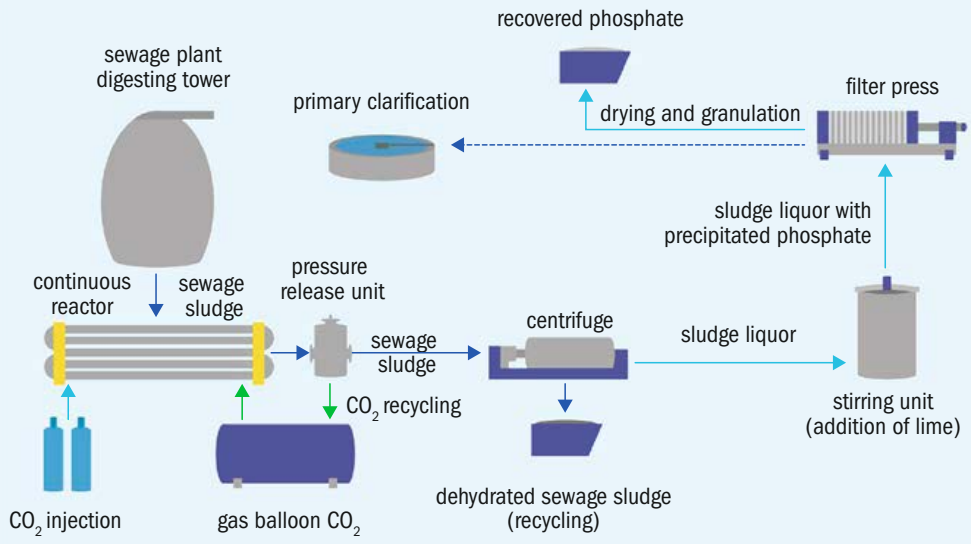
Ostara's business model addresses this problem. The take-off guarantee for the struvite product Crystal Green®, and its marketing by Ostara, takes away the selling and distribution burden from WWTP operators. In fact, this is the only example of a current business model which covers the whole value chain from recovery to reuse.

So it is not the technology alone that counts. Rather, the whole value chain has to be considered when deciding on a viable solution for nutrient recovery and reuse. The other appeal of struvite recovery is that it delivers a ready-to-use fertilizer. Struvite functions as a slow-release fertilizer with plant-available phosphorus, nitrogen and magnesium (5-28-0+10% Mg). Advantageously, struvite crystallization from wastewater also functions as a purification step. Struvite recovered in this way can even be classed as suitable for organic farming, the expert technical group on organic production (EGTOP) has recommended.

The EXTRAPHOS alternative

In most existing WWTPs, the direct crystallisation of struvite is not feasible, as phosphorus is removed from wastewater by

Fig 2: **Schematic of Budenheim's EXTRAPHOS® process**



Source: Budenheim

chemical precipitation, yielding poorly-soluble iron or aluminium phosphates. Instead, phosphorus needs to be re-mobilised before it can be recovered, normally by leaching the sludge with hard acid at low pH.

The challenge of sludge leaching is to separate heavy metals, which are also simultaneously re-mobilised by the acid, from the phosphorus end-product. The post-treatment and disposal of contaminated and neutralised leaching agents is another drawback. Also, the higher the phosphorus yield target, the higher the consumption of chemicals, and consequently the larger the impact on the WWTP and the environment. Indeed, high phosphorus recovery rates (>70%) can only be achieved at high cost (for chemicals and/or energy). There is some evidence that costs can be kept feasible by leaching at pH 5, although only limited recovery (around 40%) is achieved at this pH.

A very promising and much gentler alternative approach is the EXTRAPHOS® process developed by the chemical company Budenheim (see schematic in Figure 2). This uses carbon dioxide as a solvent to dissolve phosphorus under pressure (up to 10 bar) via a solid-liquid separation process. The dissolved phosphorus is then precipitated as dicalcium phosphate (DCP), a highly marketable product, by adding lime. The carbon dioxide consumed is recycled internally. Recovery rates above 50% have been demonstrated for the EXTRAPHOS® process at medium-scale.

A new EXTRAPHOS® pilot at Mombach WWTP in Mainz, commissioned in June, is aiming to raise recovery rates further. The plan is also to co-incinerate phosphorus-depleted sludge solids in cement kilns. This is effectively a zero waste solution that could decrease the demand for new mono-incineration capacity, this being the favoured option for sludge disposal in Germany. Co-incineration will be permitted, but only for P-depleted sludges, by Germany's new sludge ordinance which enters into force later this year. The first project to take advantage of this is already being planned in Itzehoe, northern Germany.

The potential operational benefits of EXTRAPHOS® for WWTP plants will also be investigated during the forthcoming pilot. This technology could turn out to be very attractive for those WWTPs which remove P chemically if, as expected, sludge dewatering is improved (as is also the case for some struvite recovery technologies).

Downstream: the ash route

Several downstream options for phosphorus recovery can be applied when the sludge is about to be incinerated in mono-incinerators. At present, in some European countries, only a proportion of sludge is incinerated without dilution, although there are no reliable figures. However, almost a quarter of the total 1.8 million tonnes of municipal sludge generated in Germany (dry solids) is known to be mono-incinerated.

Although it is questionable whether the phosphorus present in the ash is plant-available, some countries like Germany formally permit the use of ash as a fertilizer, as long as it meets the requirements of the country's fertilizer regulation. But some form of ash treatment to improve P availability appears to be obligatory. Otherwise, most of the phosphorus present in such ashes will be lost.

The future of thermal treatment of sewage sludge for P recovery will need to be addressed, if and when legal requirements enter into force, as is the case in Germany. Co-incineration of German sewage sludge, because it dilutes phosphorus content, will be restricted for sludge containing more than 20 g of P per kg dry matter (DM), unless the phosphorus has been extracted prior to this. Around half the P present in digested sludge will need to be removed to meet this co-incineration restriction, given that digested sludge contains about 30-40 g of P per kg DM on average.

If, instead, sludge is consumed by mono-incineration plants, a waste stream with a much higher P concentration is generated. Municipal sewage sludge ashes (SSA) in Germany, for example, contain 9% P on average. Given existing infrastructure, the partial substitution of ash for phosphate rock in commercial fertilizer plants is one obvious option. European fertilizer companies have already tested the substitution potential of sewage sludge ash and other secondary sources of P at full-scale.

Using mono-incinerated sewage sludge as a phosphate rock substitute has a number of attractive characteristics. The waste and production infrastructure already exists, and because it feeds into established high-volume fertilizer markets for fertilizers, the market and distribution network for products is also already in place.

EcoPhos®, TetraPhos® and others

Other ash recovery routes for phosphorus focus on the production of phosphoric acid, with technologies like EcoPhos® and TetraPhos® and RecoPhos being the most promising market candidates.

EcoPhos® has built a plant for low-grade rock processing in Varna, Bulgaria. This plant has the ability to run test campaigns with ashes as well. A full-scale EcoPhos® plant is currently under construction in Dunkerque, France, and is due to start operating by end of the year. EcoPhos signed a contract with the two big Dutch mono-incinerators, SNB and HVC, in 2015. Under this contract, 60,000 t/a of sewage sludge ash supplied to Dunkerque will yield phosphoric acid, DCP phosphate and metal salts.

A similar approach is being followed by Remondis and its TetraPhos® process. It has been running a pilot in Hamburg

since 2015, with a full-scale plant planned in 2019. This will have 20,000 t/a ash capacity, mainly supplied by Hamburg's VERA mono-incinerator. Phosphoric acid, metal salts and gypsum will be obtained as products.

ICL is further developing a technology to produce elemental phosphorus (P_4) from sewage sludge ash via the RecoPhos thermal-reductive process originally developed by an EU project between 2012 and 2015. If scaled-up pilot testing demonstrates its feasibility, ICL plans to implement the technology at full-scale at a European phosphates plant, the plan being to transform 400,000 t/a of sewage sludge ash into 36,000 t/a of P_4. Pilot test results are expected before the end of 2018. One benefit for ICL would be to lessen its import dependency on Asian suppliers.

Outotec is currently optimising its AshDec thermo-chemical process to deliver plant-available phosphates with a low heavy metal content. These type of calcined phosphates have also been EGTOP-endorsed for organic farming. The EUPHORE process is broadly similar in approach to AshDec. A pilot unit at German Water Utility Lippeverband is planned as part of the EU-funded INTERREG project Phos4You.

Conclusions

One thing is certain: phosphorus is a finite, non-renewable resource. Because of this, efforts need to be made to increase P resource efficiency now, while we still have a choice.

The focus needs to be on bringing currently feasible technologies to market, rather than expanding the range of technology options. In addition, advantage should be taken of existing large-scale infrastructure that is already available for P recovery and reuse, including from ash. Smarter sludge management will also help make the most of existing infrastructure without the need for huge investment.

Neither will recovery alone work. Viable value chains need to be created to bridge the gap between nutrient recovery and reuse. Both the current legal framework and the low price of primary raw materials are, however, market barriers. At current price levels for phosphate rock and other raw materials, only legal reforms will lead to the widespread adoption of phosphorus recovery on a large-scale. Such reforms are needed to create a level playing field for fertilizers, and a market which does not discriminate between primary and renewable secondary sources.

In the EU, changes to end-of-waste criteria for recovered nutrients are a crucial piece of the regulatory jigsaw. Binding but achievable P recycling targets (comparable to current goals for CO_2 emissions reduction) would also provide a much-needed market stimulus. The replacement of the precautionary principle by an approach based on risk assessment would also be highly beneficial. Without such reforms, recovery technologies will not be widely implemented in Europe, nor will viable value chains be created – the only exception being those technologies which already offer specific benefits to WWTP operators.

In a circular economy, only recovery technologies that deliver high-quality, uniform products or raw materials, and combine energy efficiency with resource efficiency, will become widely-adopted and truly sustainable. Our philosophy should therefore be: **think forward, act circular!** ■

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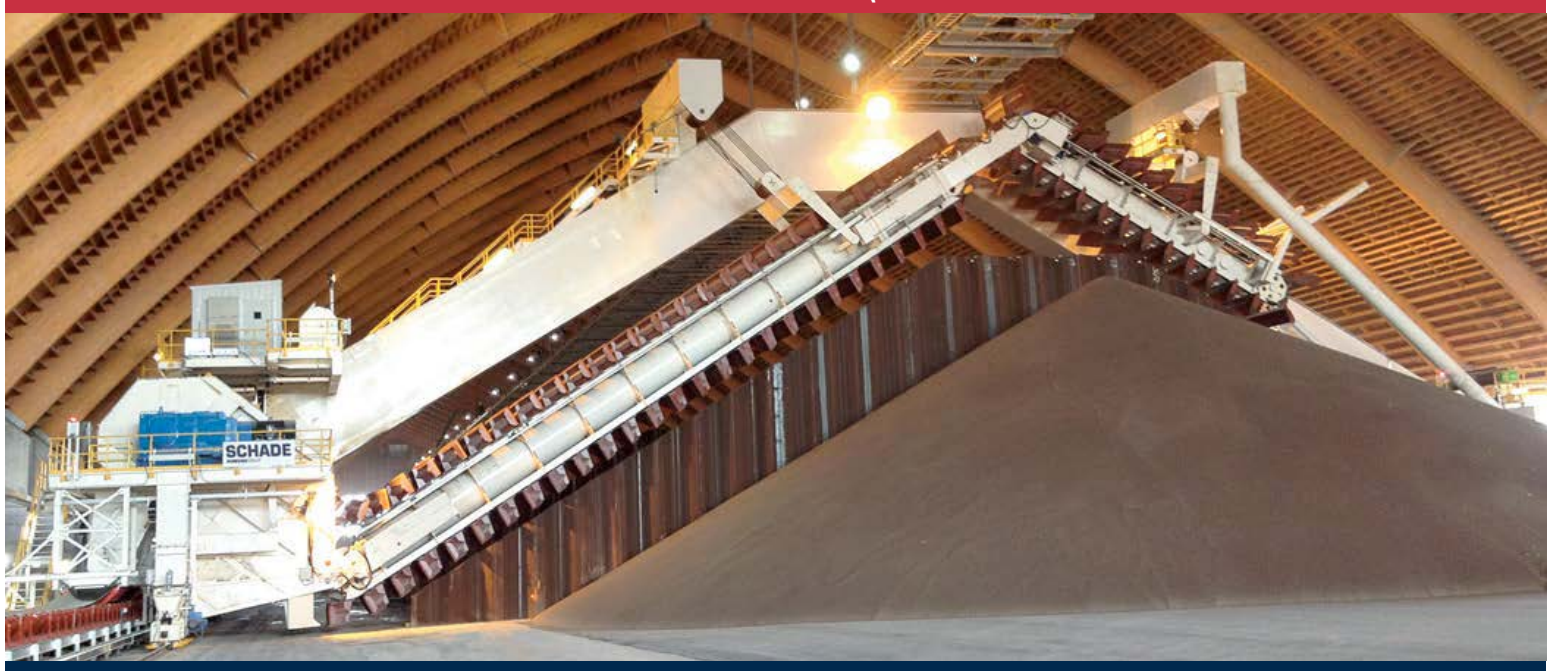

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The AIChE's 41st International Phosphate Fertilizer & Sulphuric Acid Technology Conference was held at its usual venue, the Sheraton Sand Key Resort, on Florida's Gulf coast on 9-10 June.

41st Annual Clearwater Convention

For more than 40 years now, industry engineers have gathered at Florida's idyllic Clearwater Beach for the AIChE's two-day annual convention on sulphuric acid and phosphate fertilizer technology. The convention, which is always run on a Friday and Saturday, is renowned for its relaxed atmosphere and ability to combine business with friendship, food and family. An eclectic of mix of international and US delegates attended the 2017 convention.

Water treatment and solids handling workshops were held on Friday afternoon, in parallel with the convention's traditional sulphuric acid workshop.

Water treatment workshop

The pros and cons of reverse osmosis (RO) technology were highlighted by Evoqua's **Doug Spolarich** in the opening presentation on water treatment. The upside of the technology is that it is relatively simple to operate, and can remove dissolved impurities without large quantities of chemicals. The waste generated does not require neutralisation either. The main downsides are:

- Both oxygen and carbon dioxide can pass through RO membranes
- Membranes are susceptible to fouling
- An additional polishing stage can be required: double-RO needs ion-exchange, for example
- High water use: 25 percent of feedwater goes down the drain
- The electrical requirements of pumps used

Ed Sylvester of ChemTreat was next up. He dealt with the practicalities of ensuring internal boiler water cleanliness by monitoring and maintaining RO, degasifier and demineraliser equipment. The importance of inlet water chemistry, and the need for microbial analysis and silt density index (SDI) testing, was emphasised. Florida well water can contain hydrogen sulphide, ammonia, bacteria and organics, although it is largely devoid of colloidal and suspended solids. Inspection and troubleshooting advice for equipment such as cartridge filters and RO equipment was offered.

Larry Hill wrapped up the workshop by focusing on the latest boiler control innovations from Nalco. The company has made significant advances in boiler feed water control automation, offering *3D TRASAR* technology. This prevents scaling and incorporates corrosion control stress monitoring (CCSM) to prevent corrosion. Automated systems also regulate and control feed water quality using fluorometers and pH and conductivity monitoring.

Solids handling workshop

Bob Stehlich of the Materials Handling Equipment Company opened the second workshop of the afternoon. He explained the challenges of handling different materials by conveyor. The flowability of materials is affected by their bulk density, moisture, particle size, compressability and angle of repose. Depending on these properties, materials can be placed into one of four classes:

- Granular, free flowing
- Powder, sluggish
- Powder, sluggish, fluidisable or adhesive
- Fibrous, flocculent, flaky

Moisture content can change a material's classification and its adhesiveness. Sulphur, for example has a 35-40 degree angle of repose and flows well, but can move between class one and class three, depending on moisture content.

Gene Winkler of Amerair Industries gave an example of how DAP cyclones can be designed for reduced maintenance. The company worked with Mosaic and Hatch on the DAP2 *MicroEssentials* conversion at New Wales in 2015. The main cyclone maintenance goals for this project were to minimise wall repairs, dust valve maintenance, dust build-up and cleaning time. Avoiding explosion damage was another maintenance priority. Five specific fixes were subsequently included in the project's cyclone design specification to achieve these goals.

FEECO's **Shane Le Capitaine** closed the materials handling workshop with a thorough round-up covering the design, operation and maintenance of rotary equipment. This included rotary driers and coolers, rotary kilns, granulation/agglomeration drums and coating drums. Rotary drums are a proven technology, having been used

by industry for over a century. Generally, they are low maintenance, very forgiving to operate and deliver high efficiency at low power.

Rotary driers and coolers are suited to granular industrial materials such as aggregate, bauxite and frac sand, as well as fertilizers. Their functions include the removal of surface or internal water, driving-off chemically-bound water, and cooling.

Rotary kilns, in contrast, use heat to change the chemical composition of materials. Applications include calcining, catalyst production, ore treatment, regeneration, roasting and sintering. Their construction is similar to rotary driers, although rotation is much slower, around one-tenth of drier speed.

Rotary granulators also have much in common with other types of rotary equipment, in terms of design and construction, although they are around one-third to one-half the length of a typical rotary drier and generally do not use heat. They are commonly used in the fertilizer industry for DAP, MAP, SSP, TSP and NPK granulation

Adding value from mine to market

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

Todd Parker of ArrMaz described how mining chemicals and process reagents can add value from mine to market. The goal in mining and mineral processing, according to Parker, is discovering your ore's true potential and creating a high-purity feed material for phosphoric acid production. The key to this is better flowsheet design, good equipment selection and improved reagent formulation.

Having a mineral processing system that can handle clays, mixed size fractions, and successfully reject impurities, can achieve a step-change in beneficiation performance. By improving recovery and grade at the same time, less reagents and energy are also consumed.

"The benefits that you get are extending the mine life, more tonnes per acre, better deposit utilisation and reduced costs per tonne," explained Parker. "You also preserve the environment because you're disturbing fewer acres to get the same tonnes or more tonnes. So you reduce costs by freight savings, lower customs and excise fees, and by delaying permitting fees."

He adds: "More importantly, as you get better quality rock, it takes less acid to digest the impurities and you get less foam. If you're [selling] in the market, higher quality rock also demands a higher price."

Parker listed his top 10 best practices for improving grade and recovery during rock processing:

- **Avoid ore dilution** and keep the feed clean of overburden and other contamination
- **Liberate the feed** creating as few as fines as possible
- **Wash the ore well** and remove clay and other contaminants
- **Size the feed well** for the flotation section
- **Float similar size feeds together**
- **Use the cleanest water possible** for flotation conditioning
- **Condition the feed at the right solids and the right pH** for each flotation circuit
- **Use the right amount of reagents, water and air**
- **Employ smooth non-turbulent flotation** at the froth zone
- **Feed the plant at stable rates** so as not to overload equipment

In the phosphoric acid plant, the main aims are improving digestion, filtration and evaporation – and ultimately achieve the goal of purer phosphoric acid, improving operational efficiency and making savings.

Further downstream at the granulation plant, the correct use of fertilizer process aids creates strong, uniform granules of consistent colour and appearance, and ensures regulatory compliance and high granulation efficiency. Process aids at fertilizer blending plants provide dust control, prevent degradation and also enable micronutrient blending. Finally, during transportation and storage, process aids prevent pile set and create safer, dust-free and easier-to-handle fertilizers.

"Mining chemicals and fertilizer process aids create proven value throughout the phosphate fertilizer supply chain. Mines and the fertilizer plant should work together to maximise value. Understanding the industry from beginning to end will unlock your ore's true potential to produce pure phosphoric acid [and] superior fertilizers, cost effectively and sustainably, and create more value for the producers," concluded Parker.

Quality parameters in crystallisation

Sven Hanselmann of Ekato explained the importance of mixing and impeller design in draft baffle tube (DBT) crystallisers and other types of crystallisation equipment. Mixing is a key influence on the kinetics of particle formation in commercial crystallisers; the general aim being to produce crystals of a constant and narrow particle size distribution. Crystallisation quality is determined by a number of process parameters, suggested Hanselmann, including:

- Cooling rate profile
- Evaporation rate profile
- Precipitation rate strategy
- Additives and impurities
- Solid density
- Supersaturation: concentration and temperature gradients
- Seeding: amount and particle size
- Mixing: impeller, vessel geometry and power input/output

Continuous operation DBT crystallisers offer a number of process advantages, including precisely controlled evaporation and pumping rates and a well-defined residence time.

Measures to reduce pressure drop are important design considerations for DBT crystallisers. "As an agitator manufacturer you look to what you can improve on the impeller," comments Hanselmann. "However, it's only a small component – we have to look at the whole system."

He continues: "When we talk about efficiency, we want to bring as much power as possible into flow. We don't want any turbulence and we don't want to lose any power into pressure drop." That makes it important to eliminate sharp edges and corners which create turbulence and make it more likely that crystals will collide and lose energy.

"If you have baffles in your system, they don't necessarily need to be inside the draft tube. You can also apply the baffles outside in the settling zone," explains Hanselmann. "Then you maximise the flow velocity, you reduce the turbulence and make more power available."

Hanselmann says Ekato's has taken a big step forward with *TORUSJET*, a new type of draft tube circulator: "We have further improved draft tube impellers. They are mainly three-bladed, although five-bladed versions are also available. Their guide vanes are outside the draft tube and this is a big step forward. The hydraulic load is substantial on these baffles so if you can bring them outside there is less risk of failure."

He continues: "We can improve efficiency by at least 10 percent. This means we can reduce motor power by 10 percent

[and] the gearbox becomes smaller as there's less torque. We save weight on the whole system as there are less forces acting on the vessel and the walls can be kept as thin as possible to save money."

Hanselmann summed up by saying: "For optimised mixing, by having the whole system in mind, and not just considering the agitator as a single unit, you can significantly increase productivity, improve particle size distribution, reduce the amount of fines and simplify solid/liquid separation downstream."

The MicroEssentials expansion at New Wales

Justin Graff of The Mosaic Company and Doug Belle of Hatch described the largest expansion of a granulation plant in the United States in 30 years. Mosaic commissioned a project to convert the DAP2 dual-train diammonium phosphate (DAP) plant at its New Wales site to *MicroEssentials* and granular monoammonium phosphate (GMAP) production. The original DAP granulation plant at the site dates from 1981. The expansion project involved the construction of a new closed-loop scrubbing system, storage warehouse and reclaimer.

The project involved a total of four fabrication contracts, 13 construction contracts and seven major contractors, with Hatch providing engineering, procurement and construction management (EPCM) services.

The expansion presented Mosaic and Hatch with major logistical and safety challenges as fertilizer production and construction work were taking place simultaneously next to each other, making the location a 'redfield' site rather than a brownfield one. To further complicate matters, a sulphur re-melter was also being constructed nearby. Permitting was also complex as the site straddled two Florida counties.

The project was completed in three years and 6 months and required:

- 181,397 man-hours
- 150 pieces of new equipment
- Moving/modifying 42 items of equipment
- 3,601 engineering drawings

Construction began in mid-2014 and was completed by the end of June 2016, 100 weeks later. Up to 400 workers were on site at one point during 2015. In a carefully choreographed project schedule, the East train of the DAP plant was firstly shutdown and demolished while the West plant was still operating. The West trains was then demolished once the reconfigured East train was up and running.

The project was notable for being Mosaic's largest phosphate project, and for being the first project to have its own dedicated core team. Both Hatch and Mosaic are rightly proud of the project's excellent safety record – and by the fact that it was completed ahead of schedule and under budget.

Increasing recovery in phosphoric acid plants

Phosphoric acid plant yield, as determined by P_2O_5 recovery and losses, is becomingly an increasingly important benchmark, according to **Elton Curran** of Jacobs, especially as production economics become tighter. For a 500,000 t/a phosphoric acid plant, a one percent improvement in P_2O_5 recovery, for example, is equivalent to an extra 5,000 tonnes of P_2O_5. At an overall plant production cost of around $350/t, this can generate $1.5 million of additional revenue.

Filter losses are relatively easy to measure, but account for only a fraction of the total difference between the P_2O_5 fed to the reactor and P_2O_5 ultimately produced in terms of phosphoric acid. So-called mechanical losses, which generally range from one to five percent, can be substantial and, in some cases, larger than filter losses.

Mechanical losses occur during rock handling, reaction, filtration, gypsum storage, clarification, evaporation and product storage. The size of these losses is largely a function of the plant's complexity and its operational and maintenance philosophy, as well as operator experience. P_2O_5 can be lost mechanically during plant shutdowns and wash-downs and equipment malfunctions as a consequence of fugitive emissions, spillages and scaling. Such losses can be monitored using wash records, recovering spills and washes, water stream instrumentation and by tracking sulphuric acid consumption.

Avoiding shutdowns is one way to mitigate losses, but technology design can also help. Suitable technologies for mitigating losses include:

- The high yielding dihydrate (DH) process
- Computational fluid dynamics (CFD) modelling of reactor design
- Online sulphate analysers
- Nuclear density meters on rock slurry and filtrate: advisory control
- Closed-loop wet stacks: cooling/recovery of P_2O_5
- Water balance integration

Understanding struvite precipitation

Many wastewater treatment plants globally use enhanced biological phosphorus removal (EBPR). During this process, phosphorus is accumulated by microorganisms and then removed from wastewater as waste activated sludge (WAS). However, subsequent treatment of WAS by anaerobic digestion (AD) can result in the undesirable re-release and build-up of phosphorus – although this can be avoided by recovering P using struvite ($MgNH_4PO_4$) precipitation.

Factors controlling struvite precipitation were investigated by **Nadezhda Zalivina** of the University of South Florida. Bench tests were carried out on EBPR sludge from the Falkenburg Advanced Wastewater Treatment Plant, Brandon, Florida.

The EBPR sludge was firstly passed through a thermophilic AD unit. The waste stream obtained was then fed to a fluidised bed struvite precipitation reactor. Sodium hydroxide was added to raise the pH of the reactor to 8.5. If necessary, extra magnesium salts were also added to the reactor to keep the $Mg:NH_4:PO_4$ ratio at 1.3:1:1.

One preliminary finding is that that the Mg/PO_4 ratio of the system plays an important role in phosphorus recovery, with 92% removal being achieved at a ratio of 1.6:1. Changes in pH, in contrast, appear to have little effect on phosphorus removal, possibly because the experimental system was Mg-limited.

Why solids build-up during acid storage

Todd Hutchinson of Philadelphia Mixing Solutions explained why solids build-up in phosphoric acid storage tanks. Acid is generally stored in tanks at around 60°C and contains up to five percent solids in the form of less than 250 micron-size particles. Tanks are typically up to 50 feet in diameter and designed for off-bottom solids suspension. A single hydrofoil impeller is generally sufficient to keep solids circulating and prevent them from settling on the tank's base.

However, tanks designed in this way still need to be cleaned-out every 6-12 months. Cleaning and the removal of solids can take days and the resulting damage to tank linings often requires further repairs.

Also, designing tanks purely to keep solids in suspension neglects other important factors. Critically, heat transfer

and temperature gradients allows gypsum to form on tank walls. This is undesirable as large build-ups can eventually break-off and fall to the floor, damaging the tank's agitator in extreme cases. Fortunately, computational fluid dynamics (CFD) models have shown that a dual impeller design can keep tanks walls clean and free of material. It does this by creating a wall jet that prevents gypsum from crystallising.

Bubble size distribution

Gas-liquid systems form a key part of many chemical industry processes. A range of gas-liquid contactors and reactors, including trickle beds, bubble columns and agitated vessels, are found in industrial applications such as fermentation, hydrogenation and chlorination.

The cost of simulating gas-liquid systems using computational fluid dynamics (CFD) models can vary substantially, depending on the degree of accuracy required and the assumptions used. Simpler, less costly models assume that the bubble sizes are uniform or have an average size.

Simulations can be improved considerably using the 'S-gamma' model of bubble size distribution, suggested **Ravindra Aglave** of Siemens/CD-Adapco. The computational cost of S-gamma is reasonable, being up to two times higher than the single bubble-size models. An even more accurate A-MUSIG model is also available although this is less practical option as its computation cost, up to five times greater than the single bubble-size model, may be prohibitive.

Engineer of the Year

John Ellington of Penn Pro was named this year's Hero of the Industry while Brittany Fleming of ArrMaz was announced as Young Engineer of the Year. The accolade Engineer of the Year went to David Ivell of Jacobs. Delegates will convene again in Florida for the 42nd Annual Clearwater Convention on 8-9 June 2018. ■

Product options for reducing phosphogypsum

Phosphogypsum waste is formed in large volumes during the manufacture of phosphate fertilizers. Producing wet phosphoric acid from phosphate rock generates five tonnes of phosphogypsum for every tonne of P_2O_5 obtained. Phosphogypsum is mainly composed of gypsum ($CaSO_4 \cdot 2H_2O$). The handling of phosphogypsum and its indefinite storage in stacks is a costly business.

That makes any reduction in the amount of phosphogypsum produced per tonne of P_2O_5 an attractive proposition, pointed out **Curtis Griffin** of PegasusTSI, because of the potential to reduce costs and extend stack life. Indeed, by switching over from diammonium phosphate (DAP) manufacture to a mix of other products, phosphogypsum can be reduced or even eliminated altogether. Products with the potential for phosphogypsum reduction include:

- Lower-grade monoammonium phosphate (MAP)
- Single super phosphate (SSP)
- Dicalcium phosphate (DCP) and monocalcium phosphate (MCP) via the hydrochloric acid route
- Granulated triple superphosphate (GTSP)

Examples of the degree of phosphogypsum reduction achievable for various product mixes were presented. Many of the above products can be produced from conventional DAP/MAP plants with relatively minor front-end modifications.

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

- Feasibility of solar panels in industrial processes. **Jennifer Woodson**, Mississippi State University.
- CFD simulation to improve cooling pond performance. **Angelo Stamatiou**, Hatch
- Fuming acids spill mitigation training. **Mark Salzbrenner**, Veolia
- Umm Wa'al phosphate project – sulphuric plants. **Daniel Freeman**, SNC Lavalin
- What to do when you run out of blower. **John Horne**, MECS/DuPont
- Application benefits of safety integrity level gas detection instruments. **Steve Phelps**, Sensidyne
- Increasing recovery in reverse flotation. **Kevin O'Brien**, Nalco
- Use of composite non-metallic materials in sulphuric & phosphoric acid facilities. **Michael Yee**, RTConsultants ■

*Only the presentation's lead author is listed.

Kainite crystallization flotation (KCF) unit

The Werra plant's new kainite crystallization flotation (KCF) unit: K+S mock-up.

K+S KALI GmbH is investing heavily in new production technology and environmental mitigation measures at its Werra production plant in Germany. The construction of the kainite crystallization flotation (KCF) unit forms the centrepiece of company efforts to cut the volume of wastewater discharged into nearby rivers. This major investment should also safeguard the future of K+S's largest potash operation in Germany.

The Werra plant

Werra, K+S Group's biggest potash plant, is a large-scale complex spread across four sites in two German states: Hattorf and Wintershall in Hesse, and Unterbreizbach and Merkers in Thuringia. The plant produces fertilizers alongside numerous technical and industrial products. These have a wide-range of uses, including pharmaceuticals, foodstuffs and animal feed.

Werra employs almost 4,400 people, including 300 trainees, making it an important employer and training centre regionally. The plant also supports and generates significant income for local businesses and is major tax payer for municipal government. This makes the Werra plant a vital part of the economy of eastern Hesse and western Thuringia, and a key contributor to the region's social development.

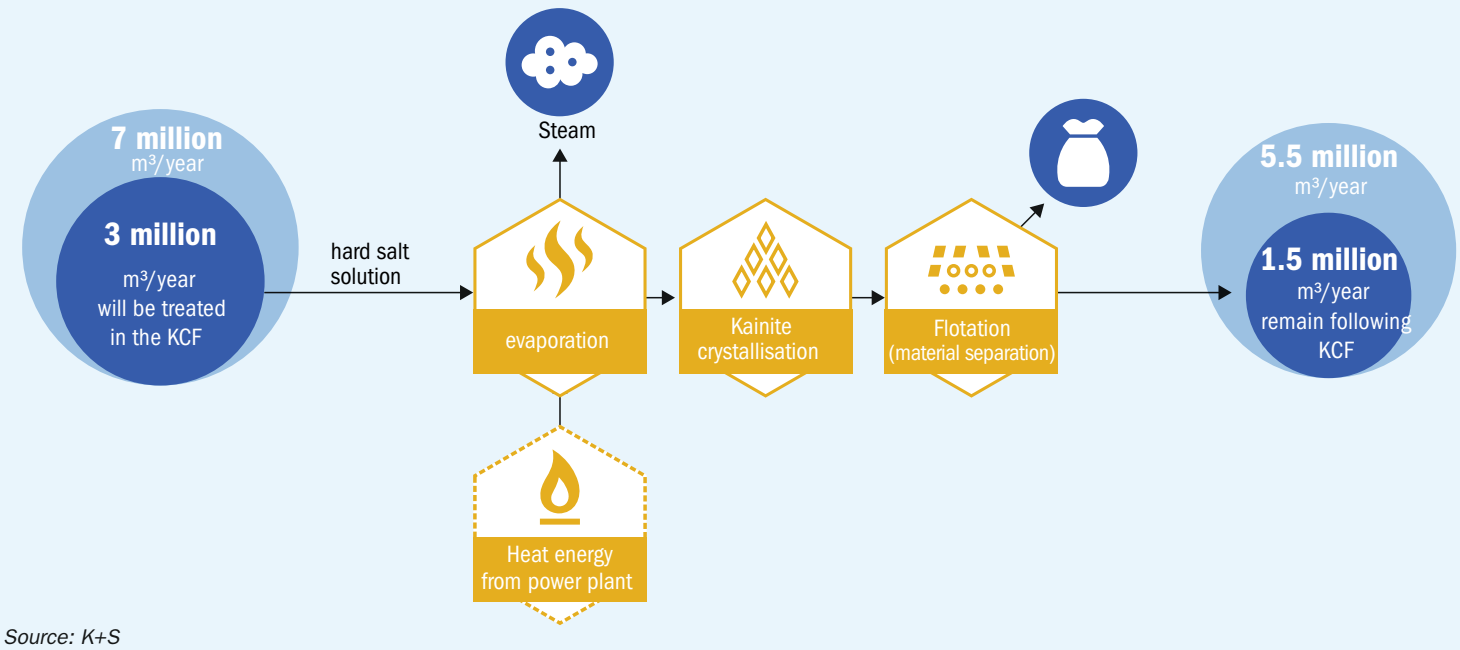
In the last few years, K+S has invested hundreds of millions of euros at the Werra plant on measures designed to protect local rivers and the environment. A key environmental commitment has been the promise to build a kainite crystallization and flotation (KCF) unit at the Hattorf site and to commission this by the start of 2018.

The KCF project is essential if K+S is to meet an agreement made with regulators to cut the volume of saline wastewater discharged from the Werra plant into the Werra and Weser rivers nearby. K+S will reduce the volume of saline wastewater arising annually at Werra from seven million m^3 currently to 5.5 million m^3 from 2018 onwards – a cut of more than one-fifth – as part of an agreement with the Hesse state government. Construction of the KCF is also advantageous for the company economically and in terms of energy usage.

K+S has already reduced saline wastewater volumes at the Werra plant – which produced 20.0 million m^3 in 1997 – by two-thirds in the last two decades.

Impressively, the €180 million ear-

Fig 1: **KCF process flowsheet**



Source: K+S

marked for the KCF project raises K+S's total investment in environmental protection measures at the Werra plant to more than half a billion euros over the last few years. The project has the full backing of K+S directors Rainer Gerling and Alexa Hergenröther, and the support of Werra plant managers Roland Keidel, Kurt Lindhof and Christoph Wehner. For both directors and managers, delivering the KCF project, on time and as promised, is an important way of demonstrating that K+S "keeps its word" to both environmental regulators and the public.

"The investment of 180 million euros is a strong indicator for the future of our Werra plant and the protection of the environment," comments K+S director Rainer Gerling.

"The construction of the KCF facility is an important step towards the long-term security of the 4,400 jobs in the Werra plant and many more throughout the region," adds Harald Döll, chairman of the company's Joint Works Council.

K+S is also investing in other measures to reduce the environmental impact of its operations. The storage of saline wastewater underground, for example, is being intensively investigated in trials which will continue into next year. Trials to cover tailings piles at Werra are also continuing.

Ending production interruptions

The limits placed on saline wastewater injection by K+S's current disposal permit affected potash operations in the Werra valley last year. In particular, current restrictions on wastewater disposal have left potash production at the mercy of water levels in the Werra river. Periods of low river flow during 2016 caused month-long production interruptions and short-time working. The effect of these production interruptions on company revenues and sales has provided a fresh incentive – if any was needed – to complete and commission the KCF on schedule next year.

Meanwhile, K+S is also working hard on delivering other wastewater disposal measures, some of which are temporary. These extra measures are necessary to prevent limits being placed on production when river levels are low. They include the transportation of saline wastewater from Werra to a disused K+S mine in Lower-Saxony and an underground cavern in Saxony-Anhalt.

Werra plant manager, Roland Keidel, emphasises the benefits completion of the project will bring next year: "The KCF plant marks a further milestone in the efforts undertaken by K+S to reduce the burden on the Werra/Weser river system. At the same time, it will reduce the risk of having to limit production at Werra plant sites in the Hesse-Thuringia potash district from 2018 onwards. The KCF will reduce the volume of saline wastewater at the plant by a further 1.5 million cubic metres – and will also recover additional resources for use in fertilizer production."

More recycling, less wastewater

The new KCF facility, when it begins operating next year, will recycle saline solutions generated by flotation operations at the Hattorf and Unterbreizbach sites. Valuably, it will extract more saleable product from process water – using new technology developed by K+S over the last four years.

The adoption of kainite crystallisation downstream of the flotation process offers two main benefits. Firstly, the KCF will halve the volume of saline water generated by production, from around 3.0 million m^3 currently to 1.5 million m^3. Secondly, the new KCF unit will recover an additional 260,000 tonnes of reusable material annually by recycling saline solution from upstream processes at both the Hattorf site in Hesse and the Unterbreizbach site in Thuringia.

How the KCF works

1. **Partial capture of process and wastewater streams:** In total, the Werra plant generates 7.0 million m^3 of process water and wastewater annually. The KCF captures over two-fifths of this volume (3.0 million m^3), the part containing reusable constituents, and recycles this to reclaim economically-valuable materials.
2. **Evaporation step:** A salt mixture, made up of kainite ($MgSO_4 \cdot KCl \cdot 3H_2O$), sylvite (KCl) and halite (NaCl), is firstly obtained by an evaporation step using

excess heat from the Hattorf site's power plant.

3. **Crystallisation and flotation step:** The recyclable components, magnesium sulphate ($MgSO_4$) and sylvite (KCl), are then separated from this salt mixture and further processed to produce sulphate of potash (SOP, K_2SO_4) fertilizer.
4. **Cutting saline wastewater discharge:** The KCF will reduce the volume of saline wastewater discharged to the Werra river, or disposed of underground, from 7.0 million m^3 currently to 5.5 million m^3 when it enters operation next year. This volume reduction will also reduce the salt load present in wastewater discharges by more than 500,000 t/a.

The KCF project is the fruition of four years of in-house technical development at K+S. The whole project is underpinned by critical process development work carried at the company's Analytic and Research Centre, in collaboration with other technical experts based at the Werra plant.

K+S has a dedicated team of 25 staff working exclusively on the construction design of the KCF project. Project coordinator Heiko Spaniol and nine other staff members have been assigned to the project from within K+S. A further 15 experts are working on secondment from outside design and consulting firms.

Project progress

Construction of the KCF is a mammoth project, due to the scale of the new €180 million processing unit (74 metres-long, 20 metres-wide and 58 metres-high). The structure required around 5,500 tonnes of steel, for example, enough to build the Berlin Radio Tower nine times over. The need to excavate 36,000 m^3 of soil during earth moving for the project further Illustrates the massive scale of this undertaking. Most of this soil was stored on-site at Hattorf for subsequent use in screening work, although a small volume has been earmarked for the building of a storage reservoir. Constructing the KCF also requires:

- More than 1,000 valves
- 180 kilometres of cabling
- 86 pumps
- 82 items of equipment and machinery
- 35 kilometres of piping

> **"The steel required by the KCF was enough to build the Berlin Radio Tower nine times over.**

Anyone driving past the Hattorf site on the B62 in Philippsthal since April 2016 will have seen signs of progress on the construction of the KCF almost daily. The plant's flotation section was also completed in just under seven months, following a roofing ceremony to mark the enclosure of the steel structure.

A progress update from K+S released in February this year confirmed that the project remains on schedule. The number of workers on-site increased from 250 at the beginning of the year to about 400 from March onwards, in time for major installation work this spring and summer.

Completion of the building's steel structure has now allowed construction work to progress to the installation of major components. The 17 items of equipment being installed include evaporators, heat exchangers, mixing condensers, and vapour and circulation piping systems. Many of these items have been customised to meet the exact requirements of the KCF.

The largest piece of equipment is the KCF's heat exchanger which weighs 110 tonnes – about 90 times the weight of a typical family car. The largest item, the V1200 evaporator, is 16 metres long, has a diameter of seven metres, and weighs 82 tonnes when empty. To procure items of this size and weight, K+S needed to engage specialised manufacturing and engineering companies: Ebner GmbH & Co KG, Anlagen und Apparate, Eiterfeld, as the general contractor, and Messer Industriemontagen und Apparatebau GmbH, Heringen-Lengers to manufacture the equipment.

K+S has worked with both engineering companies previously, as K+S project coordinator Heiko Spaniol explains: "Everyone involved had just a pretty tight timeframe available for design and production. Logistics at the construction site was a challenge, because everything had to be delivered just in time given the particular features and limited size of the space. However, we have already successfully tackled some large-scale projects, such as the evaporation plant at the Wintershall site."

Most of the equipment for the KCF plant had to be delivered by road transport, often at night, by Schlitz-based company CC Bäuml. The world's largest telescopic crane – which itself had to be delivered to the site on 15 low-loaders – was then used to raise items to a height of 41 metres and carefully move them into position. "It is a particular challenge to hinge equipment of this size and weight at such a height," comments sub-project leader Matthias Jacob. "And such a project is a real stroke of luck for any engineer involved."

Local businesses are heavily involved in the building of the KCF. More than half of the construction firms under contract are based in North Hesse, East Hesse or Thuringia.

K+S updated *Fertilizer International* on the latest project progress at the end of May. This confirmed that:

- **The steel and outer building:** construction now complete
- **Piping and measurement and control systems:** currently being expanded
- **Flotation section:** all relevant equipment items have been installed and piping assembly is on schedule
- **Evaporation section:** all relevant equipment items have been installed and piping assembly is on schedule
- **Auxiliary systems:** cooling-tower facilities are complete
- **Other installations:** the last elevated tank and the majority of the new pipe bridges have been fitted
- **Power plant:** steam turbine and steam pipes now installed
- **Measurement and control systems:** on schedule
- **Plant start-up:** currently being planned in detail

Next steps

K+S is taking steps to cut wastewater discharges from Werra even further, once the KCF is finished. The company is developing safe, long-term solutions for the disposal and storage of wastewaters in mines, for example. A long-distance saline wastewater pipeline to the Upper Weser is also being designed to begin operation in 2022, as a back-up solution to underground storage if this proves not to be feasible.

Furthermore, the company is working on covering tailing piles. Tests have shown that covering the piles reduces the volume of saline wastewater generated by rain water by 80 percent.

ICL's UK Boulby mine.

Polysulphate for NPK and PK granulation

Kim ten Wolde and **Anthony Zanelli** of ICL Fertilizers explain how existing NPK and PK fertilizers can benefit from the addition of ICL's *Polysulphate* fertilizer and the sulphur, potassium, magnesium and calcium it contains.

There is a growing need for NPK fertilizers in modern agriculture. A wide variety of NPK fertilizers – tailored to meet the needs of various crops, soils and climatic conditions – can be prepared using ICL's *Polysulphate* as a raw material. *Polysulphate* also adds value by replacing the inert filler material commonly used in NPKs with valuable plant nutrients.

Adding *Polysulphate* as a constituent is an ideal way of introducing sulphur into any grade of NPK. It can also be used to incorporate sulphur and other essential nutrients into PK fertilizer grades. The addition of *Polysulphate* to NPK+S products, because it reduces chloride levels, makes it well suited to blends used on chloride-sensitive crops. *Polysulphate*, when combined with nitrogen, ensures that sulphur and nitrogen release to crops is properly timed. The presence of magnesium also enables *Polysulphate* to replenish the crop removal of this element from soils. Valuably, standard *Polysulphate* is licensed as an organic fertilizer in the UK, Germany, Italy, Holland, USA and Canada.

Polysulphate is safe for all modes of transportation as it is a harmless, unreactive raw material that is not classed as a dangerous or harmful substance.

History

ICL is the first and sole commercial producer of polyhalite globally at present. Polyhalite ore is mined at Boulby in the UK and marketed by ICL as *Polysulphate* fertilizer. The polyhalite deposit at Boulby was formed in the Zechstein Sea, along with deposits of potash and salt, in the Permian era 260 million years ago. *Polysulphate* is directly manufactured from polyhalite ore through a simple process of crushing and screening.

The polyhalite at Boulby lies at a depth of 1,300 metres, around 150-170 metres below potash seams at the site. Polyhalite exploration began in 1999 and work on its marketing and commercial viability has been continuing ever since. The main *Polysulphate* seam was reached in September 2010, allowing the first samples to be brought to the surface. Boulby has a confirmed polyhalite resource of over 200 million tonnes. The mine is capable of providing farmers throughout Europe and across the globe with a dependable source of sulphate fertilizer, at a time when global demand is increasing. Mining of polyhalite commenced, and was first used for PK and NPK production at ICL in 2012.

Polysulphate

The polyhalite marketed by ICL under the *Polysulphate* brand name is a naturally-occurring mineral made up of the hydrated sulphates of potassium, magnesium and calcium. The molecular formula for polyhalite is $K_2Ca_2Mg(SO_4)_4 \cdot 2(H_2O)$. The name 'polyhalite' comes from the Greek for

Mining Polysulphate *at Boulby, UK.*

Standard Polysulphate.

Table 1: **Physical properties of Polysulphate**

Bulk density (mt/m^3)	1.6
Single granule strength (kg)*	6.3
Angle of repose*	38°
Size guide number*	290
Caking (kg/cake)*	0
Fracture	Brittle
Hardness (Moh's)	2.5-3.5
pH	Neutral

**= determined on a granular sample*

Source: ICL

Table 2: **Nutrient content of Polysulphate**

Sulphur (expressed as SO_3)	48%
Potassium (expressed as K_2O)	14%
Magnesium (expressed as MgO)	6%
Calcium (expressed as CaO)	17%
Chloride	3%
Moisture	1%

Source: ICL

'many salts', a reference to the material's complex composition.

Because it is a natural material, mined, crushed and screened without any chemical processing, *Polysulphate* is certified as an organic fertilizer. The product is available in both granular and powder form.

The ecological footprint of *Polysulphate* is significantly lower than that of other potash fertilizer products. This is partly because no by-products are generated during manufacturing. The avoidance of chemical processes such as flotation or crystallisation during production also minimises energy and water consumption.

Polysulphate is a translucent, hard and brittle white/grey mineral (left). Its physical properties are shown in Table 1 and its nutrient content is shown in Table 2.

PK/NPK granulation and formulations

ICL initially began testing the feasibility of using *Polysulphate* in NPK and PK grades at a pilot plant in Amsterdam, originally on exploration samples from Boulby mine. These pilot-scale tests confirmed the suitability of polyhalite for granulating NPK at several different grades. *Polysulphate* granulation was subsequently transferred to full-size NPK plants in Amsterdam, and later in Ludwigshafen, Germany. The consumption of *Polysulphate* as an NPK constituent at these two plants did not require a change in product labelling.

The main advantage of using *Polysulphate* in PK and NPK granulation is that it contains four nutrients. When substituted for filler, not only does *Polysulphate* replace the filler, it can also replace sources of K (partly) and Mg too. In addition, *Polysulphate* adds more value by incorporating Ca and SO_4 into the final granular product. Examples of NPK and PK grade formulations obtained using *Polysulphate* are provided below:

NPK 12-12-17+ 2MgO + 19SO_3

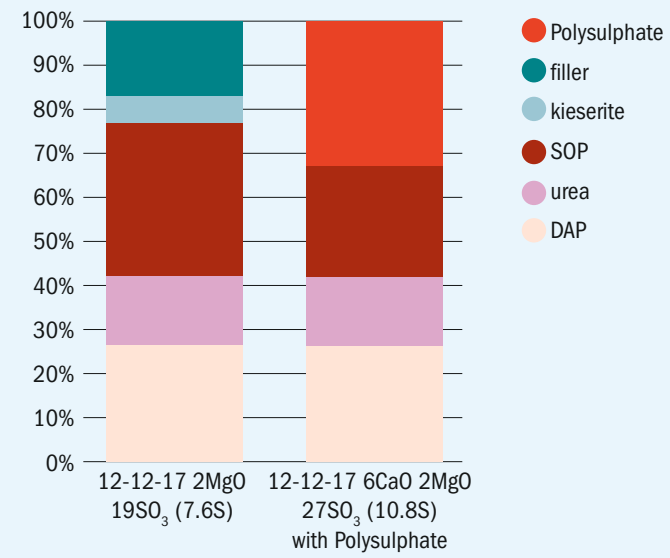
This NPK grade is derived from DAP, urea, SOP and kieserite, together with a filler or *Polysulphate*. Using the regular filler option, all the potassium content (17% K_2O) is provided by the SOP (K_2SO_4) constituent. Also, because SOP only yields K_2O and SO_3, kieserite needs to be included to provide MgO. Finally, as the combined constituents are too nutrient-rich, almost 20 percent filler has to be added as a diluent to produce the required NPK grade.

However, by using *Polysulphate* in the formulation instead, both kieserite and filler can be left out of the NPK mix, reducing the number of input materials required. Up to 33% *Polysulphate* can be added. This provides 4.6% K_2O, enabling the SOP proportion to be reduced from 34% to 25%. *Polysulphate* also adds Ca – unless the filler is limestone chips – and extra SO_3 to the product, proving the end user with more value.

PK 10-20 + 5MgO + 15SO_3

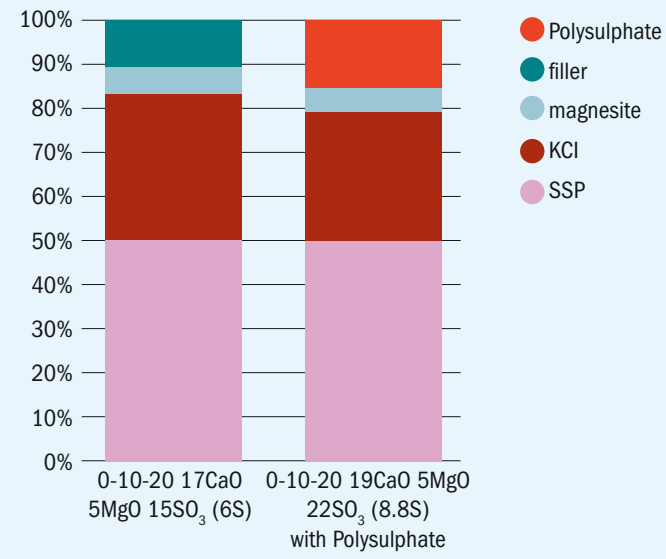
This grade is derived from SSP, KCl and magnesite, plus a filler or *Polysulphate*. Although a filler is added during the regular granulation of this product, it can be left out of the formulation and replaced with

Fig 1: **NPK 12-12-17 + 2MgO composition, without and with *Polysulphate***



Source: ICL

Fig 2: **PK 10-20 + 5MgO composition, without and with *Polysulphate***



Source: ICL

almost 15% *Polysulphate* instead. Use of *Polysulphate* reduces the KCl and magnesite input by 4% and 1%, respectively. It also adds 2% CaO (unless the filler is limestone chips) and 7% SO_3 to the final product, thereby adding more value to the final granular product.

Pilot testing

Polysulphate was extensively pilot tested at ICL's Amsterdam plant prior to full-scale production. The pilot tests initially focussed on replacing fillers, but quickly concentrated on including as much *Polysulphate* as possible into the product.

The pilot plant in Amsterdam is based on a two kilogram batch-process. 'Run of Pile' (ROP) material is produced by intensively mixing phosphoric or sulphuric acid with the phosphate rock in a reaction vessel and granulating in a rotary drum. The product is also dried in a rotary drum with lifters and hot air and sieved afterwards. The >5mm fraction is ground and fed to the recycle, as is the <2mm fraction. The process is then repeated several times using the recycle.

Water and steam volumes are monitored during the test, as is granulation bed temperature and the granulation loss (e.g. from particles sticking to the granulator wall). Particle size distribution (PSD) and full chemical analyses are performed afterwards. This test regime can be expanded by measuring caking tendency and granule hardness, both of which are also generally measured in granulation tests on new raw materials.

An increase in granulation efficiency, partly linked to the fineness of the *Polysulphate*, was observed during the initial pilot testing. Ground *Polysulphate* had a particular dramatic effect on granulation efficiency. Using *Polysulphate* less than 2.5 mm in size was optimal, however, as too fine a grind caused the product to over-granulate.

As *Polysulphate* showed good granulation properties in regular PK and NPK granulation, ICL began to investigate the granulation of *Polysulphate* without adding significant amounts of other materials in 2013. Although this pilot work showed great potential, upscaling it to full-scale plants has not yet yielded satisfactory results to-date.

Also, although *Polysulphate* was expected to change the caking tendency or hardness of the final product when used in PK and NPK granulation, this hypothesis could not be confirmed by analysing the different products obtained from pilot tests.

Plant-scale use

Polysulphate was not consumed in large quantities by ICL initially, as it was only used to replace fillers in certain grades of PK fertilizers manufactured in Amsterdam. In 2012, for example, it was mainly consumed in the PK 9-25 and PK 8-27+7MgO grades. However, from 2013 onwards, *Polysulphate* began to be used in over 13 different grades, from PK 9-25 to NPK 11-8-16+3MgO. ICL's Ludwigshafen plant in Germany is also now consuming a significant volume of *Polysulphate* to produce so-called 'PK-Plus' products. These incorporate up to 56% *Polysulphate* in specific grades.

Polysulphate consumption will increase further at ICL's Amsterdam and Ludwigshafen plants in the next few years. The potential for developing compound fertilizer grades incorporating a higher percentage of *Polysulphate* is also being actively investigated. However, the market has yet to fully appreciate the benefits of adding more *Polysulphate* to fertilizers.

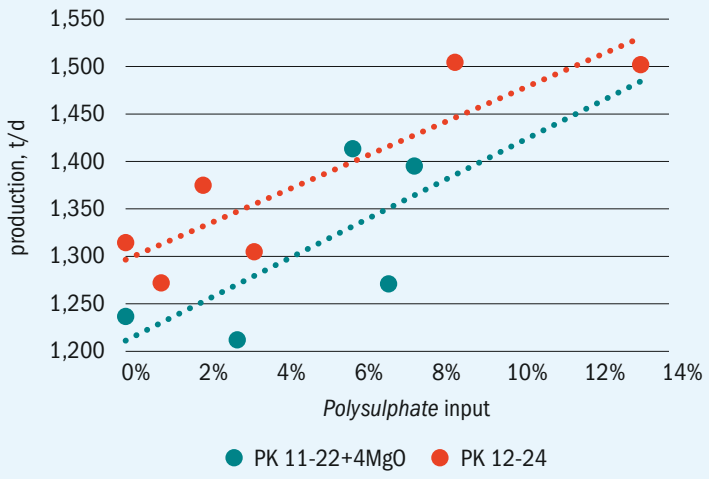
As ICL's plants produce PK and NPK grades where the potash source is mainly KCl (MOP), very few pilot tests have investigated K_2SO_4 (SOP) replacement. However, at the Ludwigshafen plant, PK 18-7+3MgO, which was first produced using SOP and SSP, is now produced with TSP and *Polysulphate*, resulting in a 15% increase in production output.

Advantages of using *Polysulphate* in NPK and PK granulation

Several distinct advantages have been observed when using *Polysulphate* in PK and NPK fertilizer granulation, both product- and process-related.

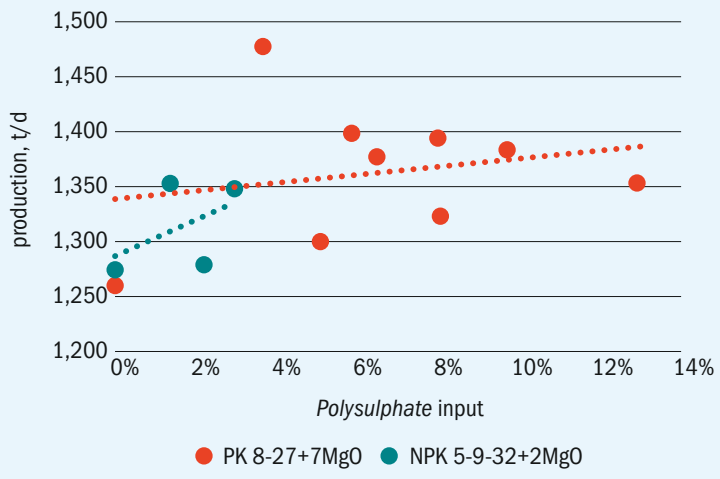
During pilot-scale tests, granulation efficiency increases when using *Polysulphate* in PK and NPK fertilizer granulation, compared to grades using KCl. This is mainly due to the fact that the amine coating regularly

Fig 3: **Product-specific production capacity increase relative to the amount of *Polysulphate* added**



Source: ICL

Fig 4: **Product-specific production capacity increase relative to the amount of *Polysulphate* added**



Source: ICL

Table 3: **Salt Index (SI) for PK 9-25, with and without *Polysulphate***

		PK 9-25		PK 9-25 + Polysulphate	
	Salt index	**% in product**	**Relative salt index**	**% in product**	**Relative salt index**
SSP	8	45.3	4	-	-
TSP	10	-	-	18.9	2
KCl	114	41.7	48	30.2	35
Polysulphate	12	-	-	50.9	6
Filler	-	13.0	-	-	-
Total	-	100	51	100	43

Source: ICL

applied to KCl is hydrophobic and hinders wettability. Because of this, KCl does not easily dissolve or agglomerate in the granulation process. This reduces granulation efficiency and, by requiring a higher input of water, increases the energy consumption needed to dry granules. Substituting *Polysulphate* for KCl, as well as having a positive effect on granulation, also decreases the environmental impact of the final product by excluding amines from the production process.

The overall conclusion of production staff at Amsterdam is that incorporating higher amounts of *Polysulphate* in products improves granulation efficiency. This increase in granulation efficiency is highest in those products where *Polysulphate* replaces a filler material or SOP. However, this positive effect decreases slightly when *Polysulphate* is added to high nutrient products due to the introduction of more dry matter.

Using *Polysulphate* in products has the added benefit of introducing a pH neutral, inert material to replace reactive magnesite. This reduces possibility of magnesium oxide reacting within granules to form magnesium phosphate. This, in turn, reduces the likelihood of caking and dusting problems in the final product. The pH-neutral properties of *Polysulphate* also reduces the potential for ammonia release during granulation with ammonium products.

The presence of the secondary nutrients S, Mg and Ca in *Polysulphate* adds value to the final product by increasing their content in most formulations. Introducing 50% *Polysulphate* has been shown to have large positive effect on crops in field trials with nitrogen/*Polysulphate* blends.

The fertilizer salt index (SI) of *Polysulphate* is only 12. Beneficially, incorporating *Polysulphate* into PK grades lowers their SI and improves the ability of crops to take up nutrients as a consequence (Table 3).

NPK production with Polysulphate

Several major NPK producers globally are using *Polysulphate* as a raw material at present. One Western European NPK producer is manufacturing NPK 7-14-14 containing 20-25% *Polysulphate*. A Chinese NPK manufacturer is also producing two formulations using *Polysulphate*:

- NPK: 12-8-10 (plus 11.1 %S, 10% CaO and 3.6 %MgO)
- NPK: 15-15-15 (plus 8.4 %S, 3.8 %CaO and 1.4 %MgO, with SOP)

These formulations, with and without *Polysulphate*, are compared in Figures 5 and 6. In both examples, the same compositional formula can be achieved using *Polysulphate*, but with the advantage of extra S, Mg and Ca.

Discussion and conclusion

Polysulphate is a product with great potential. It can be used as both a straight fertilizer and as a raw material in the granulation or blending of NPK and PK fertilizer grades. Being a naturally-occurring mineral, it is organic-certified with a significantly smaller ecological footprint than other similar fertilizers.

The presence of four nutrient constituents (K, S, Mg and Ca) with gradual-release properties is one of the main benefits of *Polysulphate*. The plant-availability of these nutrients is good and similar

Fig 5: **Formulation of NPK 12-8-10, with and without *Polysulphate***

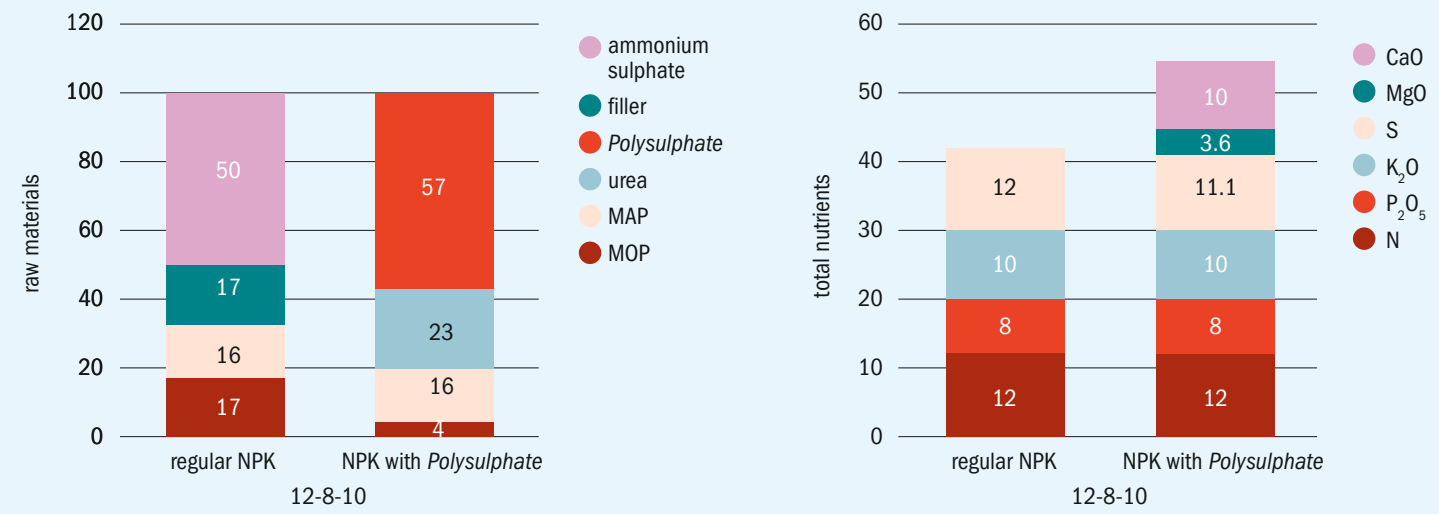


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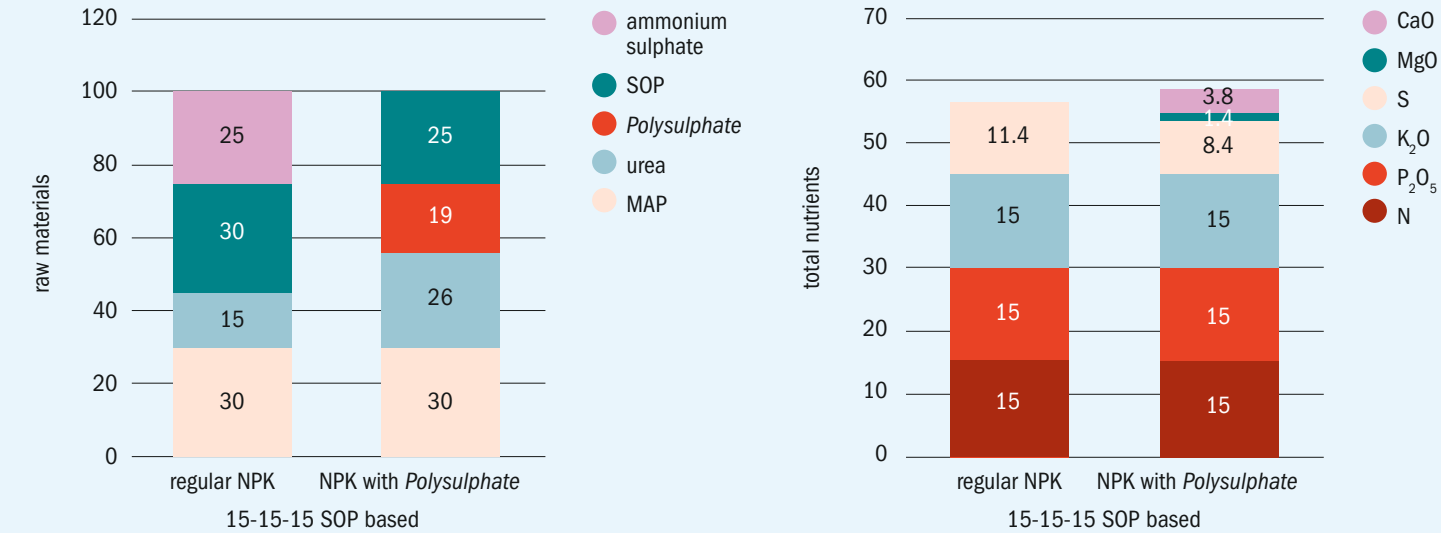
Fig 6: **Formulation of SOP-based NPK 15-15-15, with and without *Polysulphate***



Source: ICL

to other fertilizers. Gradual-release properties also mean *Polysulphate* is able to constantly deliver soluble nutrients while reducing the risk of leaching. Applying *Polysulphate* has a positive effect on crop growth, yield and quality due to its K, S, Mg and Ca content. Its low salt index (SI) is another benefit, as this increases the ability of crops to take-up the nutrients. All these benefits are conferred on PK and NPK fertilizers when *Polysulphate* is incorporated during granulation, with secondary nutrients such as S, Mg and Ca providing additional value.

Polysulphate increases production output when used as a raw material for PK and NPK fertilizer granulation, particularly when replacing a filler material or added to SOP-based product. The improvement in output is linked to the replacement of KCl and the reduction in hydrophobic amines used to coat this constituent. An increase in production has been observed for a great range of products at ICL's Amsterdam and Ludwigshafen plants, with some grades even achieving 15% higher output. These results are highly encouraging and further research should make it easier to predict the beneficial effects of *Polysulphate* on production output.

Polysulphate is pH neutral, providing great advantages over magnesite, especially for ammonium phosphate-based products as it can prevent ammonia being released during production. In PK and NPK products, *Polysulphate* can also prevent reactions within granules during storage, potentially reducing dusting and caking issues, although effects on final product quality need to be investigated further.

NPK+S and PK+S fertilizers produced with *Polysulphate* are currently being evaluated in agronomic trials. Field experiments are being performed at the Center for Fertilization and Plant Nutrition (CFPN) in Israel and other research sites around the world. These studies are comparing *Polysulphate*-based fertilizers with regular fertilizer products by monitoring crop responses, leaching, solubility and nutrient uptake. ■

List of abbreviations

DAP: Diammonium phosphate ($(NH_4)_2PO_4$ - 18% N - 46% P_2O_5)
SOP: Sulphate of potash (K_2SO_4 - 50% K_2O)
SSP: Single superphosphate (20% P_2O_5)
TSP: Triple superphosphate (49% P_2O_5)

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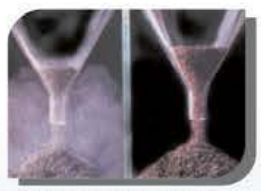
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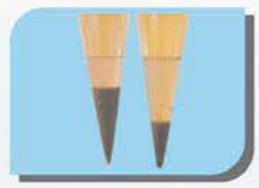
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