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INTERNATIONAL

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FERTILIZER INTERNATIONAL
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JULY-AUGUST 2015

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Cover: *Close up of sugar cane plants. iceink/Shutterstock.com*

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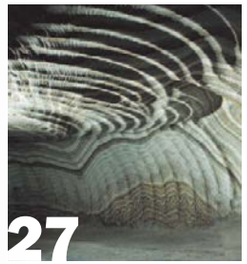

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Optimistic about Africa

My interest in Africa is not hard to fathom. It stems from having spent my twenties criss-crossing the continent from the Cape to Cairo as a young geologist. So I was pleased when Africa cropped up in conversation with former *Fertilizer International* editor Mark Evans during my recent interview (p16). Africa has also been a surprisingly common, recurring theme at recent spring and summer conferences.

I first noticed this at the Phosphates 2015 conference in March. CRU's Juan von Gernet told delegates in Tampa "our hope lies in Africa". He suggested that unlocking Africa's agricultural potential was one answer to the "worrying amount" of new phosphate capacity that is currently emerging.

The average phosphate application rate for Africa's 237 million hectares of cultivated land is just 5kg/ha currently. von Gernet pointed out that bringing application rates up to North American levels (~40kg/ha) would create a staggering 9.3 million tonne phosphate market in Africa. Even doubling current application rates would boost the current African market to 2.6 million t/a.

Juan concluded that it was in the phosphate industry's best interest to collaborate and create demand in Africa to soak-up excess new capacity.

Several months later, in Marrakech, OCP executive director, Soufiane El Kassi, echoed this call. He told delegates to the SYMPHOS 2015 conference in May: "Our mission is to produce appropriate, affordable fertilizers for farmers across the African region." SYMPHOS is all about innovation and sustainability and, in his keynote address, Julian Hilton of Alleff Group was crystal clear about who the main beneficiaries of this should be (p48). "The needs of the most poor are the one's we have to satisfy first," he said.

> **"Our mission is to produce appropriate, affordable fertilizers for farmers across the African region.**

The future of African agriculture was also on the mind of IFDC president and CEO, Amit Roy, this year's recipient of the Francis New Medal (p18). In his lecture to the International Fertiliser Society in London in June, Dr Roy said: "With its increasing population pressure, sub-Saharan Africa will have to adopt intensive farming practices, using better seeds, appropriate fertilizer and better management of natural resources."

Dr Roy's views chime with those of another industry leader, Abdulrahman Jawahery, IFA's new president. The offer of a helping hand to Africa featured in Dr Jawahery's first proclamation as president. "Sub-Saharan Africa remains a largely under-served fertilizer market and I am keen to continue IFA efforts to encourage greater access to and utilization of fertilizers for African farmers," he said at IFA's conference in Istanbul.

The development of Africa's phosphate wealth is also very much on the fertilizer industry's radar at the moment. In its latest supply forecast published in June, IFA predicts the continent will see the largest regional increase in phosphate rock supply over the next five years. IFA expects nearly 13 million tonnes to be added to African supply by 2019 (p49). Tens of junior phosphate mining projects are also spread across sub-Saharan Africa currently.

Cynics might conclude that such projects are the continuation of an African resource grab that goes all the way back to the original 'Scramble for Africa' of 130 years ago. But the truth is that much of African phosphate lies in the hands of OCP, an African-owned and staffed company that is actively promoting growth and prosperity in Morocco and the rest of the continent.

Another reason to be positive about Africa is that strong growth will – slowly but inexorably – bring the continent much greater economic power and influence. As *The Economist* approvingly noted this year, Africa has been one of the world's fastest-growing continents over the past decade, its average annual growth rate of more than 5% buoyed by better governance and economic reforms. The World Bank's *Doing Business* report even ranks Rwanda above Italy as a friendly place for investors.

Will Africa's annual demand for phosphate ever reach nine million tonnes? Realistically, that prospect is several decades away and may never be attainable. But it is possible to imagine a future in which the might of Africa's agriculture will draw in global fertilizer producers eager to access an increasingly lucrative market. With clever analysts agreeing with the IFDC and IFA leadership about its importance to the industry, surely it is time for all of us to look at Africa with fresh hope and optimism. ■

S. Inglesfield

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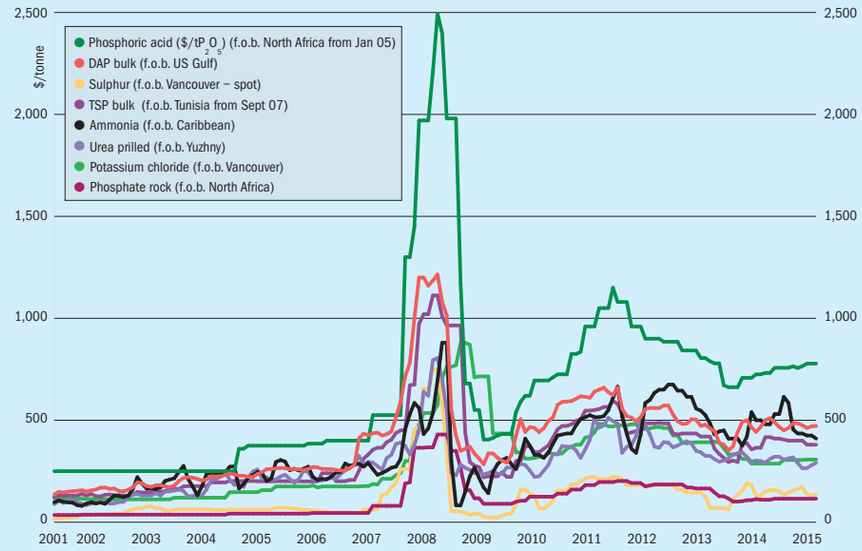
Market outlook

Historical price trends $/tonne



Source: BCInsight

Market insight courtesy of Integer Research

AMMONIA

Ammonia prices continued their decline through the second quarter of 2015, falling to a low of US$375/t f.o.b. Black Sea in mid-May. The key driver of weak pricing was slow demand from regions that would usually be expected to make seasonal purchases. In June, however, market sentiment picked up as a result of lower supply availability from some of the key global ammonia exporters. Most notably, Egyptian ammonia availability continues to be severely disrupted by gas supply issues to the country's nitrogen plants. At best, producers have been operating at reduced utilisation rates over the last few months, and all plants have suffered periods of shutdowns due to shortages of natural gas.

UREA

The urea market first began to show signs of recovery in May as a result of tightening supply, and prices increased to US$295/t f.o.b. Black Sea in early June in anticipation of a substantial tender from India. The buyer, STC India, closed the tender on 19 June, and ultimately purchased 849,000 tonnes of urea for shipment by 27 July. Of the total volumes committed, it is believed that about 450,000-500,000 tonnes of urea will come from China, 200,000 tonnes from Iran, 50,000 tonnes from Oman and around 120,000 tonnes from Russia.

PHOSPHATES

Increasing Indian DAP demand and Latin America entering the market for MAP resulted in a small uptick in business at the end of April. But the demand increase from India was short-lived, as it was unsupported by market fundamentals, and the phosphates market soon returned to a comatose state. Brazilian demand for MAP, however, continued and at the end of May prices had reached US$508/t cfr Brazil. The Tampa DAP benchmark continued to hover at just above US$470/t f.o.b. Tampa in May, as there was a lack of business in the US due to unfavourable weather. In China, producers decreased DAP operating rates to 55-60%, and prices had dropped to US$467/t f.o.b. China by the end of May.

POTASH

Indian contracts for the 2015/16 fertilizer year fell into place through May and into June, perhaps later than is typical, but volumes agreed are reasonable with over five million tonnes of potash (including optional volumes) now booked with suppliers. Israel's ICL has been able to now confirm contracts for an aggregate 835,000 tonnes for its customers in India following the resumption of supply out the Dead Sea as ICL's three month strike action came to an end in late May. After the compromise seen on the China contract price earlier this year, only a US$10 increase could be achieved on Indian contracts that run to end-March 2016. The price of these was price at US$332/t cfr with 180 days' credit. Attention has most recently turned to Brazil, where seasonal demand for granular potash has picked up and suppliers are trying to use this to their advantage to push through modest price hikes.

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Granular potash had been trading at as low as US$325/t cfr for the biggest buyers. Now, however, Russian supplier Uralkali is seeking a price of US$345/t cfr from 1 July, whilst it is also heard that buyers are being quoted US$350/t cfr and above.

SULPHUR

The global sulphur market stabilised in Q2 2015, with prices steady based on a balanced supply-demand position. A standoff remains between Middle East producers on the one side and Chinese buyers on the other, with producers bullish about pricing and buyers reluctant to back down. Middle East suppliers Aramco Trading, Tasweeq and ADNOC settled their prices in the US$141-146/t f.o.b. range in June, moving up from May contract prices of US$139-140/t f.o.b., but Chinese buyers have stayed on the sidelines. As a result, sulphur stocks at the ports in China remain low, supporting the idea that inventories are becoming less influential in forecasting future pricing. Elsewhere in the market, there have been no shortages in Europe or the Americas and the focus is moving towards Q3 contract negotiations. Demand has been most apparent in the Indian market, but with refiners running at full rates the uptick in sulphur demand there is being met by domestic capacity.

Market price summary $/tonne – Early-July 2015

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phosphoric Acid
f.o.b. Caribbean	420	n.m.	f.o.b. E. Europe 127-130	f.o.b. US Gulf	470-475	n.m	n.m
f.o.b. Yuzhny	380-390	282-287	-	f.o.b. N. Africa	487-515	380-405	720-840
f.o.b. Middle East	380-404	278-300**	-	cfr India	475-482	-	810*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	290-319	-	cfr US Gulf	70-80	f.o.b. Vancouver	130-140	
f.o.b. Middle East	289-316	-			f.o.b. Arab Gulf	140-150	
f.o.b. Western Europe	-	€470-520			cfr North Africa	145-152	
f.o.b. FSU	275-300				cfr India	160-165+	

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)*

MARKET DRIVERS

- **Ammonia outlook:** Market sentiment is that ammonia prices have now reached their floor, and emerging demand will add strength to prices going into the third quarter of 2015. Until fresh demand fully kicks in around September, supply-side restrictions are expected to keep the market buoyant. In particular, there are scheduled turnarounds planned in Russia which will limit supply from the Black Sea and Baltic regions, and there are indications that the Egyptian supply disruptions could continue into the next few months at least.
- **Urea outlook:** The urea market remains oversupplied globally, although the short-term outlook is for firmer prices than in the first half of 2015. A development which will impact the urea market notably is the closure of Ostchem's last remaining plants in Ukraine, following "unprecedented pressure" from the government. The closures bring a great deal of uncertainty to supply out of the region. Following on from the substantial volumes purchased under the Indian tender in June, other Asian demand is expected to follow, particularly from Pakistan, Sri Lanka and Bangladesh.
- **Phosphates outlook:** By early June, the monsoon had begun in India and the subsidy rates had been announced, allowing for a degree of certainty for Indian buyers. Subsequently demand is expected to pick up moving through the summer months. In China, suppliers have been quoted as being sold-out until early July and demand is expected to increase in India in August ahead of the *Rabi* season, which should allow support for higher prices. A similar trend is expected in the Americas, as Brazilian DAP demand is expected to increase in Q3, which will provide support to the DAP Tampa benchmark. These factors, alongside intermittent production in Tunisia due to civil disturbances, will stimulate prices for finished phosphates in Q3 2015.
- **Potash outlook:** There are factors at play that could stymie any price increases going forward. Demand is weak today in North America – also a granular market – and summer fill prices in the United States are likely to be lowered to counter the lack of interest from buyers. In any event, the strength in Brazil will only last through to probably September/October, and thus there is only a very limited window for raising prices. Although Indian import demand looks to have improved this year, actual consumption will hinge on the performance of the monsoon. The India Meteorological Department (IMD) recently downgraded its outlook for the Southwest Monsoon to deficient. Indian farmers have already faced difficulties this year caused by un-seasonally heavy rainfall in March-April, but now face the prospect of drought conditions.
- **Sulphur outlook:** Looking forward, sulphur market fundamentals are broadly unchanged moving to Q3 2015, and pricing is expected to be steady to firm. It appears that Chinese buyers will wait for increased supply brought online by new projects in the Middle East, as prices may have to drop considerably for them to enter the market for large cargoes. A number of projects in the pipeline will increase sulphur exports out of the Middle East region – Barzan in Qatar, and the long-awaited Shah in UAE. However, with reported delays it is not thought the new capacity will impact the market commercially until 2016. Meanwhile, the Mosaic one million t/a sulphur remelter project in Florida is also earmarked for completion in October 2015. This could have an effect on sulphur trade, as more demand will be met domestically, and less will be imported from Canada. As a result, Vancouver sulphur shipments are expected to increase as suppliers look to place cargoes elsewhere.

Fertilizer Industry News

GERMANY

K+S rejects shock $9bn PotashCorp bid

German potash producer K+S has categorically rejected a surprise $8.7bn takeover bid by its Canadian rival PotashCorp. The firm's board rejected the unexpected €41 per share offer on 2 July, saying the bid "does not reflect the fundamental value of K+S, and is not in the best interest of the company".

Potash Corp's surprise move to acquire K+S comes as the latter is developing the massive Legacy project, Canada's largest mining project and the first major greenfield potash project in the country for almost 40 years (*Fertilizer International*, 466 p72).

K+S chief executive Norbert Steiner said: "We believe PotashCorp is trying to take advantage of the valuation gap to takeover K+S and gain control over Legacy. Not only does this proposal undervalue our potash and magnesium products and our salt business, it completely disregards the value of our Legacy Project."

K+S has invested more than €2 billion in Legacy and believes the project's value and future earnings would add an extra €21 per share to its valuation, if properly accounted for in its share price. But PotashCorp responded by saying its 25 June bid, which it described as a "friendly proposal", offered a 57% premium on the average K+S share price over the preceding year, and therefore provided significant value to shareholders.

Industry commentators believe the appeal of Legacy – and conversely the threat it may pose were it to remain outside of North American control – is behind PotashCorp's move on K+S.

The three big North American producers, PotashCorp, Agrium and Mosaic, currently sell and market potash internationally through their joint Canpotex consortium. But the emergence of K+S as a major Canadian producer, via the Legacy project, could threaten this arrangement, especially as K+S has no plans for Legacy to join Canpotex.

Legacy's arrival is imminent. The project is currently under construction and is scheduled to produce two million t/a of potash by the end of 2017. K+S confirmed that Legacy was on time and budget to produce its "first tonnes of potash" by the end of 2016, and will generate "positive cash flow" for K+S from 2017 onwards.

Job losses were also a worry for Steiner: "PotashCorp has made no firm commitments to protect the interests of the more than 14,000 employees of K+S worldwide. Despite repeated requests to address this question, PotashCorp's answers have remained vague."

PotashCorp responded by insisting its bid was not based on closing mines, curtailing production, selling K+S's salt business or cutting jobs.

"We believe that the combination of our two companies would create a well-capitalized, more diversified company across products, geographies, production, distribution and customers," said PotashCorp's CEO Jochen Tilk. "We are seeking to meet with K+S management at the earliest possible opportunity so that we can jointly discuss our commitments and further specify the details that would form the basis of a successful combination."

However, PotashCorp has already said it may go past the board and attempt to acquire K+S by making a direct takeover offer to its shareholders. PotashCorp's next move, and any counter move by K+S, was therefore being keenly awaited by the industry as *Fertilizer International* went to press.

UNITED KINGDOM

York Potash project wins approval

Sirius Minerals has secured planning consent for a £1.7 billion polyhalite mine in the UK.

The North York Moors National Park Authority made the long-awaited decision in favour of the York Potash project at a special planning meeting on the 30 June, with eight committee members voting for and seven against. The authority reached a decision after considering a 200-page planning report published two weeks previously.

The authority's chief, Andy Wilson said the mine was a "once in a lifetime opportunity", and "that the economic impact of the mine outweighed the environmental harm" due to "stringent conditions" placed on the mine's construction and operation.

Sirius Minerals is proposing to mine polyhalite at a 64-hectare site, near the village of Sneaton within the national park, and transport this via a specially-constructed 23-mile (37km) tunnel to a processing plant at Teesside on England's North Sea coast. Redcar and Cleveland Borough Council had previously given its approval for the project in May (*Fertilizer International*, 466 p15). The UK planning inspectorate will decide whether to approve a proposed harbour facility next year.

The latest decision finally leaves Sirius Minerals free to develop the York Potash project. The proposed polyhalite mine is likely to take five year's to build. It could be producing five million t/a by 2020 and ultimately expand to 12-13 million t/a capacity. The company said it would formally update the markets on the project's status and its next steps in coming weeks. However, markets have already reacted positively, with the firm's shares rising substantially on news of the decision.

"This is really just the beginning for the company," said Chris Fraser, Sirius

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The York Potash project is located within a National Park.

PHOTO: QUOD

Minerals' managing director and CEO. "The case for the project has always been compelling because it will not only generate so many jobs and economic benefits, but also because it is accompanied by such extensive mitigations, safeguards and environmentally sensitive design. We now look forward to delivering it."

Raising finance will be a major challenge and an overriding priority, although Fraser has the right experience to take the project forward, having helped finance and develop major mining projects for Citigroup, Rothschild and KPMG.

The project also faces some competition from ICL subsidiary Cleveland Potash. The North Yorkshire miner is currently investing £38 million ($64 million) in expanding polysulphate production at its nearby Boultby potash mine in the UK from 130,000 t/a to 600,000 t/a – although this a fraction of the production volumes the York Potash project is aiming for.

CF Industries takes control of GrowHow UK

CF industries will become the sole owner of GrowHow UK after it announced the purchase of Yara's 50% share for $580 million on 1 July. Yara and CF Industries have owned an equal joint share in GrowHow since 2010.

"We are pleased to announce this agreement to acquire Yara's interest in GrowHow," commented Tony Will, CF Industries' president and CEO. "The operations have an advantaged position in an import-dependent region. We know GrowHow well and expect a mid-teens return profile for the acquisition."

GrowHow's two long-standing UK fertilizer production sites, at Ince, near Chester and Billingham in Teesside, together have the capacity to produce around 0.9 million short tons of ammonia, 1.2 million short tons of AN and 0.4 million short tons of NPK.

UNITED STATES

Agrium plays down phosphate sell-off rumour

Canada's Agrium has denied it is considering selling its phosphates business in the next three to five years. Speculation was triggered after chief financial officer, Steve Douglas, questioned whether Agrium's phosphates assets, unlike its nitrogen and potash businesses, were world-class in scale and cost.

"Phosphate is a little more difficult because we do not have an integrated rock supply for our Redwater plant," Douglas told the 10th Annual Farm to Market Conference in New York in May. "In the next three to five years we will have a decision to make. Do we think that there is a better owner for these particular assets, or do we spend a significant amount of capital [on] our own in-house rock source?"

But Richard Downey, the firm's vice president of investor and corporate relations, has denied that a phosphates sell-off was on the cards. He told *Industrial Minerals* magazine the rumour that Agrium was actively planning to divest its phosphate business was untrue.

The future of Agrium's Redwater plant, located near Edmonton Alberta, has been subject of speculation for some time. The plant has been reliant on imported rock phosphate from OCP since the closure of Ontario's Kapuskasing phosphate mine in mid-2013. This has affected Redwater's production and squeezed profits. Agrium's existing phosphate supply contract with OCP runs until 2018. But, without a long-term captive source of rock phosphate, conversion to ammonium sulphate, or even closure, are possible future options for the Redwater plant.

Borealis to jointly develop new ammonia project

Borealis has reached a preliminary agreement with Agrifos Partners LLC to jointly develop an ammonia plant in Texas as part of the Gulf Coast Ammonia (GAC) project.

Borealis, an Austrian-headquartered but mainly Abu Dhabi-owned chemicals and fertilizer business, is also entering into a long-term off-take agreement for around 40% of plant's ammonia production as part of the deal.

"We have a clear strategy of expanding our global nitrogen business," said Markku Korvenranta, Borealis executive vice president for base chemicals. "By participating in the development of, construction of and off-take from a world-scale project in the US, Borealis is able to secure long-term supplies of ammonia based on the attractive economics of US natural gas."

Although the final site selection has yet to be made, the project will be located at an existing chemical complex and is aiming for a 2019 start-up date. Final confirmation of the GAC project deal is awaiting Borealis board approval

INDIA

India confirms unchanged subsidy rates

The Indian government has confirmed nutrient based subsidy (NBS) rates for 2015/16. As widely-expected, subsidies for P & K fertilizers under the NBS are unchanged from 2014/15. The subsidy on DAP therefore remains at INR 12,350/t and that for MOP at INR 9,300/t. Approval of the New Urea Policy will also fix Indian farm-gate price for urea at INR 5,360/t for the next four years.

One new change that will take effect is that freight subsidies for fertilizers will be paid as a lump sum in future, replacing the current system under which the transport of fertilizers was fully-subsidised within a certain radius. Final details of the new system are awaited, but will hopefully address worries that the new arrangement

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could hamper distribution and lead to possible fertilizer shortages in Indian regions located furthest away from supply.

IPL agrees three-year PhosAgro NPK deal

PhosAgro is believed to have signed a three-year deal with Indian Potash Limited (IPL) to supply 1.35 million tonnes of Russian NPK fertilizer. This will see PhosAgro export around 400-450,000 t/a fertilizers to the subcontinent, mainly 15-15-15 and 10-26-26 NPK with some DAP.

This deal follows a number of successful sales by PhoAgro to both IPL and IFFCO earlier this year. This resulted in spring shipments of around nine cargoes of mainly DAP at $480s/t cfr. Whether these cargoes form part of the new deal is unclear.

The latest deal with IPL is particularly significant as PhosAgro has not shipped NPKs to India in such large volumes since 2012 when it exported around 250,000 tonnes. PhosAgro also opened a major new fertilizer terminal at the Russian port of Ust-Luga on the Baltic on 16 June (p37).

ISRAEL

ICL three-month strike over

ICL agreed a deal with striking workers at its ICL's Dead Sea Potash Works and Neot Hovav bromine operation at the end of May, ending a three-month labour dispute which is likely have cost the company as much as one million tonnes in lost production.

The strike, which started mid-February, has cost ICL $164 million in lost revenues in the first quarter alone. The revenue fall for the second quarter is likely to be even higher, according to ICL, due to low bromine inventory levels. However, ICL said the long term economic gains from the strike deal with unions will "significantly exceed" these short term costs. The deal allows ICL to press on with its restructuring and cut staff numbers by 248 at Dead Sea Works and Neot Hovav.

In related news, ICL said in June that it had signed several contracts to supply a total of 835,000 tonnes of potash to its customers in India, an improvement on the volume of around 700,000 tonnes it supplied to India last year.

ICL has also announced that it is to jointly create a new fertilizer and plant nutrition research centre in the Negev with the Israeli Agricultural Research Organization (ARO). Known as the Center for Fertilization and Plant Nutrition (CFPN), it will operate out of the existing ARO Gilat Research Center.

The new centre will allow ARO's scientists to link-up with colleagues in other research institutes and collaborate closely with the region's farmers. Scholarships and research grants will be offered to graduate students from Israel and other countries. Funding has also been set aside for hosting international conferences and sharing the centre's research findings with a global audience.

POLAND

European banks fund Grupa Azoty expansion

Grupa Azoty, Poland's leading chemical and fertilizer business, has secured funding for its expansion and diversification strategy.

The company will have access to PLN 700 million ($187 million) under a 10-year joint finance package with the European Investment Bank (EIB) and the European Bank for Reconstruction and Development (EBRD). A group of Polish banks are also providing an additional PLN 1.5 billion through a separate loan agreement.

This significant injection of finance will help Grupa Azoty's ambition to become a key European industry player by 2020 by enabling the firm to pursue a series of acquisitions. Paweł Jarczewski, Grupa Azoty's CEO said: "Our 2020 Strategy, accepted by the board last year, envisages a number of world-class investments and an ambitious plan of regional expansion, and I am delighted that the EBRD and the EIB share our vision for the future."

RUSSIA

UralChem-Uralkali merger rumours

News of a possible merger between Russian potash producer Uralkali and the nitrogen and phosphate producer UralChem, already a 20% shareholder in Uralkali, have emerged in the Russian press. Such a move would see Uralkali delisting in both London and Moscow prior to any merger, according to Russian newspaper *Vedomosti*.

Uralkali has not commented on the rumour. The company recently bought back 12% of its stock at a cost of $1.12 billion as part of a share buyback programme. Onexim Group's remaining 20% stake in Uralkali is likely to be an obstacle to any merger plan.

In March, Uralkali unveiled a $4.5 billion investment plan to raise capacity by 30% over the next five years (*Fertilizer International*, 466 p14). The firm's 2015 first quarter revenues fell 17% to $720 million on the back of lower production and reduced sales volumes.

EuroChem leaves door open to Uralkali link-up

Russian producer EuroChem has not ruled out jointly selling potash fertilizer with Uralkali, once its potash operations come into production.

"Everything is possible but we haven't had any discussions, even internally," Eurochem's Chief Financial Officer, Andrey Ilyin, said during an investor conference in May. However, Ilyin added that linking up with another player to sell potash would be unlikely, if EuroChem were to achieve its goal of becoming the world's lowest-cost potash producer.

EuroChem's under-construction Volgakaliy and Usolskiy mines are due to open in late 2017. They are expected to produce one million t/a of potash from 2018, ramping up to five million t/a by 2020.

Trammo and KuibyshevAzot agree JV

US trading company Trammo and Russian fertilizer firm KuibyshevAzot are collaborating on a new 140,000 t/a granular ammonium sulphate (AS) plant. The two businesses have formed the joint venture Granivert to build a RUB 700 million ($12.8 million) AS plant in Togliatti, Russia. Construction will begin this year and should be completed in 2017. KuibyshevAzot's chairman, Victor Gerasimenko, said the new project with Trammo would promote an agricultural fertilizer with "improved consumer properties", and create jobs during its construction and operational phases.

ITALY

Maire Tecnimont wins €660 million Kingisepp contract

EuroChem has awarded Maire Tecnimont a €660 million engineering, procurement and construction (EPC) contract for its Kingisepp 2,700 t/d ammonia plant in Russia. The announcement follows the recent signing of a Memorandum of Understanding for the construction of five nitrogen plants (*Fertilizer International*, 466 p14). Kingsiepp is due to become operational by 2018 and is part of moves by EuroChem to cut its reliance on external suppliers of ammonia, a major feedstock for the company.

REPUBLIC OF CONGO

Rapid payback for Hinda

The Hinda phosphate deposit in Republic of Congo could pay off its development costs in little more than two years, once operational, according to Cominco Resources Limited.

In a statement accompanying a project definitive feasibility study (DFS), the mining junior said: "The DFS demonstrates that the Hinda Project is technically and commercially robust and has the capacity to repay its US$601M development cost within 26 months of production."

The rapid payback would require the successful mining of 20 million t/a of phosphate ore, the production of 4.1 million t/a of concentrate (32% P_2O_5) and the construction of a 42km slurry pipeline to get this concentrate to the Atlantic coast. Phosphate products would then be exported after dewatering and drying through a new port facility at Pointe Indienne. Despite the new infrastructure required, the DFS for Hinda places the project in the lowest industry quartile. Its average cost of production is estimated at $36.6/t f.o.b for the first five years. The deposit benefits from a low overburden to ore ratio, enabling it to be open-mined by freedigging.

The Hinda project is said to be one of the world's largest and thickest undeveloped phosphate deposits (*Fertilizer International*, 466 p60). The DFS reveals that a 20km-section of an extensive ore body has a proved and probable ore reserve of 404.9 million tonnes (11.0% P_2O_5), enough to provide the mine with a 24-year life. Cominco says mining license approval for the project is imminent.

SPAIN

Highfield raises $101m for Muga potash project

Highfield Resources has raised AUD 101 million ($80 million) on the Australian stock exchange for its Spanish Muga potash project. In a successful May share offering (at AUD 1.80 a share), 29 million shares went to Highfield's major shareholder EMR Capital for AUD 52.3 million and 27 million shares went to institutional investors in Australia, Asia, Europe and North America.

The share issue leaves Highfield with a healthy cash balance of more than AUD 120 million, enough to fund a "significant portion" of Muga's development in the firm's view. Highfield estimates that a "very low" pre-production capital investment of $256 million is initially needed for the 1.1 million t/a potash project. The company hopes to begin construction in the fourth quarter of this year, and plans to export Muga potash to Brazil, Europe, North America and West Africa.

VIETNAM

Nitrogen revamp and new NPK plant at Phu My

Vietnam's PetroVietnam Fertiliser and Chemicals Corporation (PVFCCo) is to revamp its existing ammonia plant at Phu My and construct a new 250,000 t/a capacity NPK plant at the site at a cost of VND 5 trillion ($230 million). The major revamp project will expand the ammonia plant's capacity from 90,000 t/a to 540,000 t/a. The extra output will be consumed as feedstock by the new NPK plant or sold on the domestic market instead. Italy's Technip Group, Germany's ThyssenKrupp Industrial Solutions and PetroVietnam Technical Services Corporation signed a contract to deliver the project on 7 June. PVFCCo will bankroll the project using bank loans (70%) and its own balance sheet (30%). Completion is expected towards the middle of 2017. ■

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People

New IFA president

Gulf Petrochemical Industries Company (GPIC) president **Dr Abdulrahman Jawahery** was elected president of the International Fertilizer Industry Association (IFA) on the 27 May. His immediate predecessor as president, Esin Mete, warmly welcomed Dr Jawahery to the role.

"Abdulrahman Jawahery is one of most experienced executives in the fertilizer industry," said Mete. "His passion for the industry and for sustainability and safety, health and environmental (SHE) issues are a great asset to the association."

Dr Jawahery has been a member of IFA's board since 2005 and has served as Chair of the Technical Committee, Chair of the Finance Committee, and Vice President for Sustainable Development during this time. He is also the 2015 chairman and president of the Arab Fertilizer Association (AFA).

Dr Jawahery holds a doctorate in engineering from London and is a fellow of the UK's Institute of Chemical Engineers (ICE). He began his career in 1983 as an engineer at GPIC, rising to become its general manager in 2005 before eventually being appointed president in 2011. Dr Jawahery has also been a member of the Bahrain parliament's Upper House since 2002, actively promoting legislation on safety, health and the environment. He expressed great pride in becoming IFA president and paid tribute to his predecessor: "I am honoured and delighted to assume the presidency and will do my utmost to serve all of you and our great industry. Thank you for placing your trust in me. We really owe so much to Esin Mete, who has done a simply outstanding job during her tenure as president of IFA."

The new president's priorities will include sustainability, innovation, and safety, health and the environment. Dr Jawahery also regards African agriculture as important. "Sub-Saharan Africa remains a largely underserved fertilizer market and I am keen to continue IFA efforts to encourage greater access to and utilization of fertilizers for African farmers," he said.

Mosaic names O'Rourke president and CEO

James 'Joc' O'Rourke is to become Mosaic's new president and CEO from 5 August, succeeding James Prokopanko who is retiring. O'Rourke, 54, joined the North American phosphate and potash giant in 2009, initially as executive vice president of operations before becoming Mosaic's chief operating officer in 2012. Prior to joining Mosaic, O'Rourke was Barrick Gold Corp' s president for the Australia-Pacific region, a role which included responsibility for 10 gold and copper mines in Australia and Papua New Guinea.

James 'Joc' O'Rourke.

"The board has full confidence in Joc and the rest of Mosaic's talented management team," said Robert Lumpkins, Mosaic's chairman. "Together, they will help Mosaic build on Jim's legacy of success for our employees, customers, investors, communities and other stakeholders."

Commenting on his appointment, O'Rourke said: "Jim [Prokopanko's] leadership took Mosaic from its early days to a company that boasts the best combination of people, assets, innovation and global reach in the crop nutrition industry. We will maintain our steadfast focus on our customers and other stakeholders, and we will use today's solid foundation as a platform for further growth."

In a heartfelt resignation statement, Prokopanko thanked colleagues for their support during a recent period of illness: "It has been a great privilege to serve as CEO and help build the world's leading crop nutrition company alongside some of the most talented people I have ever known," he said. "I deeply appreciate the outpouring of support I received during my illness last year, and I am happy to be healthy today. I plan to enjoy my good health with my family."

Promotions and role changes at EuroChem

EuroChem announced in May that **Dmitry Boldyrev** is to become managing director trading, and will be relocating to Zug, Switzerland from July to take-up the position. The new role is extra to his current responsibilities as head of trade and operations. **Rudolf Graf von Plettenberg**, EuroChem Agro's current managing director, will join Boldyrev in Switzerland as head of premium products and development. He will oversee NPK and premium product strategies, R&D, marketing, and the development of international projects at EuroChem. **Andriy Savchuk** takes on the role managing director of Eurochem Agro based in Germany and has been promoted to regional director for Europe.

Kimberly Gustin and Lisa Smith join Integer Research

Integer Research formally announced on 2 July that **Kimberly Gustin** and **Lisa Smith** are joining the company to head-up its phosphate and potash research teams, respectively.

Kimberly Gustin becomes Integer's new phosphate research manager and will also contribute to the company's sulphur and sulphuric acid research. Kimberley has managed research teams and bespoke consultancy projects previously, and brings with her expertise in sulphur and phosphates markets and supply/demand and quantitative price models. She is also an accomplished presenter who has addressed audiences at numerous fertilizer industry conferences worldwide.

Lisa Smith is Integer's new potash research manager. She has worked as a fertilizer market analyst since 2002, assessing market developments and forecasting potash supply, demand and pricing. Lisa has consulted for fertilizer producers, junior miners, banks and international agencies. During the course of her career, she has charted the rapid development of the N, P and K fertilizer sectors in Europe and the Former Soviet Union.

"We are thrilled to have Kimberly and Lisa further strengthening our Fertilizer research team and we look forward to the authority and market insights they will bring to our market research," said Oliver Hatfield, director of fertilizers at Integer.

Calendar 2015

AUGUST

30-3 SEPTEMBER

AIChE Ammonia Safety Symposium,
BOSTON, Massachussets, USA.
Contact: AIChE Customer Service
Tel: +1 800 242 4363/+1 212 591 8100
Fax: +1 212 591 8888
Email: xpress@aiche.org

SEPTEMBER

8-10

23rd International Symposium of the International Scientific Centre for Fertilizers, SON, Norway.
Email: peder.lombnaes@bioforsk.no

14-16

6TH GPCA Fertilizer Convention,
Intercontinental, DUBAI, UAE.
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com
Web: www.crugroup.com/events/gpca

21-23

IFA Production & International Trade Conference,
Sheraton Tampa Riverwalk Hotel,
TAMPA, Florida, USA.
Web: www.ifa-tampa2015.org

27-29

TFI World Fertilizer Conference,
The Fertilizer Institute, BOSTON, USA.
Contact: Linda McAbee
Tel: +1 202 515 2707
Email: lmacabee@tfi.org
Web: www.tfi.org

OCTOBER

4-9

Ammonium Nitrate/Nitric Acid Conference,
JASPER, Canada.
Contact: www.an-na.org

5-9

IFDC/IFA Phosphate Fertilizer Production Technology,
BERLIN, Germany.
Contact: IFDC Training
Tel: +1 (256) 381 6600
Email: training@ifdc.com Web: www.ifdc.org

26-28

Asian Nitrogen+Syngas Conference,
JAKARTA, Indonesia.
Contact: CRU Events, Chancery House, 53-64 Chancery Lane, London WC2A 1QS. Tel: +44 20 7903 2444
Email: conferences@crugroup.com

NOVEMBER

9-12

Sulphur 2015, CRU Events, TORONTO, Canada.
Contact: CRU Events, Chancery House, 53-64 Chancery Lane, London WC2A 1QS. Tel: +44 20 7903 2444
Email: conferences@crugroup.com

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> **I do salute the business I feel privileged to have reported on.**

Outgoing *Fertilizer International* editor **Mark Evans** reminisces about a long, successful and colourful career with incoming editor **Simon Inglethorpe**.

An awfully big adventure

Interestingly, as he steps down from his long stint at the helm of *Fertilizer International*, Mark Evans says an early love of travel, youthful idealism, and parental encouragement, all helped forge a successful career later in life. "As I come to the end of my career and reflect, several things in my earlier life do seem to have coalesced very happily and made for a very, very fulfilling job," Mark recalls.

He vividly recollects his early upbringing as an only child and how the household subscriptions to American magazines such as *Look* and *Time* were both a source of wonder and a window on the world: "One seed planted in my early childhood days was, I think, my parents wished to have a cosmopolitan outlook on the world – and also wanted me to face life with a cosmopolitan world view too."

Mark continues: "I would claim to be a classic product of the late 1960s. I wanted to do my bit for a better world, a kinder world. I wasn't a hippie in any kind of way, but I wanted the world to be as one… do my bit for 'nation to speak peace unto nation', to paraphrase the BBC motto, to transcend national barriers and prejudices and all come together.

"And I'm ever so happy to feel I've done my bit in fulfilling those ideals. The fertilizer business has been an honest one and being able to report on it has been an honest trade," Mark adds with pride.

A big adventure

What's immediate apparent to anyone meeting Mark for the first time is his infectious enthusiasm, natural ebullience and positive disposition. Apparently, Mark's attitude to life owes a lot to some fatherly advice he received as a 17-year old as he left on a long train journey from Hull for an interview at St Catherine's College, Cambridge.

The prospect of his first night away from home was a daunting one, as Mark explains: "I was a bundle of nerves and terror so my father saw me off at the station and his words to me as the whistles blew were 'treat it as a big adventure'. I thought that was a great philosophy. I have this motto: 'maximise the moment, every moment' – and I can quite happily plug into my well-known hearty appetite for food and drink too!"

It all began in Upper Volta

After a stint as an analyst with banana firm Fyffes, Mark joined British Sulphur Corporation in 1984. He admits to liking the job, especially the writing, from day one.

"My instinct kicked in. The very first article I wrote was on the phosphate resources of Upper Volta and then before I finished writing it the country changed its name to Burkina Faso!" Mark recalls.

And within 11 months of joining British Sulphur, Mark had landed his first editorship: "I found myself enjoying writing articles. So when the chance came with an editorial vacancy in mid 1985 – it was actually with *Phosphorus & Potassium* – I opted for that, even though it was seen as a bit of a slow track."

British Sulphur's list of fertilizer titles then expanded over the years.

"The magazine *Sulphur* was launched in 1955, what was then simply called *Nitrogen* followed in 1959 and the third title in the stable, *Phosphorus & Potassium*, now merged into *Fertilizer International*, was set up in 1962 and had its independent existence for almost 40 years, from 1962 to 2000. *Fertilizer International* began as a sort of newsletter just with price information."

Going to sea in a tea tray

Mark is very proud that BCInsight has managed to successfully build on this long legacy and establish a strong publishing pedigree through its current titles, *Fertilizer International*, *Nitrogen+Syngas* and *Sulphur*.

"I'm delighted to have been one of the partners in BCInsight and also pay huge tribute to colleagues I've worked with down the years, starting with some great mentors, John Lancaster, Bernard Brentnall, John French. I was very lucky to encounter a lot of kindness, people were patient, people were forgiving of me."

Establishing BCInsight with partners Lisa Connock, Tina Firman and Richard Hands did require steely determination, however, and Mark admits to shredded nerves during the last stages of the deal.

"I was terrified, the negotiations were very protracted," he recalls. "A good analogy to how I felt, after the security of being part of a large group, was suddenly setting out to sail on the open sea on a tea tray!"

Game changing events

China's shift from a massive importer to fertilizer exporter has been one of the big developments over the last three decades. "When I came first into the business 30 years ago, China led by Deng Xiaoping had recognised the importance of food security. Any economic growth had to be based on that food security and self sufficiency," says Mark.

This desire for food security turned China into a huge fertilizer importer, as Mark explains: "When I first started reporting in 1984, and onwards into the 1990s, the big story was Chinese imports of fertilizers, urea, phosphates and potash, all were in enormous demand, and the Western world could hardly supply enough.

"But China was quietly getting hold of investment, building up its technology. By about the late 90s, China had built up a very large nitrogen sector, ammonia and urea, and was no longer an importer there.

"Then, in the very early days of this century, it followed suit with phosphate production. That rather changed the tectonic plates – a complete reversal – and now China is a significant exporter."

The break up of the Soviet Union also cast a long shadow over the industry. "That took more than 15 years to work its way through the system and had an immediate impact in the 1990s," Mark recalls.

"In the days of collective farms, Soviet production was primarily for internal use. Following the break up, suddenly, overnight from 1991, all this production had to find an outlet.

"Economics now intruded so basically they [former Soviet producers] now threw it out in the world market, prompting from some parties accusations of dumping. It torpedoed prices across the whole nutrient spectrum – that didn't work its way out of the system until at least 2005."

It is ironic, then, that the latter half of that decade eventually saw a commodities boom.

"That was an almost hysterical period, it was manic and I remember the culmination was IFA in Vienna in May 2008 – people I spoke to were almost despairing saying price was no longer the regulator of supply and demand," Mark remembers. "Things were skyrocketing vertically, everyone felt that something had to blow, something had to give – I almost felt this was comparable to Vienna on the eve of World War One."

Latin American and African hopes

Looking to the future of the industry, Mark is pleased that "we're seeing a more positive picture emerge from Latin America".

"Brazil still has limiting factors in infrastructure, for example in ports and onward distribution, but, all the same, Brazil looks as though it's now got that critical mass for more sustained development. Peru has better governance, Colombia is resolving its problems – so Latin America seems to be beginning to fulfil its potential."

Africa also holds much promise and is starting to show "real green shoots", comments Mark. Although its growth as a major fertilizer market is likely to be "slow and steady" in his view.

"In my own crystal ball, 30 years ahead from this point onwards, I would have high hopes for Africa. Asia had a similar predicament in the 1950s/60s with high yielding strains being the single factor that transformed food security."

Whatever next?

Mark is typically generous and full of praise for those working in the industry: "So many happy moments where there's been no significant dividing line between the professional side and friendship."

He adds: "I do salute the business I feel privileged to have reported on, the high calibre analysts, engineers, agronomists, CEOs who, in their own individual ways, added to a very positive global advance. There are still huge pockets around the globe where food insecurity remains – too many people dying prematurely through poor nutrition – but happily those pockets, inch by inch, are getting eliminated."

Asked about his retirement plans, Mark says: "In a simple phrase, the Life of Riley! What I'm looking forward to is a bit of slow travelling, taking good old-fashioned ferries, travelling by train. I still want to enjoy all the variety of the world I find."

He's not expecting to say goodbye just yet though: "Most of all I'll miss the people. I feel I've made many, many personal friends, but I'll not be disappearing into purdah and will be in contact with many good friends for a long time to come."

There are some things about publishing that Mark will not miss, however: "Please, please, never another deadline – that's a bit I will slough off quite happily!" ■

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Moving from volume to value

Dr Amit Roy presented the 2015 Francis New Lecture at the International Fertiliser Society's annual meeting in London in June.

> **"It is imperative that new, economically viable products are developed with nutrient-release properties that match plants' requirements and contain essential plant-available secondary and micronutrients.**

The International Fertiliser Society (IFS) was set up in 1947 to provide a forum for the technical, economic and agronomic aspects of fertilizer production. Every two years, the IFS pays tribute to the memory of Dr Francis New, the pioneering secretary of the society, by awarding the Francis New Medal to a prominent figure in the industry.

The award is made to individuals whose outstanding contribution has benefitted the whole fertilizer sector. The award can be for technical issues relating to production and distribution, or for matters concerning the use of fertilizers and the environment. It is customary for the winner of the Francis New Medal to present a lecture. The first Francis New Lecture was given in 1959 with subsequent lectures held at two-year intervals ever since.

The IFS Council awarded the 2015 Francis New Medal to Dr Amit Roy, president and CEO of IFDC since 1992. The citation reads: "Under his leadership, IFDC programs have broadened to help create sustainable agricultural productivity in more than 100 nations. Dr Roy was instrumental in organising the landmark 2006 Africa Fertilizer Summit in Abuja, Nigeria. To facilitate the development of next-generation fertilizers, Dr Roy established the Virtual Fertilizer Research Center."

Dr Roy chose 'Global Fertilizer Industry: Transitioning from Volume to Value' as the subject of his Francis New Lecture, presented at the IFS Technical Conference in London on 24 June. A summary of this well-received lecture is provided below.

Closing the yield gap

No agricultural innovation, other than the domestication of plants and animals, has increased food production capability more than manufactured fertilizers, observed Dr Roy. Over the past seven decades, fertilizers have been instrumental in increasing food production, reducing hunger and – with improved seeds and better management practices – creating an agricultural revolution to feed more than seven billion people.

World population will reach 9.6 billion by 2050 compared with today's level of 7.2 billion, according to UN projections. Given dietary changes, this means we need to produce 70% more food, said Dr Roy: "This increase must be achieved under land and water constraints and climate change. Fertilizers will be one of the keys to achieving these targets. However, the once-impressive responses to fertilizer applications for staple crops are tapering off under certain agro-climatic conditions and management practices."

Dr Roy reflected that closing yield gaps for high-yielding areas while reducing environmental impacts – particularly low nutrient uptake – may not necessarily be possible using currently-available fertilizers. Exclusively adding high-analysis primary N, P and K fertilizer nutrients on poor soils will be insufficient, as secondary and micronutrients are also essential for maximum economic yields and improved nutritional value.

"It is imperative that new, economically viable products are developed with nutrient-release properties that match plants' requirements and contain essential plant-available secondary and micronutrients," Dr Roy said. "For this to happen, investment in research is vital to understand both the microbial activities in soils and the micronutrient uptake and metabolic mechanisms of plants in order to drive fertilizer formulation."

The fertilizer industry, however, currently invests very little in research compared to other sectors such as the seed industry. Dr Roy pointed out, however, that some companies have recognised the inadequacies of many current fertilizers and used this a spur to develop new

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products: "They are changing their business model from selling large quantities of the same product to one selling small quantities of new products that are more effective in terms of plant uptake and profitable for the company and the farmers."

This transition, from volume to value, was a critical one for the industry in Dr Roy's view. The IFDC has launched the Virtual Fertilizer Research Center (VFRC) to help bring about this transition by providing a platform for the development of the next generation of fertilizers.

A formidable challenge

Against the backdrop of 30% forecast growth in global population by 2050, food demand is predicted to increase by nearly 70% in the next three decades as emerging regions urbanise, advance economically and consume a richer diet. The absolute increase in food required by 2050 will be as large as the increase since the Green Revolution was launched in the 1960s – at a time when available arable land and water become ever scarcer.

As with population growth, most of the increased food demand will occur in the developing world. Yield will need to increase at an average yearly compound rate of about 1.4% globally. But in developing regions a much higher 1.8% increase is likely to be necessary. Since the Green Revolution, yield increases have delivered higher food production in all regions except sub-Saharan Africa. This region has traditionally followed slash-and-burn agriculture, due to the abundance of land per capita, a practice which has steadily reduced land productivity and lowered crop yields per hectare. The minimal use of fertilizers has also led to soil nutrient mining, resulting in increasingly large tracts of nutrient-depleted land. "With its increasing population pressure, sub-Saharan Africa will have to adopt intensive farming practices, using better seeds, appropriate fertilizer and better management of natural resources," Dr Roy said.

All crops require N, P and K. These nutrients are available in various formulations and forms and often incorporate secondary and micronutrients. Current N and P formulations have been left largely unchanged since the 1970s and their use, in the absence of best management practices, can lead to a significant loss of nutrients to the ecosystem. The nutrient recovery efficiency of N, P and K macro-elements can range from only 20%to over 80%. Even under a well-managed system, N nutrient use efficiency (NUE) rarely exceeds 50%, and is often well below that in developing countries. The unused N is generally lost to the environment as a greenhouse gas. P and K typically have higher NUEs because they are less mobile, reaching 80% for P, where applied P is made slowly available to crops over several years.

Acute declines

The economic impact of low nitrogen NUE is significant, with IFDC estimating a total economic cost of over $116 billion/year for lost/unused NPK nutrients. In India,

PHOTO: REPTON1X

The International Fertilizer Society's annual meeting was in held at Burlington House.

the problem of declining productivity per unit of fertilizer applied is becoming acute, exacerbated by a subsidy system that has led to unbalanced primary nutrient applications and a lack of secondary and micronutrient applications.

The global fertilizer industry has addressed these concerns with education support and improvements in production processes and application methods. Production plant optimisation has also improved energy efficiency and reduced air and water pollution. Current research is also being directed at improving the water use efficiency of existing fertilizers through better management practices. While programs such as 4R nutrient stewardship and integrated soil fertility management (ISFM) do deliver gains, additional measures are required if desired yield increases are to be achieved and losses of nutrients to the environment reduced.

A comparison with the seed industry reveals a stark contrast in development efforts: current R&D spending by the fertilizer industry averages less than 0.2% of sales; companies in the seed industry spend about 9% of their sales on R&D.

In IFDC's view, the scale of the demand for fertilizers in the future now requires a more fundamental response if a new generation of efficient fertilizers are to be developed, in order to minimise the economic and environmental drawbacks of current fertilizers and maximise crop production. This was the reason why the IFDC established the VFRC in 2012 – to bring research institutions around the world together and advance unified research for developing new fertilizers.

Enhanced efficiency

Research on developing enhanced efficiency fertilizers in recent years has led to the development of coated, slow-release N fertilizers and inhibitor products that delay the action of biochemical processes. The very latest polymer-coated products can deliver 10% yield increases compared with conventional fertilizers. Similar to urease and nitrification inhibitors, the neem tree (indigenous to many tropical and semi-arid countries) also provides a coating material to improve N use efficiency. The use of neem-coated urea (NCU) In India can result in 2-10% higher rice yields. The government of India has recognised the benefits and in January 2015 directed domestic urea manufacturers to convert 100% of their installed capacity to produce NCU.

Phosphate is a finite resource, and negative environmental impacts (particularly in freshwater and coastal marine ecosystems) are becoming an increasing concern globally. Researchers have been able to recover P from waste streams as struvite. Initiatives to develop pathways to manage P sustainably include improving the efficiency of mining, beneficiation, conversion to fertilizers and recycling from waste streams.

Urea is the prime N fertilizer for rice cultivation but is prone to high losses (as much as 70%) under broadcasting applications. However, if urea is instead point-placed below the soil surface near the root zone of the rice plant, the N losses are lowered while yields increase. This application method was originally used by Japanese rice farmers who encapsulated prilled urea in a handful of mud, placing it below the soil surface. Today, the urea is compacted in the shape of a briquette (1-3g) and inserted below the soil surface (7-10cm) at equally-spaced intervals during the growing season. This technology is known as urea deep placement (UDP). Results show a consistent increase in yield compared with broadcasting, and a significant reduction in N concentration in floodwater and NOx emissions under certain conditions.

UDP has been widely adopted in Bangladesh, leading to a typical average rice yield increase of 15% while applying 35% less urea. This resulted in increased income of $150/ha. About 2 million famers have adopted the technology to date. UDP briquettes are produced by compacting commercial fertilizers in small briquetting machines, ranging in capacity from 250kg/hour to 450kg/hour. The manufacturing process is relatively simple and the design continues to be refined to reduce labour intensity. UDP technology is also being promoted elsewhere in Asia and sub-Saharan Africa.

Micronutrients

Micronutrient deficiency in soils is becoming more widespread and is affecting plant growth and yields, even when N, P and K are amply available. The deficiencies are most marked for zinc and copper. Micronutrient-fortified bulk blended fertilizers are currently being marketed. Field tests are also being carried out on an innovative micronutrient-containing fertilizer based on seed core technology. This involves coating a 1-2mm diameter granule, containing the desired concentration of micronutrients, with urea. Each granule contains a precisely measured quantity of micronutrients. Dr Roy also highlighted the success of zinc-fortified fertilizers in Turkey – a market which has doubled in a decade to around 680,000 tonnes by 2014.

With China announcing that it will target zero fertilizer growth by 2020, in an effort to reduce wasted resources and air and water pollution, there is added urgency for more efficient fertilizer products. New products are being developed and sold, but mainly in the developed economies for high-value crops. These new products are based primarily on existing knowledge of systems and chemistry. Harnessing knowledge of plant physiology, however, will be particularly important to developing the new generation of fertilizers. Properly understanding plant mineral nutrient uptake, translocation and metabolism will be essential for matching plant needs with the composition, amount and timing of nutrient release.

Nanotechnology could also be harnessed to supply fertilizers in nanoparticle form. Likewise, ecological processes, including interactions and symbioses with microorganisms, could be exploited for efficient nutrient delivery and uptake.

Finally, it is going to be important to look beyond agriculture and related sectors to other industries such as the pharmaceutical sector, in Dr Roy's view. To be truly transformative, joint public-private endeavours will also be necessary. "Revolutionising global food production with this new era of volume to value will only prevail when everyone is fully engaged and supported," Dr Roy concluded. ■

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Asian companies and investors are moving into the Russian fertilizer industry, and being warmly welcomed, reports **Eugene Gerden**.

Investors rushing to Russia

PHOTO: PUNKNE

Lena Pillars, a geological formation located on the banks of the Lena River in Yakutia, approximately 104 km from the town of Pokrovsky.

Russian state corporation Rostec and India's Global Steel Holdings Ltd have unveiled a joint plan to bring large-scale fertilizer production to Russia's Sakha (Yakutia) Republic in eastern Siberia. Rostec is participating through its subsidiary RT Global Resources.

The new plant will be built in Nizhny Bestyakh on the east bank of the Lena River and will specialize in the production of nitrogen fertilizers from natural gas, according to Andrey Panov, head of Yakutia's Trade and Industry Ministry. India and China look be the main markets for the plant's output. The two project partners believe that steadily growing demand for natural fertilizers in both emerging and developed countries will also help secure sales.

The plan to set up fertilizer production in Russia was also confirmed by Ashok Kumar Sinha, CEO of Global Steel Holdings, during his recent meeting with Paul Marinychev, First Deputy Prime Minister of the government of Yakutia. Kumar Sinha says the new plant will focus on ammonia and urea production and will have a two million t/a capacity for each.

The plant will be commissioned in 2018-2019 if all goes according to plan. In addition to the fertilizer plant, Andrey Panov signalled that the project may also involve the construction of methanol production plant and a river port to supply fertilizer to both the domestic market and China. The government of Yakutia has promised investors that it will supply the new plant with water, electricity and gas. The proposed plant will consume about 2.2 million cubic metres of natural gas a day and is likely to create more than 500 new jobs.

The new project meets the objectives of a newly-adopted Russian government strategy to boost domestic fertilizer production and target exports at China, India and other Asian countries. But the planned building of the Nizhny Bestyakh plant has already sparked fierce criticism from local protestors concerned that implementation of the project may damage the region's ecology and pollute the Lena river, the most easterly of three large Siberian rivers that flow into the Arctic Ocean. They have called on investors and the Yakutia government to conduct an independent assessment of the impacts of the project on the local environment. The protesters want the plant moved 50-70 km away from the Lena river, if possible.

Indian investors target potash

The proposed Nizhny Bestyakh plant is not the only example of Indian investor interest in the Russian fertilizer industry. In recent weeks, a consortium of five Indian chemical producers, headed by the National Mines Development Corporation (NMDC), has announced plans to acquire a 30% stake in the Verkhnekamsk Potash Company (VPC) controlled by Russian fertilizer company Acron. Other Indian investors in what could be an INR10 billion ($163 million) deal include Rashtriya Chemicals and Fertilizers, National Fertilizers Ltd, Fertilizers and Chemicals Travancore Ltd and Kribhco.

Both sides have so far signed a Memorandum of Understanding, although a final deal is expected to be signed later this year after the completion of due diligence. The conclusion of a successful deal would help Acron finance its Verkhnekamsk potash project and see it launched in 2019, according to Acron's chairman, Alexander Popov. The venture will eventually require a total investment of around S$2 billion. With potash reserves of almost 710 million tonnes, the project is due to be commissioned in 2021 and is forecast to reach its full 2 million t/a design capacity by the middle of 2023.

Analysts at the Russian Ministry of Industry and Trade see Indian investment in the Russian fertilizer industry as a perfectly logical step, given the ever growing consumption of fertilizers on the Indian market, particularly potash. India remains the world's second largest consumer of potash and Uralkali, Russia's only producer of potash currently, provides about 25% of India's needs. The company has supplied 800,000 tonnes of potash to India this year at a price of $322/t.

An official Russian Ministry of Industry and Trade spokesperson also highlighted the interest shown by Chinese and South Korean companies in setting up new fertilizer production plants in Russia. Interest has been led by the China National Chemical Engineering Co Ltd, a Chinese state-owned construction and engineering firm.

Far east of Russia to benefit

The centre of gravity of Russia's fertilizer industry is expected to shift to the country's far eastern region over the next few years, if Russian government plans come to fruition. In addition to the proposed Yakutia Republic plant, another new large-scale urea production plant is planned for the port of Nakhodka in Primorsky Krai, a city located on the Trudny Peninsula in the Sea of Japan.

National Chemical Group (NChG), one of Russia's largest fertilizer and chemical companies, has plans for a nitrogen complex at Nakhodka with 2.1 million t/a of ammonia, 2 million t/a of urea and 1 million t/a of methanol capacity. The plant will have its own water and electricity supply and loading terminal and is expected to create more than 2,000 new jobs. It will be built in stages and could be commissioned as early as 2018.

Much of the proposed plant's production will be exported, mainly to India and other Asian countries, according to Taras Ganges, NChG's technical director. The $6 billion project is expected to be bankrolled by NChG itself and also financed through bank loans.

China National Chemical Engineering Co Ltd has also expressed an interest in building a fertilizer plant in Primorsky Krai, a region bordered by both China and North Korea. Such plans are just the beginning though, according to Maxim Shereikin, Russia's Far East Deputy Minister. He is planning new fertilizer production plants in every large city in this region.

"According to our plans, such plants will be established in all regions of the Russian far east. A preliminary list of such regions must be ready by 1 May 2015. After this, everything will depend on funding. The government, from its side, will try to ensure the establishment of reliable infrastructure for such projects," Shereikin said.

Analysts at Russia's Ministry of Industry and Trade also believe the announcement of another large-scale Russian fertilizer project may be imminent. This is because a group of Chinese investors recently decided not to proceed with the development of a fertilizer production project in Kyrgyzstan, mainly due to a lack of guarantees from the Kyrgyz government. Kyrgyzstan's loss may well be Russia's gain.

The Chinese were backing a $600 million, 320,000 t/a capacity fertilizer plant in Kyrgyzstan, split between 120,000 t/a of urea capacity and 200,000 t/a of ammonium nitrate capacity, to be commissioned within the next four years. It is thought Chinese investors may now decide to relocate the project to Siberia or far eastern Russia instead. ■

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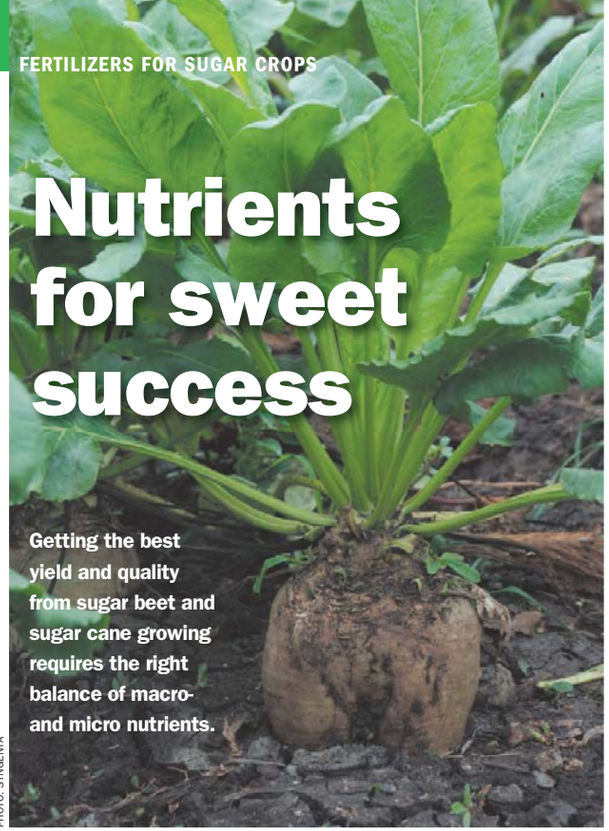
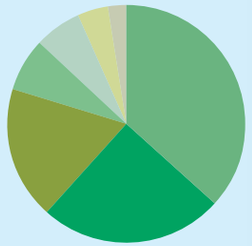


Nutrients for sweet success

Getting the best yield and quality from sugar beet and sugar cane growing requires the right balance of macro- and micro nutrients.

PHOTO: SYNGENTA

Fig 1: **World sugar production by region,** 2011-12



37%	Asia
25%	South America
18%	Europe
7%	Central America
6%	Africa
4%	North America
2%	Oceania

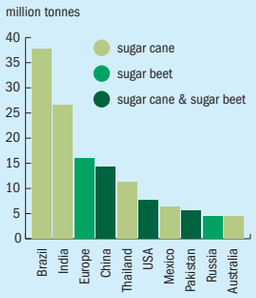
Sugar beet: 40,635,000 tonnes (23%)

Sugar cane: 136,810,000 tonnes (77%)

Total: 177,445,000 tonnes

Source: Bartens/Mosloff (2013)

Fig 2: **Top 10 sugar producing countries and crop,** 2013-14



Source: USDA

Demand for sugar remains strong with the global market continuing to grow at a time when production is falling. USDA predicts that world consumption will hit a record 173.4 million tonnes in 2015/16. This will bring it level with global production which is forecast to decline for the third consecutive year, down from a peak of around 177 million tonnes in 2012 (Figure 1).

Around three quarters of world sugar is derived from sugar cane, the remainder from sugar beet. Sugar cane is cultivated in tropical and sub-tropical countries such as Brazil and India, whereas sugar beet thrives in the temperate climates of North America and Europe (Figure 2).

Temperate sugar beet

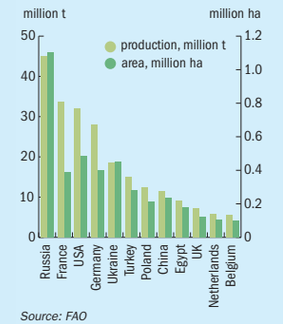
Sugar beet (*Beta vulgaris*) is a biennial broadleaf crop suited to a temperate climate. It is normally spring-planted, propagated from seed and then harvested for its sugar-storing root before the onset of winter. Cultivation is concentrated in Russia, Europe, the US, China and France. Average global crop yield is around 55 t/ha although yields of more than 85 t/ha are achieved in France (Figure 3). Sugar beet production has grown around 1.7 times in the last 50 years while growing area has halved.

Sugar beets grow best at pH 6-8 and do not thrive on acid soils. Cultivation on soils below pH 6 should not be attempted without liming to neutralise the soil first.

Nitrogen, followed by phosphorus and potassium, are the nutrients which most affect sugar beet growth and yield[1]. Nitrogen tends to be most studied nutrient for sugar beet because of its direct relationship to yield and its control on plant productivity[2]. Beets are able to source nitrogen from residual soil content as well as from applied fertilizer and organic matter.

Nitrogen's link to early canopy growth and plant development makes it a particularly important. High beet yields require the rapid development of full leaf canopy that can intercept around 90% of incoming sunlight and maintains its greenness throughout the growing season. The overall goal of nitrogen management is therefore to supply sufficient nitrogen in the early and middle part of the growing season – to ensure optimal sugar beet growth and canopy development – but to exhaust soil nitrogen reserves towards the end of the growing season to optimise crop quality. This is difficult balancing act and application of too little nitrogen is associated with lower root yields, poor leaf canopies and premature yellowing, whereas over-application reduces root sugar concentration and causes excessive leaf growth (Table 4).

Fig 3: **Top 10 sugar beet producing countries and crop area,** 2013-14



Source: FAO

The application of sufficient phosphate to allow uptake of 80kg of P_2O_5 per hectare is said to be adequate for high sugar beet yields. Seedlings lack vigour and grow slowly in the absence of sufficient P and produce small plants susceptible to physical damage[3].

Potassium also greatly improves early vigour and growth and increases sugar yield. The quantity of potassium taken up by sugar beet varies widely, with values ranging between 168-660kg/ha K_2O. This equates to 3.5-8.2kg of K_2O per tonne of sugar beet harvested. Uptake of 400-500 kg/ha K_2O is reported for the UK and France[3]. Potassium is generally concentrated in sugar beet tops which contain 1.7 times more potassium than the roots. Suggested K application rates for a root yield of 60 t/ha are shown in Table 5.

Sugar beet micronutrients

Sugar beet is susceptible to micronutrient deficiency although its response is not uniform. The crop is most responsive to boron, iron and manganese, moderately responsive to copper, molybdenum and zinc and least responsive to chlorine (Table 6). Copper or zinc deficiency is occasionally found but molybdenum deficiency is rare[3]. Boron deficiency affects sugar beet growth and leaf expansion and leads to root deterioration, reducing both yield and quality.

Manufacturers' recommendations for sugar beet

Producing 10 tonnes of sugar per hectare from sugar beet typically requires about 200kg N, 75kg P_2O_5 and 400kg K_2O, suggests Tessenderlo Chemie. Nitrogen demand is highest during the third and fourth months after planting, whilst potash demand is highest between the third and sixth months. Germination damage may occur if seeds and seedlings come into direct contact with excess nitrogen or potassium fertilizer. Other nutrients requirements for sugar beet include calcium (250 kg/ha CaO), magnesium (65 kg/ha MgO) and sulphur (50 kg/ha SO_3).

Haifa Group reports broadly similar sugar beet nutrients uptakes for N (180-220 kg/ha), P_2O_5 (80-100 kg/ha), K_2O (250-350 kg/ha), CaO (80-120 kg/ha), and MgO (40-50 kg/ha). Sugar beet yields

Table 4: **Role of sugar beet nutrients and effects of deficiency**

Element	Role	Effect of deficiency	Made worse by
N	Crop development, root yield, quality	Inhibits growth, smaller plants, leaves pale green then chlorotic yellow	Low or high pH, sandy or light soil, drought, high rainfall or heavy irrigation, un-decomposed organic matter
P	Crop establishment and maturation, early root development, yield	Inhibits growth, stiff appearance, dark green or blue-green leaves, red/violet leaf veins and edges	Acidic or very alkaline (calcareous) soils, cold or wet conditions, poorly developed roots, soils with low P reserves or high P capacity, Fe-rich soils
Mg	Crop establishment, healthy foliage, root yields, sugar content	Intercostal chlorosis spreads from tips and edges of older leaves followed by necrotic spots	Sandy, acidic or potassium-rich soils, high potash application, cold wet periods
S	Crop development, more efficient nitrogen use	Stunted growth, stiff upright appearance, brittle leaves and petioles, inner leaves and then entire foliage turning chlorotic yellow, including veins	Acidic and light, sandy soils, low organic matter, poorly-aerated/waterlogged soils, areas with industrial emissions
B	Root yields, sugar content, reduces heart rot	Small, crinkled, brittle younger leaves later going dark brown and dying, wilting older leaves	Sandy and alkaline soils low in organic matter, high nitrogen or calcium levels, cold wet weather, drought
Cu	Healthy green foliage, root yield and quality	Stunted dark green or purple foliage and possible wilting	Organic, chalky or sandy soils, reclaimed heathland, high nitrogen application
Mn	Healthy foliage, yield, sugar content	Leaves curl upwards, chlorotic blades on younger leaves, upright appearance	Organic or sandy soils, high pH, cold wet weather
Zn	Healthy green foliage. Root yield, quality	Severely stunted growth, chlorosis on large leaves near plant centre, small yellow or white spots on upper sides of leaves, dry and necrotic intercostal area	Organic, high pH and phosphorus-rich soils, high phosphorus applications, cold wet weather

Source: Yara

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Table 5: **Potassium fertilizer recommendations for sugar beet**

Soil K (mg/l)	0-60	61-120	121-180	181-240	241+
Category	deficient	low	moderate	high	
Advised application					
UK (kg/ha K_2O)	150	125	100	75	0
US (kg/ha K_2O)	166-285	50-151	0-65	0-31	0

Source: Draycott (2006)

Table 6: **Average micronutrient content of healthy sugar beet plants**

Element	Tops content (mg/kg)	Roots content (mg/kg)
Boron	335	40
Chlorine	19,000	2,000
Copper	44	7
Iron	1,900	200
Manganese	50	30
Molybdenum	7	5
Zinc	20	10

Source: Draycott (2006)

of 40-50 t/ha are typically expected from a planting density of 140,000-180,000 plants per hectare in open fields on a sandy loam soil.

Haifa publishes sugar beet fertilizer recommendations for various application methods including base dressing, fertigation and foliar feeding. A base dressing (40 kg/ha N, 100 kg/ha P_2O_5 and 150 kg/ha K_2O) should be applied in the month prior to sowing and worked into soil by shallow disking. The application of DAP fertilizer (220 kg/ha) and SOP (300 kg/ha) as a base dressing is recommended.

Foliar feeding with micronutrient-enriched potassium nitrate (*Multi-K ME* with Mn, B, Fe, Zn, Mg, Mo) is advised by Haifa if plants show signs of micronutrient deficiency. A 3-4% concentration is recommended at the eighth leaf growth stage at a spray volume of 800-1,000 l/ha. A stronger 4-6% concentration, at a lower spray volume of 500-800 l/ha, is suggested at the sixteenth leaf stage. For fertigation, Haifa recommends applying AN, MAP and potassium nitrate (*Multi-K*) at different junctures during the growing period (Table 7).

Yara recommends use of NPK fertilizers during seed drilling, either *YaraMila COMPLEX* or *YaraMila SUPERBEET*, and the application of granular AN (*YaraBela EXTRAN*) or a compound nitrogen-sulphur fertilizer (*YaraBela AXAN*) during plant emergence. Foliar application of micronutrient fertilizers, such as *YaraVita BEETRAC* and *YaraVita MANTRAC PRO*, is advised later in the growing season.

Sugar beet is known to be tolerant to chloride and salt. But, according to Tessenderlo, high MOP application may have a detrimental cumulative effect on yield in certain soils due to chloride accumulation, leading to a poor response at higher potash doses. The best sugar beet yields are achieved under semi-arid conditions, such as those prevailing in North Africa and the Middle East, when there is no increase in soil salinity. Trials in Egypt suggest that substitution of SOP for MOP is an effective way of safeguarding sugar beet yield and improving production in semi-arid areas.

Foliar application of Tessenderlo's *K-Leaf* water-soluble SOP is also reported to be quicker and more efficient way of correcting potassium deficiency than applying SOP to soil. The critical stage for potassium application is 50 to 100 days after sowing and field trials in France suggest that spraying three to four applications of *K-Leaf* at a 4% concentration to supply 15-20 kg/ha K_2O provides the best economic results.

Table 7: **Fertigation recommendations for sugar beet**

	Recommended fertilizer application (kg/ha/day)			Equivalent nutrients (kg/ha/day)		
	MAP	AN	KNO_3*	N	P_2O_5	K_2O
N-P-K (%)	12-61-0	33.5-0-0	13-0-46	-	-	-
Days after sowing						
1-30	1	0	0	0.12	0.6	0
31-60	0	8	2.2	3	0	1
61-90	0	7.2	4.4	3	0	2
91-120	0	0	4.4	0	0	2

**Haifa Multi-K* *Source: Haifa*

Sugar cane predominates

Sugar cane (*Saccharum* spp.) is widely grown by Asian smallholder farmers but the majority of production comes from large farms and plantations in Brazil and elsewhere (Figure 4). Sugar cane area and yield increased globally by 1.3% and 0.8% per annum, respectively, between 1991 and 2010. Brazil dominates the world sugar cane market and production is partly supported by policies promoting ethanol production. Egypt has an ideal high-radiation climate for sugar cane and produces a yield of 118 t/ha from a 135,000ha growing area.

Sugar content of fresh cane ranges from 7-10% in South Asia to 11% in Thailand and 13-14% in Brazil and Australia. Sugar yields vary with crop variety, growing environment, harvesting and processing methods.

At least 13 nutrients are considered to be essential for good sugarcane growth and the plant's reproductive cycle. These include primary macronutrients, nitrogen, phosphorus and potassium, and secondary macronutrients, calcium, magnesium and sulphur[4]. The micronutrients zinc, copper, iron, manganese, boron, chlorine and molybdenum are also essential for sugar cane growth. Sugar cane is also a large accumulator of the "beneficial nutrient" silicon.

The uptake and removal of N and K by sugar cane during growing is particularly rapid, averaging 1.16 and 2.00 kg/t (Table 8). Sugar cane grown by irrigation in a high-temperature climate will generally remove more soil nutrients than rainfed sugar cane grown in cooler regions.

Nitrogen is essential for photosynthesis and sucrose production, and sugar cane has the ability to store more N than is necessary for vegetative growth. Ensuring the correct timing and placement of N is critical. Sugar cane is also notoriously

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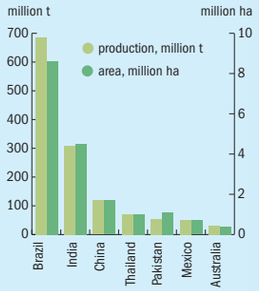
Harvesting sugar cane in South Florida.

PHOTO: ARS

Fig 4: **Sugar cane growing by country**



Source: FAO (2013)

inefficient at recovering applied N, with efficiencies of 6-45% being typical. Nitrogen deficiency reduces yield and sugar content and stunts growth. Deficiency is indicated by slender stalks, light green or yellow leaves and necrosis on the tips and edges of older leaves. Too much nitrogen, in contrast, delays maturity, reduces sugar levels and increases the risk of fungal disease.

Recommendations for nitrogen depend on the soils ability to mineralise N and its organic matter content. The nitrogen requirement of plant cane and ratoons (shoots) also differ with the later requiring around 40 kg/ha more N on average. The N required by irrigated cane is also typically higher than for rain-fed cane due to the higher yields obtained.

Urea is probably the most common nitrogen fertilizer used by the sugar industry globally, although CAN use is also widespread. Highly-soluble carriers such as potassium nitrate are favoured in fertigation.

In South Africa, the highest N recommendation (140 kg/ha) are for dryland sugar cane grown in soils with low organic matter (<2%) falling to a 100 kg/ha for high organic matter soils (>4%). Similar recommendations apply to Australian dryland sugar cane growing. Here, 80-100 kg/ha N is recommended for cane growing on soils with more than 2.4 % organic matter, rising to 140-160 kg/ha N for soils with less than 0.4 % organic matter. In India, application rates range from 0-50 kg/ha N in Bihar, to 250-300 kg/ha N in Karnataka and Maharashtra, to over 350 kg/ha N in the south-east coastal area of Tamil Nadu.

Phosphorus promotes root development and is particularly important for enhancing sugar cane yields in highly-weathered acid soils. Various NPK products, such as superphosphate (SSP, DSP or TSP) or MAP or DAP, are generally applied in the furrow at planting to ensure healthy roots develop on newly-established cane. The risk of P deficiency is especially high for the red oxisols common throughout tropical and sub-tropical producing areas. Poor stunted roots, thin stalks and thin, narrow, short leaves (bronze, blue-green or purple in colour) are all typical signs of P deficiency. Phosphate fertilizer recommendations for different countries are generally based on the addition needed to bring soil P content above a critical threshold (Table 9).

Potassium is essential for cane growth and maintains photosynthesis by preventing chlorophyll degradation. It also plays a role in regulating plant moisture. The response of sugarcane to applied K, however, is not generally as marked as that of nitrogen. Maximum potassium recommendations vary for Australia (120 kg/ha), South Africa (200 kg/ha), Hawaii (560 kg/ha) Florida (233 kg/ha) and Brazil (116 kg/ha).

The fact that sugarcane is capable of removing sulphur at around 25-40 kg/ha means S is often considered the fourth most important nutrient after N, P and K. Symptoms of S deficiency are similar to those of N deficiency except that they first appear in the top youngest leaves. Signs include light green to yellowish-green leaf colour with purplish margins developing on both sides of the leaf. Maturity is also delayed by S deficiency and plants tend to be small with thin stalks.

Table 8: **Sugar cane: macro- and micronutrient removal from soil**

	Macronutrients (kg/t)					
Country	N	P	K	Mg	Ca	S
Australia	1.3	0.18	2.23	0.22	0.29	0.36
India	1.2	0.20	1.19	-	-	-
Brazil	0.8	0.13	1.10	0.30	0.3	0.25
South Africa	1.35	0.16	3.26	0.39	0.42	-
Hawaii	1.13	0.29	2.22	0.35	0.43	-
Average	1.16	0.19	2.00	0.31	0.36	0.31
	Micronutrients (g/t)					
	Fe	Mn	Zn	Cu	B	Mo
Australia	78	42	4.95	0.75	-	-
Brazil	31	11	4.5	2.0	2.0	0.01
South Africa	-	11	2.5	0.5	1.2	-

Source: IFC (2011)

Manufacturers' recommendations for sugar cane

Sugar cane is suited to various soil types but grows best in a well-drained soil with a pH of around six, according to Tessenderlo, who suggest a standard fertilizer application of 100-159 kg/ha N, 50-60 kg/ha P_2O_5 and 120-200 kg/ha K_2O.

Haifa suggests that sugar cane yields of 200-300 t/ha can be expected from the harvesting of 90,000-150,000 stalks per hectare on a medium-to-heavy soil at an optimum pH of 5.0 to 8.5. It recommends nutrient application rates of 45-90 kg/ha N, 60-120 kg/ha P_2O_5 and 60-120 kg/ha K_2O for Brazilian sugar cane cultivation (Sao Paulo). Much higher N rates (200-300 kg/ha) and slightly increased K rates (80-150 kg/ha) are advised for the Indian tropics.

Haifa recommends application of fertilizer to sugar cane as both a base and side dressing (Table 10). Nitrogen applications are designed to supply one kilogram of N per tonne of plant cane and 1.25-1.50 kg/t for ratoon cane. Nitrogen is applied during the early stages of growth. For a 12 month crop, a small amount is applied as a base dressing with the remainder added as a side dressing in three or four applications within 3-4 months of planting. As a general rule, N application is completed at least five months before harvesting.

Potassium is applied as single base dressing in heavy soils. However, in lighter soils half the recommended amount of K is applied as base dressing and the rest then applied six months later. Haifa advises that soil analyses are used to determine the application of phosphate.

Potassium is essential for sugar cane metabolism and an important influence on yield, mainly due to the dependency of sugar synthesis on both K and N, according to Tessenderlo. In Egyptian irrigation trials, sugar yield improved by several tonnes per hectare in response to K additions.

Although MOP is widely used as a K source in sugar cane cultivation, Tessenderlo advise that SOP is used in fertigation or where these is a risk of salinity. Tessenderlo also stress the importance of SOP as source of sulphur, suggesting that a lack of this nutrient may cut the production of sucrose by a half.

Industrial sugar cane plantations are increasingly switching from pivot or sprinkler irrigation to sub-soil drip irrigation systems. The use of soluble SOP products, such as Tessenderlo's *SoluPotasse*, are useful as they allow potassium applications to be split during fertigation.

Fertigation offers a number of distinct advantages over conventional methods. Plant nutrients are more evenly distributed over the whole of the root zone, increasing nutrient availability and uptake. This, in turn, contributes to higher crop growth rates and cane yields. Fertigation also allows the supply of nutrients to be adjusted over the growing season so they match nutritional requirements during the different stages of plant development (Table 11). Nutrient losses to weeds, leaching and runoff are also minimised.

Beet versus cane

Despite a strong European and North American presence, and the yield improvements achieved in recent decades, there are question marks about the future of sugar beet as a large-scale sugar crop, particularly if the long-term decline in cultivation continues. Sugar beet's global harvested area contracted by 5.2% per annum between 1991 and 2010 and the crop faces stiff competition from both sugar cane and maize-derived fructose. Land management issues for sugar beet, such as the need to plant a fine seedbed and dig to harvest roots, also place it at a relative disadvantage – although zero-till practices for beet do show promise. However, the widespread use of hybrid varieties and monogerm seeds has helped sugar beet maintain its competitiveness. But the future of beet as a sugar crop may require the adoption of other new technologies, such as the glyphosate-tolerant, genetically-engineered sugar beet being championed in North America. ■

Table 9: **Phosphate recommendations for sugar cane**

	Australia	South Africa	Florida	Brazil
Soil P threshold (mg/kg)	10-20	11-31	<14	<5
Plant cane (P, kg/ha)	20-80	0-60	0-40	0-50
Ratoon cane (P, kg/ha)	0-80	0-50	0-40	0-30

Source: IFC (2011)

Table 10: **Fertilizer recommendations for sugar cane**

Recommended fertilizers (kg/ha)			**Nutrient demand (kg/ha)**		
Base dressing					
SOP	MAP	AN	N	P_2O_5	K_2O
100-200	100-200	-	12-24	60-120	50-100
Side dressing					
KNO_3*	MAP	AN	N	P_2O_5	K_2O
110-220	-	500-730	188-276	-	50-100

**Haifa Multi-K* *Source: Haifa*

Table 11: **Guideline fertigation schedule for 12 month sugar cane crop**

Days after planting	**Nutrients (kg/ha/day)**		
	N	**P_2O_5**	**K_2O**
1-30	1.20	0.10	0.20
31-80	1.50	0.40	0.24
81-110	2.00	1.00	0.40
111-150	0.75	0.30	0.75
151-190	0	0	1.50

Source: Netafim

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Change looms for niche nitrates

The arrival of new US urea ammonium nitrate (UAN) capacity is poised to disrupt the nitrates market, as Integer Research's lead nitrogen analyst, **Laura Cross** explains.

The 20 million tonnes of nitrogen sold as ammonium nitrate (AN), calcium ammonium nitrate (CAN) and urea ammonium nitrate (UAN) represents almost 15% of the global nitrogen market.

The niche nitrates sector displays a number of distinct differences compared to the urea-dominated mainstream nitrogen market. While the global market for urea has grown robustly by 2-3% annually in recent years, in both fertilizer and non-fertilizer segments, much of the growth in nitrates over the last decade has been driven by demand for industrial explosives.

Fertilizer demand for nitrates, in contrast, has been comparatively static, particularly for straight (non-mixed) products. Geographical patterns of consumption are also highly varied. Nitrate fertilizers are mostly consumed in Europe, the CIS countries and – primarily as the mixed product UAN – in the US. Most urea fertilizer consumption, in contrast, takes place in Asia and Latin America.

> **A significant disruptive change in the nitrates market looks imminent.**

In many markets, urea and nitrates compete head-to-head for market share, with both producers and consumers substituting and switching between the two – according to availability and relative pricing. A significant disruptive change in the nitrates market looks imminent though.

Over the next few years, Integer Research expects the addition of new, primarily UAN, capacity in North America to displace existing suppliers currently shipping to the US market. The development of new North American capacity could also stimulate greater UAN demand in the US, if prices adjust favourably. The impact of new stateside capacity and other critical market issues are discussed in more detail below.

Predominantly Russian

The three primary nitrates markets have quite different characteristics. Ammonium nitrate, with a global volume of around 16 million tonnes N, has the largest market share and a diverse range of end-uses. Of that total, around 3-4 million tonnes N in nitrate form goes to the production of UAN solution (with an equivalent volume of nitrogen in UAN coming from urea), a further five million tonnes N produces solid fertilizers, with most of the rest going to make explosives.

The CIS, predominantly Russia, is the world's biggest AN producing region. Production of AN in this region has generally been on the increase, boosted both by rising internal demand for fertilizers and the increasing use of AN in UAN production, primarily for export.

Russia is also by far the biggest exporter of AN, making up around 40% of global trade. Imports of AN are widely dispersed, but Latin America makes up around a third of the total. Brazil alone imports around 0.7 million tonnes N as AN each year to supply its expanding agriculture sector. Imports of AN into Brazil have increased almost six-fold during the 2000s.

Many countries, however, have moved to outlaw the use of AN as a fertilizer due to widespread security concerns, and this has either constrained its growth or eliminated its use altogether in many markets. Europe is the logical export destination for Russian AN output but it is deterred by trade defence measures. European AN imports have now settled at around 0.5 million tonnes N following significant declines in the early 2000s.

European CAN do

The market for CAN is comparatively static compared to AN – and even more regional – being dominated by production, consumption and trade within Europe. Volumes have fluctuated relatively little in most European markets in recent times. The exceptions are markets like Hungary where producers have chosen to switch from AN to CAN. This is partly to avoid security concerns but is also a defensive measure as competition from CAN producers outside the region is relatively limited currently. A few producers in Russia and Ukraine have converted some AN capacity to CAN – to diversify and make better use of idle assets – but the effect of this on overall trade has so far been modest.

The market for urea ammonium nitrate (UAN) solution is reasonably dynamic with consumption even more localised. With a two thirds global market share, the six million tonnes N consumed as UAN in the US (about half of which is in nitrate form) make it by far the biggest world market for this mixed product. To some extent, UAN in the US competes for market share with direct application ammonia and urea fertilizer use, especially for broad acre crops. In Europe, there is also sizeable and stable demand for UAN in France and Germany. Markets such as Hungary and Poland are also growing strongly, albeit from a small base, as local producers have sought to diversify their nitrogen product mix.

Europe and the US dominate UAN supply currently. US production is led by CF Industries and meets the majority of domestic requirements, the remainder being topped up by imports from Russia and Europe. Eurochem and Acron are leading exporters and have both ramped up production of UAN in the last 10 years. China is the new kid on the block, having entered

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the merchant UAN market in the last couple of years with shipments to the US and Australia. Chinese UAN exports are essentially opportunist, the aim being to find alternative products and markets for the country's sizeable nitrogen supply overhang. The fact that the solid AN market in China is strictly controlled due to security concerns provides yet another reason to export.

Following urea on price

As substitutes, nitrates prices generally track those of urea. Both nitrates and urea have experienced cyclical and energy price related changes in the years since the 2008 spike (Figure 1). The global nitrogen supply surplus has dominated general nitrogen pricing in the last 24 months and set the price floor for urea at around $270-300/t (f.o.b. Black Sea), with occasional flutters below and above.

Prices do diverge regionally from international benchmarks. Regional prices typically reflect the degree to which products are supplied locally or as imports burdened by long-distance transportation and logistics costs. The European 'nitrates premium' has also become a key point to watch, particularly for big nitrates suppliers like Yara. The European premium is due to many factors, including duty protection, but also reflects the superior agronomic efficiency of nitrates over urea, and the successful marketing of this advantage by suppliers.

Market flux looms

Looking ahead, the market looks set to enter a period of significant flux with major changes to volumes and prices looming on the horizon, largely triggered by new developments in North America.

Although there has been relatively limited nitrates capacity development in the last 10 to 15 years –this is now set to change. The start-up of several new UAN capacity projects in the US over the next 12-24 months will result in the displacement of most (if not all) of the country's UAN imports. In fact, the US is likely to become a seasonal UAN exporter as new capacity is commissioned. This emergence of extra domestic UAN volume will intensify competition for the US market, and may also shake up prices for straight nitrogen products in the US Midwest and other key US regional markets.

This development will pose a major challenge for producers currently shipping UAN to the US, particularly Russian manufacturers who are facing a similar, simultaneous challenge from the Chinese in UAN import markets like Australia. So where will Russian producers turn? The weak rouble means Russian nitrogen production costs are in the lowest quartile and will remain cost competitive. The real problem is the limited alternative markets for UAN outside Europe, where duties are a continuing constraint. Switching production away from UAN and back to solid urea and/or AN is one avenue for producers with this ability, but in a static AN market this option is also limited.

The market will need to adapt to accommodate rising UAN production in the US, although the space left by the collapsing Ukrainian nitrogen industry may provide partial, temporary respite. However, the nitrates market is certain to be much more dynamic and volatile over the next few years than in the recent past. This fluctuating market will inevitably put nitrates under the spotlight and give the sector a much higher profile.

Integer is developing a service to integrate analysis of all nitrogen products and the substitution effects which link them together – which we believe is groundbreaking and the first of its kind. This will provide better insights and provide more robust forecasts and analysis of each product market.

Mega UAN projects

Around 15 AN, CAN and UAN projects are currently in the pipeline globally (Table 1). ThyssenKrupp Industrial Solutions is either the contractor, licensor or both for nine of these projects (Figure 2). Three very large-scale UAN projects are set to add nearly 13,000 t/d of UAN capacity to US production.

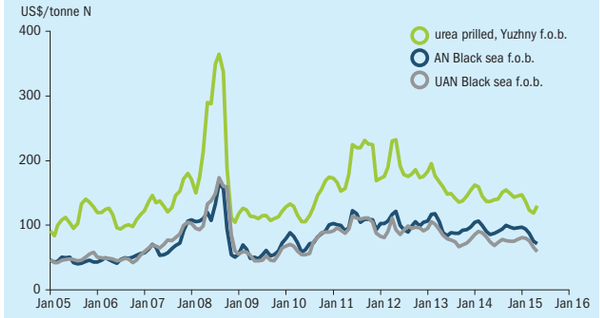
ThyssenKrupp is providing engineering and procurement (EP) services and plant licenses for two of these US projects. IFCo's (Orascom Construction Industries, OCI) nitric acid, AN neutralisation and UAN production complex at Wever, Iowa, is one of these. CF Industries' ammonia, nitric acid, AN neutralisation and UAN complex at Donaldsonville, Louisiana, is the other.

These two 4,300 t/d UAN projects are currently under construction and due to be commissioned this year. Both projects are based on the *Uhde Mega UAN Concept* used previously in AUM's 2010 Point Lisas UAN plant in Trinidad. The 3,395 t/d Grodno Azot plant currently being built in Belarus is ThyssenKrupp's other current *Uhde Mega UAN Concept* project.

A complete UAN complex consists of an ammonia plant, a urea synthesis plant, a nitric acid plant and an ammonium nitrate neutralisation plant with a UAN mixing unit. CF Industries' Donaldsonville complex, for example, incorporates separate trains for ammonia (3,300 t/d), urea synthesis (Stamicarbon license, 3,500 t/d), urea granulation (UFT license, 3,500 t/d) and nitric acid (dual pressure with *EnviNOx* tailgas treatment, 1,520 t/d).

Uhde Vacuum Neutralisation and UAN mixing is the central process in both *Uhde Mega UAN Concept* plants in the US (Figure 3). *Uhde Vacuum Neutralisation* offers a number of technological and cost advantages. The process is simple to operate, start-up and shut down, as well as being

Fig 1: **Urea nitrates price developments**



Source: ICIS, Integer

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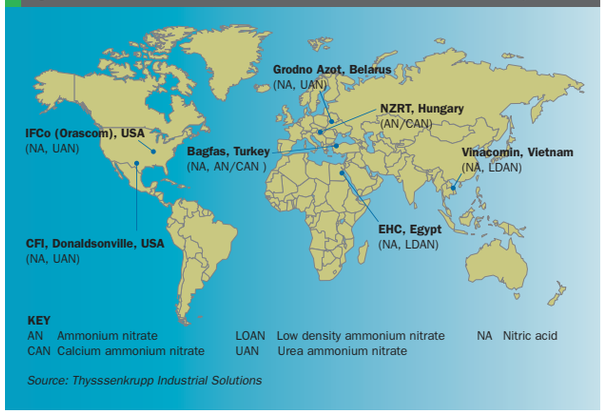
Table 1: **Nitrate project listing**

Contractor	Licensor	Company	Location	Type	Capacity (t/d)	Status	Date
N/A	N/A	Incitec Pivot	Kooragang Island, Australia	AN	1,000	P	2017
Tecnicas Reunidas	Espindesa	Yara Pilbara Nitrates	Burrup, Australia	AN	965	C	2015
ThyssenKrupp I.S.	ThyssenKrupp I.S.	Grodno Azot	Grodno, Belarus	AN	3,395	UC	2016
ThyssenKrupp I.S	ThyssenKrupp I.S	EHC	Suez, Egypt	AN	1,050	C	2014
N/A	ThyssenKrupp I.S	Nitrogenmuvek Zrt	Petfurdo, Hungary	AN	1,550	UC	2016
N/A	N/A	Deepak Fertilizers	Paradip, India	AN	1,000	P	2017
Tecnicas Reunidas	Espindesa	Nitratos del Peru	Paracas, Peru	AN	1,060	UC	2015
N/A	NIIK	EuroChem	Novomoskovsk, Russia	UAN	1,200	DE	2015
ThyssenKrupp I.S	ThyssenKrupp I.S	Bagfas	Bandima, Turkey	AN	1,550	UC	2015
ThyssenKrupp I.S	ThyssenKrupp I.S	Bagfas	Bandima, Turkey	CAN	2,000	UC	2015
ThyssenKrupp I.S	ThyssenKrupp I.S	CF Industries	Donaldsonville, LA, USA	UAN	4,300	UC	2015
OCI Construction	ThyssenKrupp I.S	OCI Nitrogen	Wever, IA, USA	AN	1,900	UC	2015
OCI Construction	ThyssenKrupp I.S	OCI Nitrogen	Wever, IA, USA	UAN	4,300	UC	2015
Tecnimont	Stamicarbon	Midwest Fertilizer Co.	Mt Vernon, IN, USA	UAN	4,300	CA	2017
TEC, ThyssenKrupp I.S	ThyssenKrupp I.S	Vinacomin	Thai Binh, Vietnam	AN	625	UC	2015

KEY:
N/A: Not Available *C: Completed / Commissioning* *CA: Contract Awarded* *DE: Design Engineering* *P: Planned* *UC: Under Construction*

Fig 2: **Selected Thyssenkrupp Industrial Solutions AN, CAN and UAN projects**



Source: Thysssenkrupp Industrial Solutions

relatively inexpensive to maintain. The fact that no exotic materials are necessary also keeps the investment cost low.

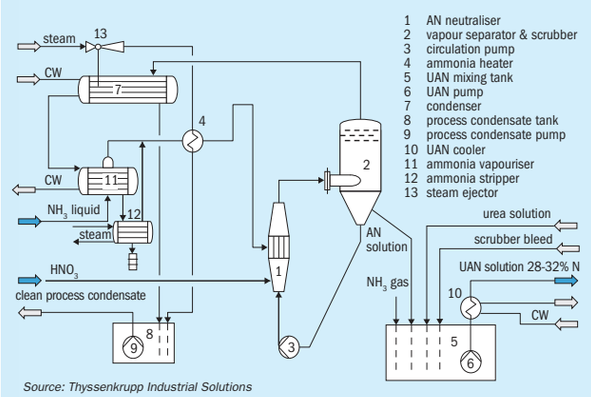
Uhde Vacuum Neutralisation generates process vapours which are free from surplus ammonia. Total condensation of these allows the UAN plant to produce an extremely clean condensate (<15 ppm N) and operate without any gaseous emissions. The vacuum separation stage is able to deliver a high AN concentration solution (maximum of 93% by weight) at low temperature (around 110°C). A forced circulation system stops vapour bubbles from forming, so preventing ammonia losses.

The *Uhde Vacuum Neutralisation* process is also flexible. Ammonium nitrate concentrations can be easily adjusted through regulation of vacuum pressure and temperature. The process can also be tailored to different urea solution concentrations and deal with different acidic scrubber bleed flows and compositions. Importantly, the technology can make it possible for nitrogen complexes to operate on a 'zero liquid effluent' basis. Excess condensate from the process can be used as make-up water and fed to the nitric acid absorption tower or the urea granulation scrubber, for example.

In addition to the two ThyssenKrupp projects, Midwest Fertilizer Corporation (MFC) are also proposing to build a third major UAN plant in the US at Mt Vernon, Posey County, Indiana. Last July, Maire Tecnimont SpA signed a memorandum of understanding (MoU) with MFC and Pakistan investors Fatima Group Principals (FGP), firming up moves to develop a large greenfield nitrogen complex at the site.

The Mt Vernon project consist of an ammonia plant (2,200 t/d), urea synthesis plant (2,200 t/d), urea granulation plant (1,200 t/d), UAN plant (4,300 t/d) and diesel exhaust fluid (DEF) plant (900 t/d). Last July's MoU named KBR as proposed licensor of the ammonia plant and Stamicarbon as the licensor for the remaining plants – including that for UAN production. But this agreement is provisional and the project's final licensors and contractors have yet to be named. Financial close was expected last September and FGP has already secured $1.3 billion of finance for the $1.6 billion project under the United States Midwest Disaster Relief Program. The project is expected to take three years to complete once notice to proceed is given.

Fig 3: **Uhde vacuum neutralisation technology used for UAN production**



Source: Thyssenkrupp Industrial Solutions

Flexible or lean

Stamicarbon's track record in UAN production stretches back to the licensing of its first US plant in 1965 a plant that remains in operation today. Its current UAN technology, which complies with the latest European Fertilizer Manufacturing Association (EFMA) recommendations, is available in two variants:

- **Flexible multi-fertilizer technology**, suitable for the production of both liquid UAN and solid urea fertilizers
- **Lean design for liquid urea technology**, suitable for dedicated UAN and diesel exhaust fluid (DEF) production

Both these designs incorporate proven, reliable pool condensation technology, and consequently benefit from low operational expenditure, ease of operation and infrequent downtime.

The low capital expenditure requirements of the lean design option make it an attractive choice. The urea melt plant consists of just nine items of equipment with only two of these, the pool reactor and stripper, operating at high pressure. The process characteristics of the lean design option also confer additional advantages. For example, all the off-gasses (ammonia) from urea synthesis can supply the feedstock for neutralisation. This avoids the need for a recirculation, evaporation, and desorber/hydrolyser section, significantly reducing plant complexity. The lean design route also maximises plant efficiency and effectiveness by making it possible to integrate DEF and UAN production.

The main advantage of the multi-fertiliser design option is its high efficiency and flexibility. The product mix from a multi-fertiliser plant can be altered throughout the year, allowing UAN, solid granular urea and DEF production to be tailored to meet seasonal demand. The multi-fertilizer design and lean design options do have a number of common features though. Both designs use the same AN section, for example, and the multi-fertilizer design also uses virgin ammonia vapour, from the urea or ammonia plant, as feedstock for the neutraliser.

One interesting technological development in the UAN sector is Stamicarbon's new corrosion inhibitor, *ADVANCE® PROTECT UAN*. This innovative product can be added to UAN solutions as a preventative measure to counteract its corrosive nature. The film-forming polymer present in *ADVANCE® PROTECT UAN* protects carbon-steel surfaces which come into prolonged contact with UAN, such as those found in storage facilities and agricultural machinery. The proprietary product inhibits UAN corrosion by over 99%, according to Stamicarbon. *ADVANCE® PROTECT UAN* is also said to be non-toxic, non-polluting, and biodegradable, and its low foaming characteristics make it suitable for barge, railway and truck distribution. ■

Additional reporting by Simon Inglethorpe.

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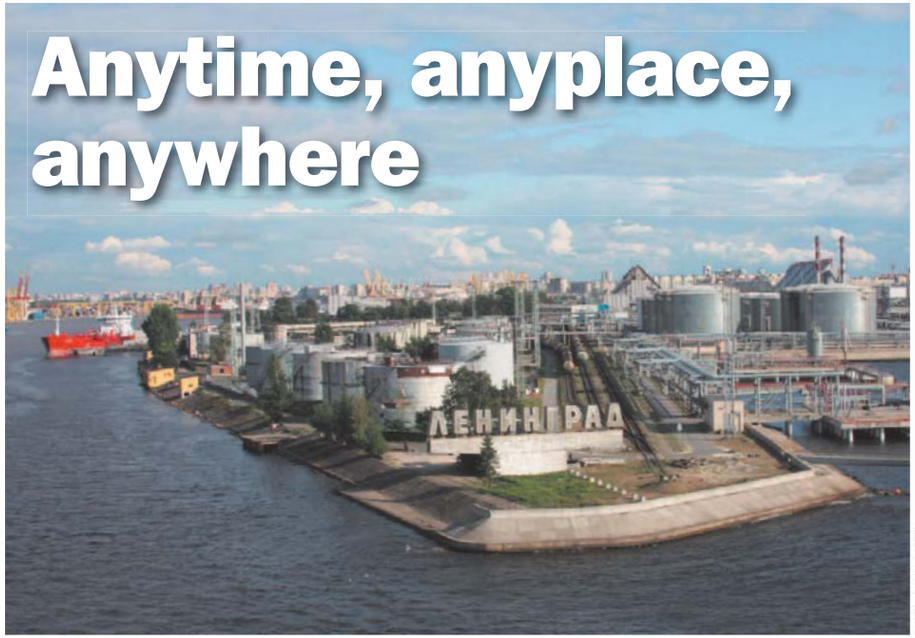

PHOTO: BIN IM GARTEN

We look at recent fertilizer port investments in the Baltic, Brazil and India and some advances in bulk handling equipment.

The port of St Petersburg.

Logistics is one of those specialised parts of a business that are rarely noticed when working well. But for an international industry like fertilizers, whose existence depends on massive global flows of raw materials and finished products, the importance of logistics should never be underestimated.

The role of logistics as a a vital conduit for the supply of fertilizers is particularly important. Keeping customers satisfied requires the delivery of the right fertilizer product in the correct volume, wherever and whenever it is needed. That makes logistics a critical link in the supply chain between those producing and those consuming fertilizers.

The economics of the fertilizer industry relies on access to agricultural markets and rapid, flexible transport and distribution. Getting shipping wrong can be costly and lead to shortages at times of high demand. The import of fertilizers into Brazil, for example, has been hit by severe truck queues and port delays in recent years. This has led to high vessel demurrage rates, estimated at $12,000-15,000 per day.

Baltic gateway

Fertilizers are an important cargo for the Eastern Baltic sea ports, accounting for 7% of total cargo handling in 2013. These ports are a major shipment route for exports from Russian producers such as EuroChem, PhosAgro, UralChem and Uralkali, and the Belarusian producers Belaruskali and Grodno Azot. The largest fertilizer terminals in the region are in Riga (Riga fertilizer terminal, Alpha Osta), Ventspils (Kalija Parks), Tallinn (DBT) and Klaipeda (KLASCO fertilizer terminal, BEGA fertilizer terminal).

The Lithuanian port of Klaipeda, with a two fifths market share, is the Baltic's main fertilizer hub and exported 8.57 million tonnes in 2013 (Table 1). The port relies on fertilizer cargo for almost 30% of its turnover.

Belaruskali is particularly dependent on Klaipeda. Over 95% of the company's seaborne exports, including 6 million tonnes of MOP, exited via the port in 2013. KLASCO and BKT fertilizer terminals in Klaipeda each export around three million tonnes of Belaruskali fertilizer annually. Klaipeda's five million tonne capacity BEGA terminal, in contrast, exports fertilizers for the Belarusian producer Grodno Azot. EuroChem also holds export capacity at Klaipeda for 3.5 million tonnes of bulk fertilizers, 1 million of phosphate rock, and 0.5 million tonnes of liquid chemicals.

Fertilizer cargo flows through the Baltic ports fell back between 2011 and 2013, although St Petersburg bucked this trend. But volumes recovered in the first four months of 2014 particularly for Ventspils (+115%), St Petersburg (+46%), Riga (+39%) and Klaipeda (+23%), compared to the same period in 2013.

Russia's Baltic fertilizer shipments grew from 11.7 million tonnes to 13.8 million tonnes between 2008 and 2013, with over half of this volume (7.3 million tonnes) being exported from domestic Russian ports particularly the Big Port of St Petersburg (6.0 million tonnes).

Uralkali exported 8 million tonnes of MOP to destinations in Asia, Latin America, Europe, Africa and the United States in 2013. St Petersburg is the firm's main sea port and Uralkali increased shipments through the port's Baltic Bulk Terminal by 1.2 million tonnes in 2013.

The volumes of fertilizer exports exiting through Russian ports compred to ports of other Baltic state ports looks set to change due to recent investments. UralChem's new €60 million, 2 million tonne capacity fertilizer terminal at Riga port opened at the end of 2013. This forms part of Riga port's €1.1 billion development programme and was jointly developed with Riga Commercial Port. Ammonium nitrate exported by UralChem will account for about half of the terminal's capacity. Belaruskali has also acquired a 30% stake in the BKT terminal In Klaipeda, and has plans to build two 40,000 tonne warehouses there as part of its expansion plans.

Fertilizer capacity at the Russian port of Ust-Luga is also increasing massively. PhosAgro opened a new 1.5 million tonne dedicated fertilizer terminal at the port in June. This volume represents about 25% of PhosAgro annual sales. The 'Smart Bulk Terminal' will reload fertilizers from railcars into specialised shipping containers and also provides 80,000 tonnes of fertilizer storage space. The investment is of strategic importance to the company. "Developing our own port terminal capacities enables us to decrease transportation costs and further strengthens PhosAgro's position as the leader on the global cost curve," according to PhosAgro's CEO, Andrey Guryev. Russian container transport company Ultramar also owns a 30% stake in the $12 million terminal.

EuroChem's investment plans for 2012-2017 include the construction of a five million tonnes fertilizer terminal at Ust-Luga at a cost of $229 million. ICT is also reported to be spending $140 million on a new four million tonne general cargo and fertilizer terminal there.

Some analysts predict that the Russian fertilizer exports may be redirected away from Baltic EU member states to domestic ports such as Ust-Luga, in response to rising political tensions between the two blocs.

Destination Brazil

A major destination for fertilizers shipped from sea ports such as those in Baltic will be Brazil. The country's fertilizer imports surged from 16.2 million tonnes in 2010 to 23.6 million tonnes in 2013. Imports supply around three quarters of Brazil's domestic fertilizer consumption with the main port of Paranaguá in the southern state of Paraná bringing in around two-fifths of overseas fertilizer deliveries.

Producers are recognising that securing access to market requires investment in both destination ports as well as the port of embarkation. Uralkali, for example, is investing more than BRL 160 million in a new berth, two new warehouses and an improved cargo handling system for the Ponta do Felix terminal at Antonina port. The investment should double the port's fertilizer unloading capacity from two to four million tonnes annually.

The port of Paranaguá is also preparing for rising fertilizer imports. The addition of a third berth during 2015, dedicated to the unloading of fertilizer cargo, is expected to increase the port's capacity for fertilizers by a half. Four new shiploaders installed at Paranaguá in 2015 will also increase loading capacity by an additional 2,000 tonnes per hour. The maximum size of ships accommodated at the port is also expected to increase from 70,000 to 90,000 tonnes by next June, following a BRL 484 million dredging programme.

Fertlizer company Fospar's terminal at Paranaguá berths seven to ten ships a month, each vessel discharging about 30,000 tonnes of fertilizer. Fospar, which is jointly owned by Mosaic and Fertipar, imported 960,000 tonnes on fertilizer in the first five months of 2014 and was expected to move around two million tonnes of fertilizer through the port by the year's end.

Mosaic invested BRL 14 million in a Terrex-Gottwald gantry cranes in 2014 to increase throughput and discharge capacity through the terminal. This part of a five-year $300 million Mosaic investment in port improvements and renovations at Paranaguá. The 32 metre-long, 33.8 tonne-capacity model 4316B Portal Harbour Crane purchased last year is identi-

Table 1: **Export of mineral fertilizers through top five Eastern Baltic ports**

Port	Fertilizer exports (million tonnes)					
Lithuania	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Klaipeda	7.22	7.05	8.66	11.61	9.73	8.57
Bulk	5.56	5.70	7.48	9.56	7.68	6.90
Liquid	1.30	0.97	0.79	1.59	1.53	1.27
Packed	0.36	0.37	0.39	0.46	0.52	0.41
Russia						
Big Port of St Petersburg	6.20	4.46	6.07	6.04	4.75	6.02
Estonia						
Tallinn	0.62	1.10	1.63	1.82	2.39	1.73
Latvia						
Ventspils	2.67	1.10	2.38	3.30	2.36	1.57
Riga	1.94	1.93	1.37	1.70	1.42	1.41
Eastern Baltic total	**19.68**	**16.32**	**21.04**	**25.51**	**22.70**	**21.69**

Source: Baltic Transport Journal (2014)

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cal to an initial Gottwald crane installed at Fospar' s pier in 2012.

Such investments in port infrastructure are needed as Brazil still suffers from costly import delays. During the peak season, vessels can wait up to 60 days to berth at Paranaguá due to port congestion. Demurrage charges for the ports of Paranaguá and Antonina, although down by nearly a fifth on the previous year, were still $89.6 million in 2013.

Increasingly, international suppliers are resorting to storage in large bonded warehouse at the ports of Paranaguá, Antonina and Aratu to hedge against delays. Products in a bonded warehouse are treated as if they are still in international waters, even though they've been unloaded at port and stored. Only later, when the product is sold, does the buyer become responsible for paying import fees and taxes.

Storage in a bonded warehouse has the advantage of allowing international suppliers to sell fertilizer in Brazil in US dollars and be exempt from state taxes. The use of bonded warehouse comes at cost though. Bonded storage at Paranaguá costs roughly $50/t for 30 days, covering a range of port costs such as stevedoring, handling, warehousing and demurrage charges.

Around 300,000 tonnes of fertilizers were imported through bonded warehouses in 2013. This is expected to grow as major fertilizer producers realise they offer a reliable, effective way of managing the time and cost of transport and distribution in Brazil.

Russian potash producer Uralkali is reported to have access to 80,000-90,000 tonnes of bonded storage space at the Brazilian port of Ponta do Felix, secured through its acquisition last year of a 25% stake in Equiplan Participacoes, the terminal's principle shareholder. Trader Ameropa has supplied finished phosphate products to Brazil by making use of Intermaritima's extensive 40,000 m^2 bonded warehouse at the port of Aratu.

Koch subsidiary Koch Fertilizer Trading Sarl Sucursal Uruguay (KFTU) opened a 57,000 tonne bonded warehouse in Paranaguá in April last year. Koch also has access to two other bonded warehouses In Brazil under an agreement with Rocha Terminais.

India gets into deep water

India is also investing heavily in port infrastructure – and automated terminals in particular – to ensure its agricultural sector has access to the fertilizers it needs. Similar to Brazil, the subcontinent is heavily reliant on fertilizer imports, and is a large volume market for Chinese producers. That explains the recent investment in ports on India's east coast such as Vizag and Kakinada.

Vizag's six million tonne dedicated fertilizer terminal project reached financial close in 2013 and is due to be commissioned in the second quarter of 2017. The INR 3.1 billion ($49 million) project is aiming to be most modern and efficient fertilizer terminal on India's east coast. The fully-mechanized berth should vastly reduce vessel turnaround times and dramatically increase fertilizer handling capacity at Vizag. The 225m-long terminal is designed to accept Panama-size vessels and will be dredged to a depth of nearly 15m. Its key features include two rail-mounted electric cranes (25,000 t/d capacity per crane) linked to a conveyor belt (2,100 t/h feed rate), an automated bagging plant and a dedicated siding and rake loading facility (four rakes per day capacity). The terminal will have a daily output of up to 35,000 tonnes and a covered storage capacity of 225,000 tonnes.

Kakinada Deep Water Port is investing INR 6.5 billion ($102 million) between 2013 and 2015 in deepening its entrance channel from 14 to 16 metres. This will enable the ships of up to 150,000 deadweight tonnage (dwt) to berth at the port, over twice the size of the 70,000 dwt ships it can accept currently.

A project to fully mechanise Kakinada's fertilizer terminal to increase its capacity to six million tonne is almost complete. This will enable the 300m-long terminal to unload up to 20,000 t/d of DAP, urea, MOP, MAP, NPK and rock phosphate. A combination of two ship cranes and two harbour mobile cranes (HMCs) will unload cargo from Handymax, Supramax and Panamax size vessels.

The terminal's fully-enclosed, handling system is designed to be flexible. The two-stream system allows fertilizer to be unloaded from ships, bagged and loaded onto wagons using one stream – and can simultaneously reclaim fertilizer from a 440,000m^3 warehouse for bagging and wagon-loading using the other stream. Each stream has a loading and bagging rate of 1,000 t/h. The two covered rake sidings can be loaded with a different cargo every four hours. The ship unloading system has been operative at the terminal since last November and the bagging system is currently in the final stages of commissioning.

Destination bagging

One innovation that has transformed vessel turnaround and helped eliminate cargo loss and damage in fertilizer transport has been destination bagging. A high level of cargo damage is a particular problem for pre-bagged fertilizer shipments, due to splitting en route, or as a result of snagging

Fig 1: **Nectar Group's M140 destination bagging machine**

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during slow and labour-intensive unloading. Shipping free-flowing fertilizers and bagging at the destination port instead can reduce vessel loading and discharge costs by as much as 70%.

UK company **Nectar Group Ltd** helped pioneer destination bagging on quaysides. Its innovative bagging machines are used at destination ports to convey un-damaged bags straight to the back of loading trucks, avoiding the snagging associated with loading trucks by sling.

Nectar Group's involvement in destination bagging began when an international aid agency asked the company how it could increase the shipping efficiency of bagged products to developing countries. Nectar Group's answer was to ship the product in bulk and have it bagged on the quayside to reduce costs, cargo damage and vessel turnaround times.

The firm subsequently introduced the *Nectar Compac M140* bagging machine after several years R&D. The fully mobile unit was the first of its kind and fits into two 20ft ISO containers (Figure 1). The *Compac M140* introduced destination bagging of fertilizers, and other free flowing bulk products, in challenging and varied locations such as Afghanistan, Somalia, DPR Korea and Zimbabwe, and now bags over 2 million tonnes each year.

Nectar equipment is capable of bagging over 6,600 tonnes from one ship in a single day, meaning a 30,000 metric tonne cargo can be discharged from port in around five days roughly twice as fast as for pre-bagged cargo. The company also offers clients a logistics package that guarantees discharge speed and covers certain demurrage claims. Nectar's Commercial Director, Guy Wilkes, explained the company's thinking: "Not only have we dramatically reduced the vessel turnaround times but we have also guaranteed to the client that if it says 50kg on the bag – that is what is in the bag."

Nectar is moving into end-to-end logistics and in 2013 invested in a fleet of modern trucks in Ghana. Nectar now oversees handling and distribution for its client, from the moment fertilizer is unloaded from the vessel's hold all the way through to when it leaves the warehouse in clean, undamaged bags.

> **"Bedeschi has developed a strong partnership with Yara in France and Germany in recent years.**

Yara partners Bedeschi

Italian industrial manufacturer **Bedeschi Spa** moved into the marine sector 15 years ago and now offers a range of large-scale onshore ship-loading equipment. An innovative feature of Bedeschi's ship-loading 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 also developed a strong partnership with Yara in France and Germany in recent years.

Bedeschi is currently completing an EPC contract to provide Yara France with a new urea shiploader at the port of Le Havre. This 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 new machine, a replacement for the existing shiploader at the terminal, is due to be commissioned in the middle of next year. The terminal is the main export route for Yara's nearby Le Havre urea plant. located just a few kilometres away.

The Le Havre contract is the latest of three awarded to Bedeschi by Yara. In 2012, Bedeschi engineered, constructed, erected and commissioned a new ship-

A Bedeschi shiploader in operation.

PHOTO: BEDESCHI

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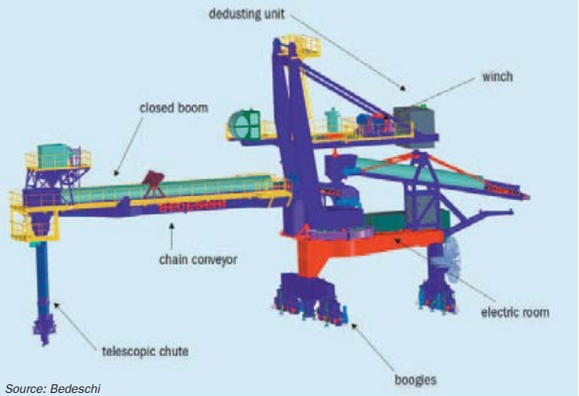
Fig 2: **Bedeschi shiploader**



Source: Bedeschi

loader at Brunsbuttel, Germany, as part of a turnkey project with Yara Germany to replace its existing shiploader at the port.

Bedeschi's shiploader is essentially a travelling portal fitted with four corner wheels that moves along the quay on a set of rails. A transfer chain conveyor on the upper part of the portal receives urea or other bulk fertilizers – from a tripper car fitted to the fixed gallery belt conveyor on the quay – and delivers this to the main chain conveyor installed on the boom of shiploader (Figure 2). The main chain-conveyor then transports urea along the boom to a telescopic, tilting loading chute for discharge into the ship's hold.

Shiploading is carried out using a combination of slewing, luffing-lowering and telescoping movements. Bedeschi's telescopic chute can be fitted with either a launching belt or with a loading spoon. Its design keeps dust generation and particle breakage to a minimum by reducing free fall height and the velocity of material during loading.

Safe and innovative

UK-based **Loadtec Engineered Systems Limited** recently added a range of marine loading arms to its portfolio which includes both road and rail tanker loading arms and a wide range of other liquid handling equipment and safe access systems.

"The transfer of bulk fluids and solids from storage to transport is critical," explains Alec Keeler, Loadtec's managing director. "The point at which the product is transferred to road, rail and marine tankers creates a number of very real risks for both the integrity of the product, the operators handling it and the environment."

Keeler points out that liquid fertilizers and raw materials can be particularly difficult to handle: "In the fertilizer industry, the volumes of fresh and waste liquids that can be classified as highly dangerous is abnormally high when compared to many other industries. In particular acids, ammonia and other noxious chemicals that need to be handled with great care, are transferred on an hourly basis to provide feedstock."

Safety is a key aspect of a Carbis rail loading system being designed for CF Industries' Port Neal nitrogen complex. Carbis is Loadtec's manufacturer and distributor in America and both companies work closely to ensure the systems designed are of the highest safety standard. The Port Neal site, located on the Missouri River, Iowa, is currently undergoing a $2 billion expansion. CF Industries plans to transport powdered urea from the complex to a Gulf Coast processing plant in rail cars using a continuous loading system. Compartments in the cars are filled from overhead hoppers using a bellows system and then sealed using "coffin lid" style closures.

To add to the technical and safety challenge, trains do not stop at the complex so the loading of urea has to take place as the cars constantly roll along the track. An innovative 43m long safety cage is designed to protect operators, as the risk of falls is high, and allows the compartments to be filled quickly, safely and cleanly (Figure 3). Operators can travel the length of the cage in safety using a built-in, fully-enclosed walkway and, if necessary, gain access to the 0.8m compartment openings through a spring-shut gate. Operators wear harnesses as a further safeguard and can be lifted out of danger in an emergency using an overhead lifeline system. ■

Fig 3: **Carbis/Loadtec urea loading system for rail cars**

Source: Loadtec

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phosphates & potash INSIGHT

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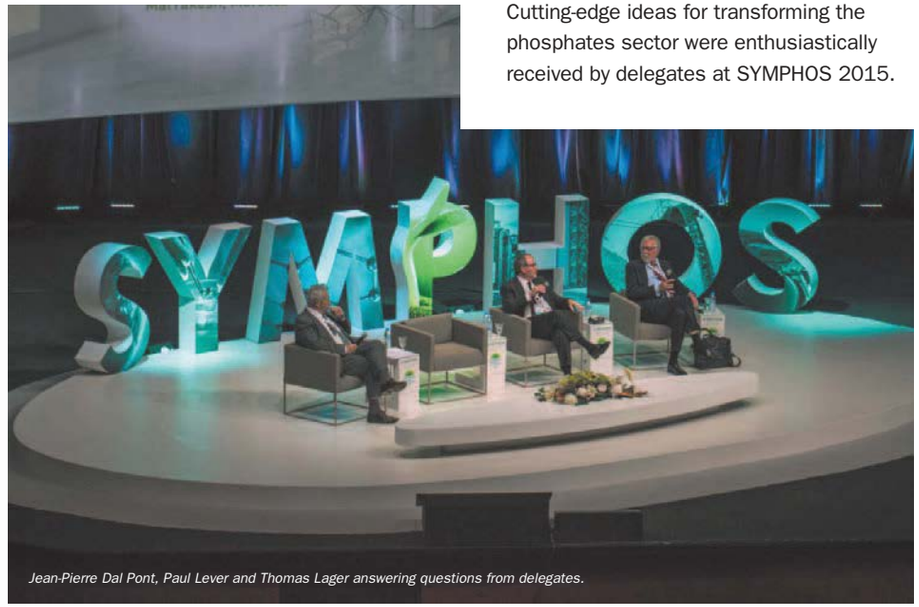
Celebrating phosphate, prince of nutrients

Cutting-edge ideas for transforming the phosphates sector were enthusiastically received by delegates at SYMPHOS 2015.



Jean-Pierre Dal Pont, Paul Lever and Thomas Lager answering questions from delegates.

OCP held the 3rd International Symposium on Innovation and Technology in the Phosphate Industry, SYMPHOS 2015, in Marrakech, between 18-20 May. Conference organiser **Rachid Boulif**, OCP's research and development director, welcomed the 1,200 delegates attending from 45 countries and looked forward to the three-day programme of more than 160 presentations. We report on the keynote plenary presentations below. The full conference proceeding will be published by Elsevier as a *Procedia Engineering* volume next year.

Robert Tucker, president of Innovation Resource, gave the keynote introductory presentation. The US author of *Managing the Future* explained why he thinks for companies to survive "innovation is everyone's business". **Jean-Pierre Dal Pont**, SFGP president, then explored what the manufacturing plant of the future might look like. Process industry innovations such as lean manufacturing and more modularisation, through the use of disposable reactors, for example, look likely to become increasingly important.

Mining smarter

Profitable mining businesses are going to need to find new and smarter ways of extracting minerals, in both their current and future projects, according to **Paul Lever**, CEO of CRCMining. The mining industry is being hit by a combination of declining labour and capital productivity, inefficient work practices, higher operational costs, increasing ore complexity and decreasing quality. Challenges such as the long-term decline in feed grade will require a fundamentally fresh approach. The traditional industry response of going bigger to make savings – with ever larger, more expensive plants, bigger trucks and shovels – may no longer be effective in Lever's view.

Resorting to the economies of scale is not always the right approach. Having a 400 tonne truck load of extracted material, for example, is a mixed blessing as it can only be designated as either ore or waste. However, the introduction of new technology should allow mineral extraction to move to "intelligent grade engineering" in future.

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By 2020, high-capacity continuous cutting systems could offer the phosphate industry an alternative to conventional surface mining methods. Automated technologies developed by CRCMining for the shovel load assist project (SLAP) are also likely to be deployed on mining projects in the next couple of years. Other innovative mining technologies such as the surface longwall system (SLS) and the novel 'dynacut' hard rock cutting system are currently being trialled too. These innovations will build on previous R&D breakthroughs at CRCMining such as universal dragline and dump (UDD) technology, slope stability radar and advances in drill automation and rock recognition.

Innovation creates ore

"Mining needs to leap forward 25 years in the next five years," **Thomas Lager**, EMINES professor at Morocco's Mohammed VI Polytechnic University told delegates. "The question is not if we need to innovate, but how do we innovate."

"Process innovation creates ore," added Lager, warning that a strong materials supply base is at risk of degrading into a weak base without innovation. Process industry companies need to think about their future position in the supply chain when devising an innovation strategy, suggested Lager. This involves deciding whether they will be producing commodities, functional products or both. Process and product development, although for different customers, are analogous in Lager's view. "The process is the product in the process industries," he commented.

Open innovation is one way of delivering improvements but requires cooperation between the process industries and their industrial, business-to-business customers. Conferences such as SYMPHOS play a part in helping firms innovate together in Lager's view. "I believe SYMPHOS will be a very successful event in the spirit of open innovation," he concluded.

Going beyond operations

The fact that operational excellence is apparently the second highest priority of CEOs was not a surprise to **Andre Kotlarevsky**, CEO of DuPont OCP Operations Consulting, a joint venture between OCP and DuPont that dates from 2013. DuPont fundamentally changed its approach to operational excellence nearly a decade ago.

CRC Mining's Paul Lever addressing the conference

"This was a significant transformational journey which touched all aspects of operations. I use the phrase transformational journey because it required us to fundamentally change our mindset and behaviour throughout the organisation – to significantly build leadership and capabilities around people – this was a major, major change," Kotlarevsky told delegates.

This year's SYMPHOS conference marks the second anniversary of DuPont's joint venture with OCP. Achieving operational excellence requires collective effort by talented individuals. Kotlarevsky agreed with Mostafa Terrab, OCP's chairman and CEO, when he said: "It is within human capital that lies at the very soul of our company, the driving force of its success and influence."

DuPont changed its approach to operational excellence in 2006 and has subsequently implemented a new, integrated way of achieving this across more than 200 sites. This had resulted in some large cost savings. The transformation of one of DuPont's oldest and most challenging US manufacturing sites, for example, delivered $107m of savings between 2009 and 2014.

> **Mining needs to leap forward 25 years in the next five years.**

Kotlarevsky explained how an integrated approach to excellence requires firms to go "beyond operations". He believes it is the existing cultural strengths of a company, such as the mindset and behaviour of employees, which drive operational excellence –and the further development of the capabilities of employees which then sustains any gains made.

Making innovation feel safe

The conference heard that regulation does not necessarily need to stifle innovation. **Garth Kirkham**, president elect of the Canadian Institute of Mining (CIM), instead argued that regulation is what makes innovation work, telling delegates: "That's why we have standards, best practice, regulation – to make sure innovation feels safe, is transferable and has a future. I believe it all goes hand-in-hand."

CIM is responsible for compiling NI43-101, the well-known definition and standard for mineral project disclosure. The standard, which carries the force of law in Canada, dates from 2000 and was revised in 2005 and 2013. Its existence is necessary, believes Kirkham, because mining is a "high-risk industry" and not necessarily well-understood by investors. The value of NI43-101 is that it allows disclosure that is not misleading and provides a technical report compiled to a common standard.

CIM is currently working on better definitions of preliminary economic assessment (PEA), pre-feasibility study (PFS) and feasibility study (FS). These will be published as new, non-legally binding, best practice guidelines. Similar guidelines on potash estimation and cost reporting in mineral projects are also currently being updated by CIM to reflect the latest version of NI43-101.

Optimise, educate, innovate

Jamal Chaouki, a professor at Montreal's Polytechnique University, returned to a common conference theme – the need for waste to be treated as a resource. "We are flooded by waste. In future, the situation will become worse," he warned. The generation of municipal solid waste in Morocco at the rate of 3.1 tonnes per citizen per year illustrated the problem, especially as 60% of this volume was dealt with by "unsound disposal".

There is much potential for converting waste and biomass into synoil and syngas using pyrolysis and gasification technology in Chaouki's view. Phosphogypsum is also a potential resource and Chaouki is working on the extraction of sulphur from this type of waste as part of an OCP project with Total.

Transcarbon International president and CEO, **Sebastien Raoux**, gave his view on the prospects for a comprehensive climate change agreement in Paris later this year: "In December, 195 countries are going to meet in Paris to negotiate the international agreement to address climate change. This is arguably the most important issue we as humanity will face in the 21st Century.

"We must act, we must find a solution. It is simply about our ability to continue living on the planet. A 'no action' scenario will have catastrophic consequences," Raoux warned.

Farming will not be immune from climate change, as reduced agricultural productivity of around 30% is predicted this century, said Raoux: "Loss of agricultural yields is pretty much everywhere, and in areas where it is needed the most." According to Raoux, emissions from fertilizer use are about 1.5% of global greenhouse gas emissions – with emissions from manufacturing NPK fertilizers making up about 0.9% of that total.

"It's small but not negligible and the problem is those emissions are growing," he said. "Annual emissions from fertilizer use increased by 37% in the 2001-2011 period and are expected to increase by 48% by 2050."

Raoux said the solution to climate change was "to optimise, educate, innovate". He urged the industry to improve the precision of fertilizer usage, ramp up its production of controlled-release fertilizers and, in particular, cut back nitrous oxide emissions as they were "the largest source of emissions from the agricultural sector."

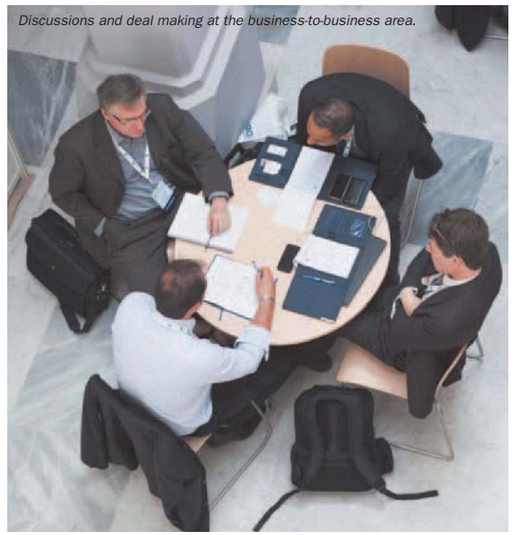
Radically increasing agricultural productivity, concluded Raoux, would mean "developing agricultural systems based on biological systems" and "restoring stocks of natural capital". Encouragingly, a number of countries have already drawn up Nationally Appropriate Mitigation Actions (NAMAs) to reduce their agricultural emissions.

Urban farms and industrial ecosystems

Prayon's innovation director, **Fabrice Renard**, described some recent developments in precision farming. In the past, precision phosphorus fertilisation has been the "poor relation" compared to progress for other nutrients such as nitrogen, although this situation is changing. Recent innovations by Prayon include the development of its *miconutri Fe* horticultural fertilizer product. Prayon is also involved in a project developing urban farms on disused industrial sites.

OCP procurement manager **Saad Mikou** explained how the firm's numerous links with Moroccan business and its large impact on the country's economy has created what it calls an "industrial ecosystem". OCP takes its responsibility for this ecosystem seriously and is using its investment and procurement policies to support smaller Moroccan businesses. It has also used joint ventures to bring world-class industrial partners such as Jacobs and DuPont to Morocco. OCP is investing heavily in training and R&D, including helping Mohammed VI University to become a national centre of excellence. An OCP skills programme is also providing vocational training to help young people enter the workforce.

Discussions and deal making at the business-to-business area.



Billions in batteries

Professor **Rachid Yazami** of Singapore's Nanyang Technological University explained the lithium ion battery (LIB) market for phosphate and phosphate derivatives. These are used widely in LIB components such as the electrolytes, cathodes and anodes.

Lithium hexafluorophosphate ($LiPF_6$), for example, is used as an electrolyte in 95% of all LIBs on the market. Yazami predicted that the LIB electrolyte market for $LiPF_6$ will be worth $2bn by 2020. "If we have all the ingredients in Morocco this [production] is definitely something my colleagues in OCP should think about [as] 41,000 tonnes of LiPF6 could be produced at $50/kg," he said.

Cathodes made of LFP ($LiFePO_4$) are used for LIB applications such as energy storage, electric vehicles and hybrid electric vehicles, although its low energy density means it is not suitable for portable consumer electronics. LFPs generally last for 2,000-7,000 charging cycles and have a life of 8-10 years. Cathodes made of LFP are expected to have a 25% market share by 2020, equivalent to $9billion based on a price of $15/kg. The development of LMP cathodes (where M is a transition metal such as Fe, Mn, Ni, Co and V) is a rapidly growing area of research, according to Yazami. Their much higher energy density means they are likely to replace standard LFP types over the next 5-10 years.

The prince of nutrients

In a wide-ranging, impassioned keynote address, Aleff Group's chairman, **Julian Hilton**, discussed the significance of the EU's decision to add phosphate rock to its list of critical materials in May last year. He praised SYMPHOS for giving "phosphates a space that's suited to the importance of the raw material," adding: "It [SYMPHOS] is the first phosphate event I've been to where the size of the event starts to feel in proportion to

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the significance of the material we're all fascinated by."

Hilton rejected the idea that the phosphates sector was the 'Cinderella' of the fertilizer industry in thrall to a "godmother called nitrogen that we all respected". Phosphates were of primary importance, in Hilton's view, due to role of phosphorus in regulating other soil nutrients: "So far from being the Cinderella of the story, phosphorus is the prince. How we manage phosphorus changes the way we manage the rest."

Hilton suggested that tackling poverty had to be the prime objective of phosphate sustainability and innovation. "The needs of the most poor are the one's we have to satisfy first", he said. Hilton also quoted from OCP executive director **Soufiane El Kassi's** opening address: "Our mission is to produce appropriate, affordable fertilizers for farmers across the African region."

He then commented: "That is what will lift the region out of poverty. Is this the moment when Morocco embraces the mission of turning this energetic resource, directly or indirectly through batteries or food, into something which enables the lights to go on [in Africa]?"

The phosphate industry may end up straddling the fertilizer and energy sectors due to the presence of rare earths and uranium, according to Hilton: "You have the future of the planet in your hands. God has given Morocco this extraordinary endowment [in phosphate]… the entire periodic table is in this material so don't be surprised at what you find. The world's largest uranium deposit is in Morocco and it's in the phosphate."

Hilton concluded: "If I had to choose between N, P and K, I wouldn't be able to do without P. Phosphate is essential for all life forms on the planet, we can't do without it. So you in Morocco, god has not just given you a lot of phosphorus, he has given you a major challenge – to lead in stewardship for the next generation of how this resource is valued, how it's looked after."

The fact that only 15% of mined phosphate rock ends up as plant nutrient was also of great concern to Hilton: "My challenge to the industry is, given that we're at best at 15% efficiency, with all your great powers, wisdom, passion, could we conceivably get to 50% efficiency with this wonderful resource called phosphorus by 2050."

Helping Africa attain scientific, educational and economic self sufficiency is the bold ambition of the African Institute of Mathematical Sciences (AIMS). Its president and CEO **Thierry Zomahoun** explained how the institute was educating Africa's brightest students as part of efforts to bridge the continent's science, technology, engineering and mathematics (STEM) skills gap. An impressive 748 STEM students, nearly a third of these women, have graduated from AIMS since it was established in 2003. More than 80% of AIMS graduates have gone on to study for masters degree or a PhD either in Africa or abroad. The plan is to build up to 15 AIMS centres across Africa by 2023.

SYMPHOS 2015 included over 100 exhibitors.

Maintenance management improvement

Maintenance is a significant part of operational costs yet successful implementation of computerised maintenance management systems (CMMS) at large, complex industrial operations was "surprisingly low", **Michael Wienker** of ThyssenKrupp Industrial Solutions told delegates. "It is surprising that 60-75% of even large well-organised and well-resourced organisations fail when trying to implement CMMS," he said.

The total cost of maintenance is not always apparent as, according to the "iceberg model", hidden maintenance costs are five times higher than direct maintenance costs.

"Shifting from a traditional reactive approach to a proactive reliability-based approach will help reduce these costs," commented Wienker. "A well-implemented CMMS will help improve the overall business of an organisation that has a proactive management strategy. The key to that is quick access to organisational data and turning these into helpful and meaningful reports."

A lack of readiness and a "fix it when it breaks" mentality is one reason why CMMS implementation fails to deliver. The failure to realise that CMMS is simply a tool – and not a substitute for a maintenance strategy – is also frequently misunderstood. This kind of misunderstanding can divert staff away from key tasks and cause a costly drop off in maintenance performance. An "annoying" lack of IT infrastructure and a lack of sustained senior management support are also behind the poor success rate of CMMS. Poorly-resourced implementation and human factors – especially poor communication and the absence of an organisational champion – are the main other reasons.

Wienker proposed a number of fixes to these problems such as nominating a senior management champion for CMMS and making sure a "CMMS-ready" maintenance strategy was in-place in advance of implementation. A "very high level" of hardware and internet/intranet availability are also the key to success, concluded Wienker.

The conference ended as it began by returning to the theme of "the factory of the future". **Jean-Claude Charpentier**, research director at LRGP, explained how an "eco-efficient" and "green" approach to chemical engineering should enable industrial processes to "produce much more, and better, using much less" in future. ■

Africa and Middle East rise as China stalls

African phosphate mine at SNPT (Societe Nouvelle des Phosphates de Togo). PHOTO: SSR

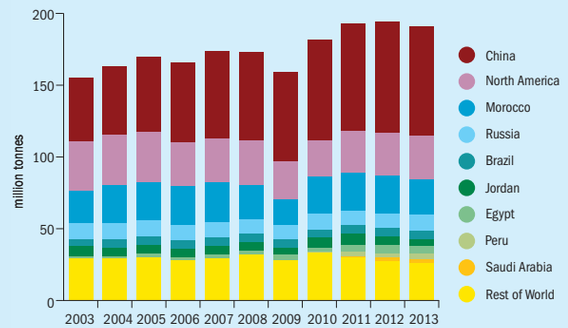
The global supply of phosphate rock is set to rise by as much as 35 million tonnes by 2019. But where will this new capacity come from and who will provide it?

World phosphate rock production has expanded rapidly in the last decade, rising by almost a fifth between 2003 and 2013, with China responsible for almost 90% of rising global output over this period (Figure 1). Definitive annual statistics for 2014 are not out until the autumn. But the latest quarterly figures suggest global phosphate rock production reached 222 million tonnes last year. Provisional Chinese output for 2014 is a massive 120 million tonnes, although IFA thinks the true production figure is likely to be closer to 80 million tonnes.

However, the decade-long surge in world phosphate rock production appears to have stalled in recent years. Global output changed little between 2011 and 2013, suggesting that China is longer the engine of growth it once was. But, if China's influence is waning, where will new phosphate rock production capacity come from over the next five years and who will provide it? IFA's latest global supply outlook for 2014-2019, published in June, provides some of the answers.

IFA predicts a 35 million tonne rise (16%) in global phosphate rock supply over the next five years with 70% of this increase coming from Morocco, China and Saudi Arabia. It forecasts 255 million tonnes of phosphate concentrate supply in 2019, compared to a 2014 baseline of 220 million tonnes. (Figure 2).

Fig 1: **Phosphate rock production** 2003-2013



Source: IFA

The emergence of Africa and the Middle East

Although large capacity developments will continue in most regions, Africa looks set to play an increasingly important role as a phosphate producer. IFA predicts the continent will see the largest regional increase in phosphate rock supply in the five years after 2014, adding nearly 13 million tonnes

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Fig 2: **Forecast world phosphate capacity by region**

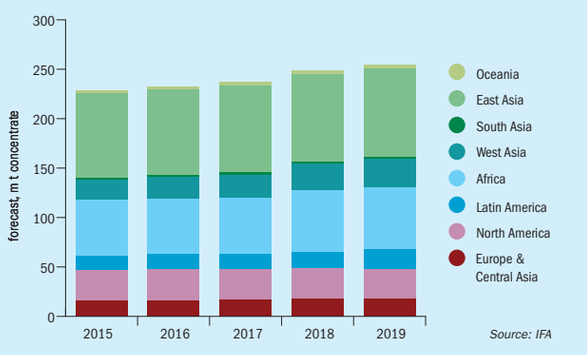

Table 1: **The last five years and the next: world phosphate rock production, 2008-2013, compared to 2014-2019 forecast change in supply.**

Key producing countries	2008	2013	2008-2013 change	2014-2019 forecast
Million tonnes				
China	61.8	77.0	15.2	7
North America	31.8	30.9	-1.0	0
Morocco	24.2	25.5	1.3	10
Russia	9.8	10.7	0.9	1
Brazil	6.3	5.9	-0.4	3.1
Jordan	6.1	5.4	-0.7	3.2
Egypt	3.1	5.3	2.2	0
Saudi Arabia	0	3.1	3.1	5.3
Peru	0	3.5	3.5	1.9
World	**174.9**	**193.3**	**18.4**	**35**

Source: IFA

to take African supply to 63 million tonnes by 2019. This will largely be delivered by OCP's mining expansion in Morocco and, to a lesser extent, by smaller supply additions in Algeria, Egypt and Tunisia.

The Middle East (West Asia) region is also likely to emerge as a major phosphate rock player with 2014-2019 supply potentially rising by nine million tonnes to 28 million tonnes, as Ma'aden and JPMC make expected additions to capacity in Saudi Arabia and Jordan, respectively. Not to be outdone, Latin America is likely to witness a five million tonne rise in regional capacity, linked to new projects from Vale and Galvani in Brazil and Miski Mayo in Peru.

Chinese slowdown

China should not be discounted, though, as the country's phosphate production will still continue to grow over the medium-term. New projects in Yunnan, Hubei, Guizhou and Sichuan will potentially add a hefty seven million tonnes to supply over the next five years, taking Chinese phosphate rock production to 85-87 million tonnes by 2019.

But, if IFA's latest phosphate rock supply forecast is correct, China role as the main engine of global growth is set to end. Predicted supply growth for China over the next five years is half the production increase of the last five years (Table 1). The combined additions to 2014-2019 phosphate rock supply from OCP in Morocco and Ma'aden in Saudi Arabia are also double that expected from China. This is evidence that a regional shift in production away from China towards Africa and the Middle East is underway.

Those who believe China's decade-long stranglehold on supply growth has crowded out investment in new capacity in other parts of the globe are likely to welcome any shift to more widespread, multi-regional growth in phosphate rock production over the medium-term. But which particular countries, producers and projects will benefit from such a change? IFA has named a number of a project prospects with a "high probability of realisation" before 2019, taking account of likely project slippages (Table 2). It believes such projects are likely to ensure phosphate supply is potentially adequate to meet growing demand over the next five years.

Riders and runners

Analysts CRU keep track of phosphate rock developments globally using its Project Gateway System. This allows CRU to build-up a realistic base-case for future supply outlook based on firm and probable projects. Speculative and inactive projects are also monitored – and then re-categorised if they get go-ahead.

CRU estimates 2014 global phosphate rock capacity at 250.2 million tonnes of concentrate, and forecasts this will rise to around 268.1 million tonnes by 2019. This latest forecast includes 10.8 million tonnes of 'firm' project capacity and 18.4 million tonnes of 'probable' capacity. This overall estimate also allows for closures, half of which are forecast to occur in China. A regional breakdown of CRU's firm and probable phosphate projects is provided below.

Two projects in North America are categorized as probable: Agrium's 1.2 million t/a **Rasmussen Valley** project and Yara's 1.4 million t/a **Mine Arnaud** project in Canada, which are expected to be commissioned in 2016 and 2018, respectively. Neither North American project is mentioned by IFA in its latest supply outlook.

Latin America has three strong project prospects, one in Peru and two in Brazil. The commissioning date for FOSPAC's 2.5 million t/a **Bayovar** project in Peru was recently pushed back to 2019, largely due to rock quality concerns, as also experienced at Vale's Bayovar mine. In Brazil,

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Anglo American Fosfatos' **Ouvidor** expansion is a firm prospect that should see the site's capacity rise from 1.3 to 2.0 million t/a by 2017. Also, the probable Galvani **Serra do Salitre** project in Brazil is scheduled to bring 1.2 million t/a of rock online by 2018.

Two expansions in Russia and one in Kazakhstan provide the CIS region with three firm projects. In Russia, PhosAgro's **Apatit** project looks set to provide 0.6 million t/a of extra capacity by 2017. Similarly, Acron's 0.6 million t/a **Oleniy Ruchey** expansion should raise its total capacity to 1.7 million t/a by 2017 through a 0.6 million t/a addition. EuroChem's 0.4 million t/a **Taraz (Araltobe)** project in Kazakhstan is due to bring the site's capacity up to 1.0 million t/a by 2018.

Ma'aden's **Al Khabra** project at Wa'ad Al Shammal in Saudi Arabia is the Middle East's sole firm project prospect. Around five million t/a of capacity is on track to be commissioned in 2016 and fully ramped-up the following year.

China remains active with two firm rock projects and five probable projects forecast. Yihua Group's 1.5 million t/a **Jiangjiadun** mine is one of the firm projects. It has a commissioning date of 2016 and should reach full capacity a year later. Xingfa's 2.0 million t/a **Wawu IV Section** project, also due to be commissioned in 2016, is the other firm prospect. The five probable prospects in China are:

- Xingfa Group's 1.3 million t/a **Dianziping** project
- Kingenta's 2.0 million t/a **Yuhua** phosphate project
- Kailin's 2.0 million t/a **Yangshui Mining Section** expansion
- Dadi Yuangtong's 1.0 million t/a **Hebei** project
- Yihua Group's 1.0 million t/a **Kahualuo** project

All five are due to be commissioned between 2016 and 2018.

Now that OCP's **Beniamir** project is up and running, two probable African projects look likely. Cominco's **Hinda** project in DR Congo is expected to be commissioned in 2017 and have a final capacity of 4.1 million t/a. The project took an important step forward when Cominco published a definitive feasibility study for Hinda in June (p13). The 0.2 million t/a Ugandan government-run **Sukulu** project is scheduled for commissioning in 2017, although the project is at risk of being re-categorised as inactive.

Table 2: **Selected medium-term phosphate rock projects.**

Country	Project	Company	Capacity m t/a	Start-up date
Russia	Oleniy Ruchey 2nd Phase	Acron	1	2015
Kazakhstan	Zhanatas	EuroChem	0.6	2014
Brazil	Patrocinio Salitre	Vale Fertilizantes	1.1	2019
	Serra do Salitre, Santa Quiteria	Galvani	2	2019
Peru	Piura	Miski Mayo	1.9	2019
Morocco	Khourigba, Gantour	OCP	10	2016
Saudi Arabia	Umm Wu'al, Al Khabra	Ma'aden	5.3	2016
Jordan	Eshidiya	JPMC	3.2	
China	Yunnan, Hubei, Guizhou and Sichuan	Various	5-7	2019
Australia	Paradise	Paradise Phosphate Limited	2	2019
Total			**34.1**	

Source: IFA

African junior mining boom?

IFA reports that the eventual realisation of all announced phosphate rock projects could add a further 88 million tonnes to world capacity, on top of the realistic 35 million of supply forecast between 2014 and 2019. That is an unlikely outcome and, as IFA notes, many of these new ventures, including a large number of junior phosphate mining projects, would not enter production before 2020 anyway. Junior phosphate miners are particularly numerous in sub-Saharan Africa. IFA's list of post-2020 African projects includes notables such as:

- Great Quest's **Tilemsi** project, Mali
- Minibos Resources' **Cabinda** phosphate project, Angola
- GB Minerals' **Farim** phosphate project, Guinea-Bissau
- Montero Mining's **Phosco** project, South Africa
- Vale's **Nampula** phosphate project, Mozambique
- Namibian Marine Phosphate's **Sandpiper** project, Namibia

This is just the tip of the iceberg. Integer, for example, currently tracks over 40 "highly speculative" African projects, extra to those being undertaken by established producers on the continent. Finance, however, remains a problem and weak investor confidence means some junior mining companies will struggle to raise the necessary capital.

Short-term supply prospects

Much of the forecast growth in phosphate rock supply, especially in Brazil, Russia, and Kazakhstan, will be kept in-country for captive, domestic use. Of the 35 million tonne increase in supply forecast for 2014-2019, nearly 29 million tonnes is likely to be earmarked for downstream production, leaving a surplus of just 6 million tonnes for export. That would grow the global export market to 36 million tonnes by 2019.

Although current world trade in phosphate rock fluctuates around 25-30 million t/a, the merchant market is closer to 20 million t/a – equivalent to the output of 10 average mines – as around 5 million tonnes is tied-up in joint ventures or by long-term supply agreements. The spare merchant capacity that is left is also mostly in the hands of OCP currently.

In the short-term, CRU predicts a general tightening of the phosphate rock market in the eastern hemisphere and a loosening in the west. More downstream integration in Egypt and Algeria, low export availability from Tunisia and exclusive supply deals, such as Jordan's joint venture with Indonesia, will contribute to a tight market. In contrast, a number of other developments are likely to loosen the market. These include 0.8-0.9 million tonne lower US demand resulting from the closure of MissPhos, the expansion plans of Anglo American and Galvani in Brazil, and the recent permitting of Yara's Mine Arnaud project in Canada. ■

Different ores, different challenges

We review the mining and mineral processing of the principal potash ores, sylvite, carnallite, langbeinite and kainite.

Potash is the collective name given to the ores, minerals and products which contain the element potassium in a water-soluble form. The term dates from the 1800s and originally referred to potassium carbonate and potassium hydroxide recovered by boiling the washings of wood and leaf ashes in iron pots.

Potash minerals were mined Dallol region of Ethiopia's Danakil Depression as far back as the fourteenth Century. In the west, Germany was the first to discover substantial underground quantities of potash in the Zechstein Basin in the 1850s.

Mined potash first became available when a purification process to remove sodium and magnesium chloride from the carnallite found at Stassfurt, Germany, was developed in 1859. This enabled potash to start being used for high-value crops such as cotton and vegetables, following the earlier discovery in 1840 by Justus von Liebig in Germany that potash was a nutrient for crops.

Main mined ores

The minerals sylvite (KCl), carnallite ($KCl \bullet MgCl_2 \bullet 6H_2O$), kainite ($(4KCl \bullet MgSO_4) \bullet 3H_2O$), and langbeinite ($(K_2(SO_4) \bullet 2MgSO_4$) are the main commercial sources of potash (Table 1). Of these, sylvite and carnallite are the most commonly occurring geologically, with sylvite being the most economically important. Sylvite is generally the mining industry's preferred ore mineral due to its relatively low processing costs. Langbeinite is also mined commercially on a relatively large-scale at present in Carlsbad, New Mexico. Kainite has been mined in the past, most notably in Sicily, as well as in Poland, and mixed langbeinite-kainite deposits also occur in the Carpathian region of west Ukraine.

Although carnallite was mined, beneficiated and processed in Germany for 130 years – and was the original target ore in the 1860s – potash production in the country now concentrates on lower cost sylvite ore mining.

In fact, carnallite ores are not generally targeted by conventional ore mining for the following reasons[1]:

- Carnallite ores are lower grade with a 17% K_2O content compared to 63% for sylvite
- Carnallite has unfavourable mechanical properties making it more difficult to mine in comparison to sylvite
- Its deliquescent nature makes it unsuitable for direct use as fertilizer
- The dissolution and recrystallization methods used to process carnallite ores are energy intensive and expensive
- The conversion of carnallite to sylvite during processing produces large volumes of $MgCl_2$

The highest-grade, naturally-occurring potash ore is sylvinite, a mixture of sylvite (typically 35%), halite (around 60%) and insoluble minerals such as clay (roughly 5%). Carnallite is generally classed as an unwanted contaminant when present in sylvite deposits.

Agricultural importance

The term potash is also applied to commercially manufactured end-products such as potassium chloride (KCl, commonly known as muriate of potash, MOP) and potassium sulphate (K_2SO_4, sulphate of potash, SOP) and potassium magnesium sulphate (sulphate of potash magnesia, SOPM). MOP accounts for more than 95 % of the world's potash fertiliser production and has a minimum K_2O content of 60%. SOP and SOPM fertilizers are usually applied to crops sensitive to high chloride levels and together make up make up much of the remaining 5% of potash fertiliser usage.

Potash fertilizers are widely used in the production of fruit and vegetables, maize, wheat, rice, sugar, cotton, soybeans and palm oil. Potassium increases plant resistance to drought, disease and pests, is essential for root system, fosters nitrogen fixation in leguminous crops and also improves the size, colour and sugar content of fruits and other crops.

Mining

Generally, the underground mining of potash is only economic for an ore grade of 14% K_2O and a bed thickness of 1.2m. Economics of scale also mean that potash plant and mills typically need to have a K_2O capacity of at least 300,000 tonnes if they are to compete in a marketplace where many plants are in the one million tonne production range. For a new mine, proved ore reserves needs to be enough to ensure a minimum of 20 years of potash production for a given plant size[2]. Mineral processing also needs to be highly efficient. Production from Carlsbad potash ore (sylvite) in New Mexico typically operate at a mill recovery of 80-85%. The use of dissolution-crystallisation (see below) to capture of potash from waste liquor can raise potash recovery to 92%.

Ore recovery and mining practices vary with geology and depth. Carlsbad mines, for example, operate at a depth of 270-430m and recover about 75% of the ore on the first pass, rising to 90% on the retreating pass. Recoveries are, however, much lower in Saskatchewan mines operating at depths between 1,000 and 1,100m. Patience Lake Member mines, for example, achieve ore recoveries of 35-40% whereas Esterhazy Member mines are able to recover about 45%, as the Esterhazy ore benefits from a competent overlying roof (salt back) at least 18m thick.

Potash mining is typically a highly-mechanized, continuous process employing boring machines, drum miners, longwall miners and road headers. Boring machines

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PHOTO: LUIGI NIFOSI/SHUTTERSTOCK.COM

Realmonte Kainite mine, Sicily.

with two or four cutting arms are an effective, economic mining method for relatively flat and uniform potash beds that are uniform in thickness. In mines where potash beds gently slope, undulate, or thin and thicken, continuous miners with drum cutters mounted on moveable arms are most effective (Figure 1).

Froth flotation

The processing of sylvinite and other potash ores is a comparatively simple, standardised process performed in a similar same way at many potash plants[3]. The four basic beneficiation techniques used to process potash ore are froth flotation, heavy media separation, electrostatic separation and dissolution-crystallisation (hot leaching). In conventional processing, the ore if first ground to liberate potash from halite, deslimed to remove insoluble fines, separated into a coarse and fine feed and beneficiated by froth flotation (Figure 2).

The potash industry first adopted flotation for processing sylvinite at Carlsbad, New Mexico, in the early 1930s, and the technology later spread to France, England, Germany, the CIS countries and Israel. In Saskatchewan, almost 90% of fertilizer-grade MOP is produced by froth flotation, sometimes supplemented by heavy media separation.

The objective of froth flotation is to separate sylvite from halite using a cationic collector[4]. Insoluble slimes such as clay and hematite are firstly removed using hydrocyclones, hydroseparators or fluidised-bed separators. The flotation of insoluble slimes from the ore in two stages is also practiced, although reagent costs can be high. The deslimed froth flotation feed is then usually processed separately as a fine and coarse fraction.

A suspension of crushed ore in saturated brine, known as the pulp, is typically conditioned with a small amount (50g/t) of long-chain amine collector and a frother such as pine oil before it passes to an agitation cell. Inexpensive depressants such as guar gum and dextrin can also be added to inhibit the flotation of clays and other insoluble materials not removed during desliming. An extender oil may also be added to coarse-size flotation pulps.

During flotation, a froth of bubbles produced by compressed air at the bottom of the agitator cell entrain potash particles and carry these to the surface where they are mechanically recovered from the side of the flotation cell. Carnallite needs to be specifically avoided during flotation of sylvinite because of its detrimental effect on recovery[2]. Sulphate minerals such as kieserite or kainite, if present, can be floated from potash ore using a fatty acid collector[4].

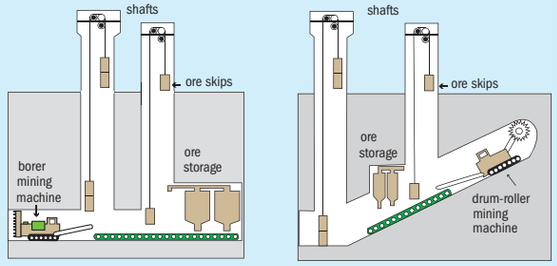
In Saskatchewan, coarse and fine potash pulp is processed using conventional Denver DR-type froth flotation cells, ranging from 100-300 ft³ in size, in a three-stage rougher, cleaner and re-cleaner flotation process[5]. Rougher concentrates (less than 0.84 mm size) usually become the final premium product after cleaner and re-cleaner flotation stages remove entrapped fine salt. The rougher tailings (above 1.41 mm) are generally re-crushed and floated in either a conventional or column flotation cell as a scavenger stage.

Belaruskali uses froth flotation to process potash ore from the Elets horizon of the Pripyat Basin, Belarus, in Productions Units 1, 2 and 3. This sylvite-halite ore contains minor carnallite, anhydrite, silicates and carbonate and is processed as follows:

- Ore crushing and pre-screening
- Ore milling and pre-sizing
- Mechanical and flotation desliming of ore
- Sylvite flotation
- NaCl leaching from the floatation concentrate
- Hydro-thickening and dehydration of tailings
- Hydro-sizing and dehydration of concentrate
- Concentrate drying

This process is used to manufacture Belaruskali's standard reddish-pink granular

Fig 1: **Potash ore mining – conventional extraction**



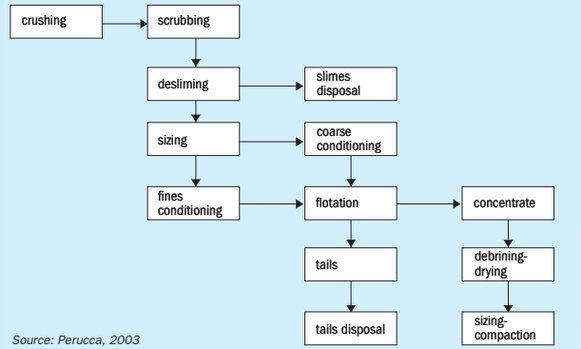
Source: Warren 2015

Table 1: **Potash minerals and major ore types**

Name	Chemical Formula	K_2O content (%)	Comments
Potash minerals			
Sylvite	KCl	63.17	Principal ore mineral
Carnallite	$KCl•MgCl_2•6H_2O$	16.95	Ore mineral and contaminant
Kainite	$4(KCl•MgSO_4)•H_2O$	19.26	Important ore mineral
Langbeinite	$K_2SO_4•2MgSO_4$	22.69	Important ore mineral
Common contaminants			
Halite	NaCl		Principal ore contaminant
Polyhalite	$K_2Ca_2Mg(SO_4)4•2H_2O$	15.62	Ore contaminant
Kieserite	$MgSO_4•H_2O$		Common ore contaminant
Anhydrite 0	$CaSO_4$		Common ore contaminant
Leonite	$K_2SO_4•MgSO_4•4H_2O$	25.68	Ore contaminant
Ores	**Mineralogy**	**K_2O content (%)**	**Occurrence**
Sylvinite	Sylvite, halite	10–35	Canada, USA, Russia, Brazil, Congo, Thailand
Langbeinitite	Langbeinite, halite	7–12	USA, Russia
Kainitite	Kainite, halite	13–18	Italy, Ethiopia, Belarus
Carnallitite	Carnallite, halite	10–16	Germany, Spain, Thailand
Hartsalz	Sylvite, halite, anhydrite, kieserite	10–20	Germany
Mischsalz	Sylvite, carnallite, halite, anhydrite, kieserite	8–20	Germany

Source: Prud'homme & Krukowski, 2006

Fig 2: **Conventional potash ore processing**



Source: Perucca, 2003

MOP fertilizer. Flotation produces a concentrate of 95-96% KCl grade at 85.5-87.2% recovery, according to Belaruskali.

Dissolution-recrystallisation

The dissolution-recrystallization method for potash manufacture was developed by the French in the early 1910s and was widely-adopted as an ore beneficiation method in the early days of the industry. Potassium chloride is crystallised from a clarified brine obtained from a hot leach of the ore. The method leaves behind insoluble material and undissolved salt (halite). Hot leaching is still used to recover potash processing fines and waste liquors and for the treatment of complex ores. K+S used the following hot leaching method at its Werra plant in Germany:

- The ore is firstly ground to less than 4mm and treated with hot brine
- Potassium Chloride dissolves while kieserite and halite remain undissolved
- The hot KCl-enriched brine is separated from kieserite and halite residue
- Potassium Chloride is obtained by vacuum crystallisation and washed, dewatered and dried using centrifuges and a gas-fired drum drier
- Solid-liquid separation and crystal washing yields a 96% KCl concentrate
- Froth flotation of the residue from hot leaching (<1 mm) is used to separate and recover a kieserite concentrate from halite

Belaruskali's Production Unit 4 also uses the hot leaching method to produce white, finely-crystalline granular product with 96-99% KCl grade at 88-89% recovery.

Electrostatic separation

Electrostatic separation of potash was first investigated in Carlsbad in the 1940s only to be later commercialised in Germany after years of development. The method,

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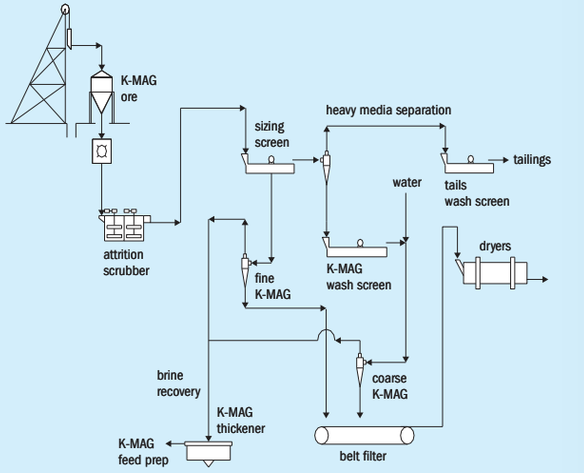
such as K+S's *ESTA* process, was used by a number of German potash mines. The process involves heating the ore and coating it with reagents and requires careful control of humidity. Electrostatic separation is said to be fast and very efficient with low energy, maintenance, operating and capital costs[3]. The waste product is also dry so there are no waste brine disposal problems.

The aim of the first electrostatic run is to separate halite from crushed ore (<1.2 mm) after conditioning with 75 ppm salicylic acid and heating to 50°C in fluidised bed. The bed uses friction to impart a 'triboelectric' charge on ore particles, the size of the charge depending on their mineral composition. Relative humidity is regulated at 10-15% and the ore introduced to a 10m high chamber lined with electrodes charged at 10,000 volts DC. Further electrostatic passes at a relative humidity of 5% with a fatty acid conditioning agent are then used to separate potash minerals from kieserite. Middling fractions often need to reground and reprocessed to achieve high yields and purity.

Fig 3: **Flowsheet for the production of KMAG from langbeinite ore**



Source: Mosaic

Heavy media separation

Heavy media separation has been a very successful processing method for coarse-grained Esterhazy potash ore in Sakatchewan, as well as langbeinite ore from Carlsbad (see below). This beneficiation method exploits the density difference between minerals to achieve a separation. Mosaic, for example, uses heavy media separation at its Saskatchewan plants to separate halite (specific gravity 2.16) from sylvite (specific gravity 1.99). Halite will sink and sylvite will float during separation if the brine slurry density is adjusted to an intermediate value such as 2.07.

The ore is crushed to less than 1 mm, leached to remove carnallite and deslimed to remove clay. Deslimed feed is then screened at 10 mesh (2 mm) and the oversize sent to the heavy media separation circuit where finely-ground magnetite (<200 mesh, 0.074 mm) is added to the ore slurry. Sylvite is concentrated by two rougher and cleaner cyclone processing stages[3]. This yields a concentrate, middlings and tailings fraction. Middlings are usually reground and, together with the fines from initial crushing, processed by froth flotation[5]. Compared to a conventional froth flotation plant, heavy media separation has lower reagent costs although maintenance costs are higher because of the abrasive properties of the magnetite used.

Carnallite

Carnallite processing generally involves dissolving an ore concentrate and the recrystallization of KCl with the generation of a halite-rich solid waste and saline liquid effluent. Hot leaching and cold leaching are the two main processing options for potash production from carnallite. Hot leaching was used to treat carnallite ore from the Hattorf and Wintershall mines in Germany. The ore was ground to less than 4mm and leached at around 90°C to yield a brine. Any halite and kieserite impurities remained as solids allowing them to be separated from the brine by filtration. Sylvite was subsequently recovered by precipitation by allowing the brine to cool to 30°C in vacuum crystallisers. A 60% grade KCl product was ultimately obtained by this route after centrifuging.

Cold leaching has also been used to process carnallite ore from Poland. The K3 Zechstein evaporite unit at Kłodawa, a 15-30m thick bed containing carnallite, halite and kieserite, has been sporadically mined in the past. Magnesium chloride is removed from the ore (8.5% K_2O and 8.1% MgO) by cold leaching at 20-25°C to leave coarse halite and a fine residue of sylvite (46%) and kieserite (45%). The residue's chemistry makes is suitable for use as a magnesium potash fertilizer although kieserite can be removed by froth flotation if necessary.

Langbeinite

The manufacture of sulphate of potash magnesia (SOPM) fertilizer, *K-Mag*, from what Mosaic described as the "the world's largest and purest deposits of langbeinite ore" at Carlsbad, New Mexico, began in 1939 and celebrated its 75th year of production in 2014. Around 3.8 million tonnes of langbeinite ore (5.1% K_2O) was mined to produce around 1.0 million tonnes of finished product in 2012. The Carlsbad basin is responsible for around 80% of US potash production although Mosaic ceased MOP manufacture (0.5 million t/a) from sylvite at the site at the end of last year.

Langbeinite is mined at Carlsbad from a 10 ft bed at a depth of 800-1,000 ft using five continuous miners. Langbeinite can be separated from sylvite and halite by heavy media separation or froth flotation. Mosaic process the langbeinite ore to produce *K-Mag* using a combination of attrition scrubbing, wash screening and a heavy media separation circuit (Figure 3). The specific gravity (SG) of the ore slurry is adjusted by adding a dense, finely-divided, easily recoverable solid such as ferro-silicon or magnetite. Langbeinite (SG 2.83) is denser than minerals such sylvite (1.99) or halite (2.16) and so 'sinks' and discharges with the hydrocyclone underflow.

Kainite

Kainite was conventionally mined underground, processed and leached in Sicily for several decades from the 1960s until Italkali ended production in 1992. The ore was crushed and beneficiated by flotation to produce a fine-sized kainite concentrate with a halite content of less than 5%.

The Sicilian ore feed for the flotation circuit was crushed and ground to pass 28 mesh (0.6mm) and contained 63% kainite, 37% halite and <0.5% insolubles. The feed was prepared as a 30% slurry, conditioned with a coconut amine acetate collector and an isopropanol modifier and split between four rows of 12 Salla flotation cells operating in parallel with a total capacity of 142 cubic metres[3]. This yielded a 80-90% kainite (15-17% K_2O) grade flotation concentrate. Hot leaching with epsomite brine then converted the flotation concentrate into a langbeinite slurry. This in turn was reacted with a schoenite brine to precipitate potassium chloride and epsomite.

Potash production patterns

Potash grade and ore composition have influenced the changing patterns of world potash production over the last 60 years. Several potash basins which were important producers after the Second World War, such as the Kainite ore of the Sicilian Basin, kainite-langbeinite ore of the Carpathian Basin and the carnallite-sylvite ore of the Rhine Graben in France, have since become depleted or closed due to economic and environmental pressures (Figure 4).

In the United States, potash mining in the Salado Basin of New Mexico has also been on the decline for decades, as the resource has become increasingly depleted. The higher grade potash (sylvinite) is largely mined-out and the remaining lower grade ore (mixed langbeinite, kieserite and sylvite) is more expensive to process than potash from Saskatchewan[6]. This is not an isolated problem. Mines in Europe's Zechstein Basin, their production long since eclipsed by that of Canada, Russia and Belarus, are also facing depletion within the next 30 years and are typically burdened by older, higher cost production.

Rising costs are a particular issue for established potash producers. Maintenance and mining costs generally increase as potash operations age due to the decline in reserves and ore grade, longer mining distances and thinning seams. This means the economics of each plant largely depend on its ore body and the age of the operation. Plants tend to remain as they were originally designed with older plants undergoing only limited modernisation and mining and processing improvements. Investment in new technology, cost reductions and efficiency improvements are relatively infrequent and often simply not worthwhile due to the economics of potash production.

However, the potash sector remains a dynamic segment of the fertlizer industry and enlightened producers do recognise that its future success and profitability depends on developing new, efficient processes, by-product recovery and manufacturing new, innovative downstream products.

Polyhalite is also poised to disrupt the potash industry, a subject *Fertilizer International* will return to in a future issue. ■

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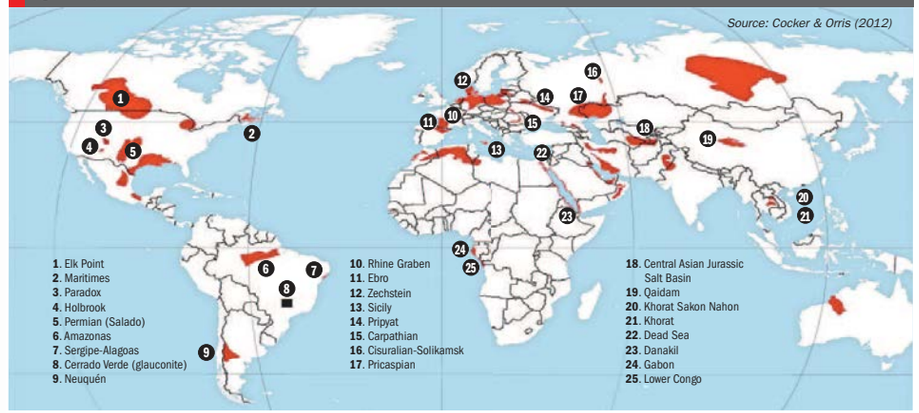
Fig 4: **Major world potash basins**



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