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Number 465

March | April 2015

Fertilizer INTERNATIONAL

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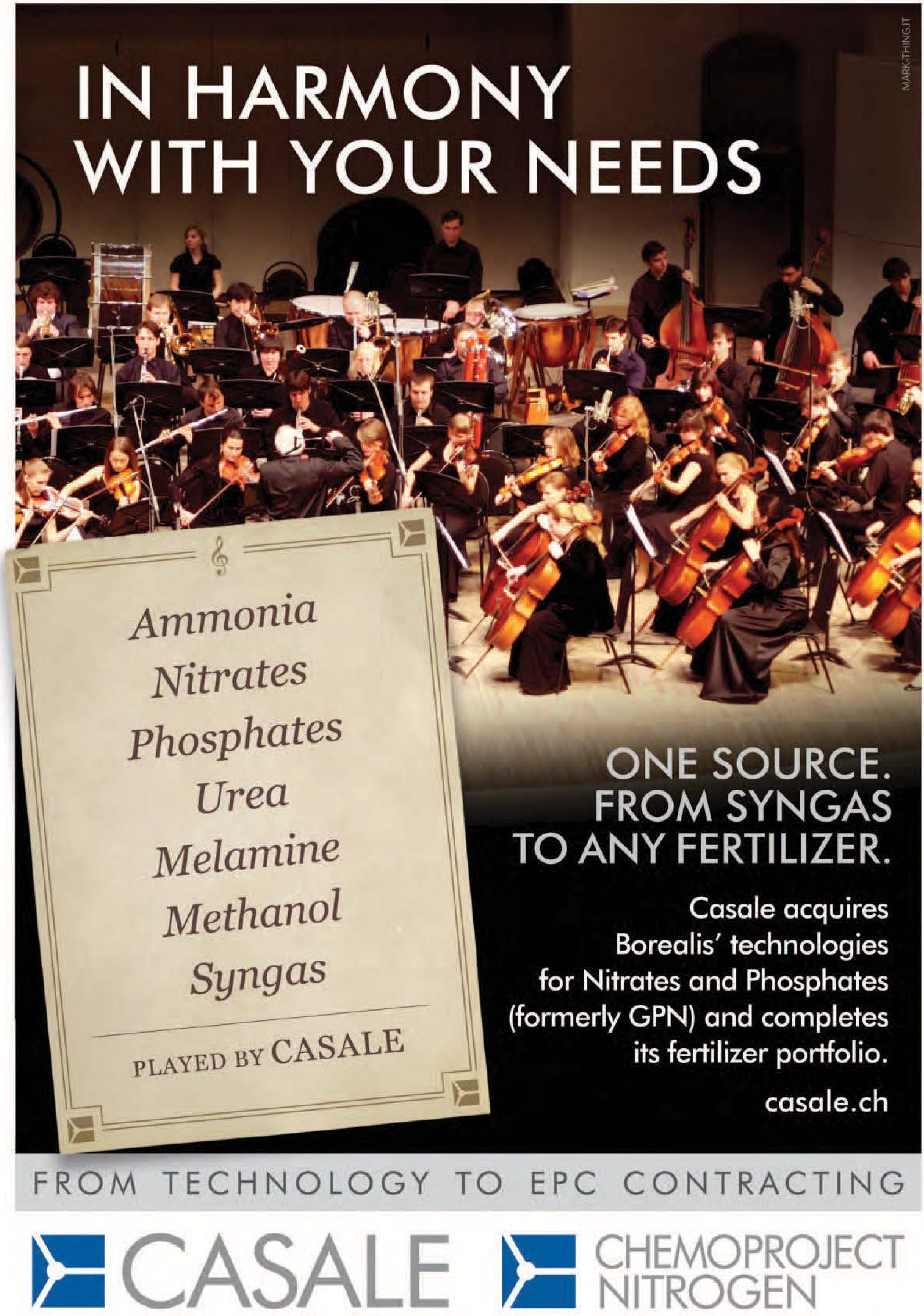
Phosphates 2015 preview

Paddy rice fertilisation

Global phosphate outlook



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INTERNATIONAL
Fertilizer

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NUMBER 465 MARCH | APRIL 2015

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Will the Indian reform drive get blunted?

Fertilizer markets have been lacklustre in the opening months of 2015, with buyers and traders adopting a wait-and-see approach on the direction of prices before making major commitments. Sellers meanwhile hope that the key markets of India and Brazil will revive.

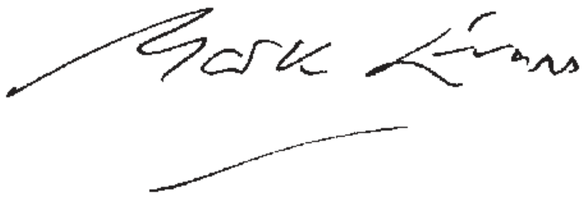
The scenario in India is a familiar one: what will the new budget offer? The stakes are high every year, given the sheer scale of the annual fertilizer subsidy. In advance of the 2015 budget – the first full budget of the Modi government – the Indian fertilizer industry has been lobbying hard for the government to address the chronic imbalance in nutrient ratios, as well as the disparity in price between urea and the decontrolled nutrients of phosphates and potash. Hopes are high that Prime Minister Narendra Modi will seize the opportunity to tackle a thorny and sensitive issue by significantly reducing the subsidy on urea. Farmgate prices for urea would therefore rise. At the same time, the Indian fertilizer industry is seeking the decanalisation of urea, as well as its inclusion in the Nutrient Based Subsidy (NBS) scheme.

Modi's promised reforms may bring short-term pain for the rural sector. He is promising a shift from indiscriminate subsidy to capital expenditure as part of the government's new strategy for rural development, but the immediate effect of such schemes would be a loss of purchasing power – and thus pose a threat to farmers' buying intentions with fertilizers. The continuing weakness of the Indian rupee is also making the cost of fertilizer imports ever more expensive.

Paradoxically, the fertilizer subsidy may actually increase in the immediate term. To boost the finances of India's all-important railway sector, rail freight charges are being raised by 10%, impacting on the price of urea. The government of India has however promised to offset these costs by increasing the urea subsidy by INR 3 billion from a current estimate of INR 30 billion. Farmers will pay no more for their urea, and the price will remain at INR 5,360/t ($87/t).

The inefficient distribution of energy resources has long been a weakness of the Indian economy. Modi has pledged to change allocations of domestically-produced natural gas to favour power generation and other users. The Fertiliser Association of India (FAI) opposes moves that would place its members further down the energy pecking order from their present top-priority status.

The Indian fertilizer industry has been marked by only minimal investment in recent years mainly due to high levels of debt. Policy-makers within the government recognise the need to kick-start investment although tangible results from pro-investment policies may take several years to filter through. The Indian fertilizer industry meanwhile will have to carry on as best it can while the Modi government wrestles with the Herculean task of fundamental reform. ■

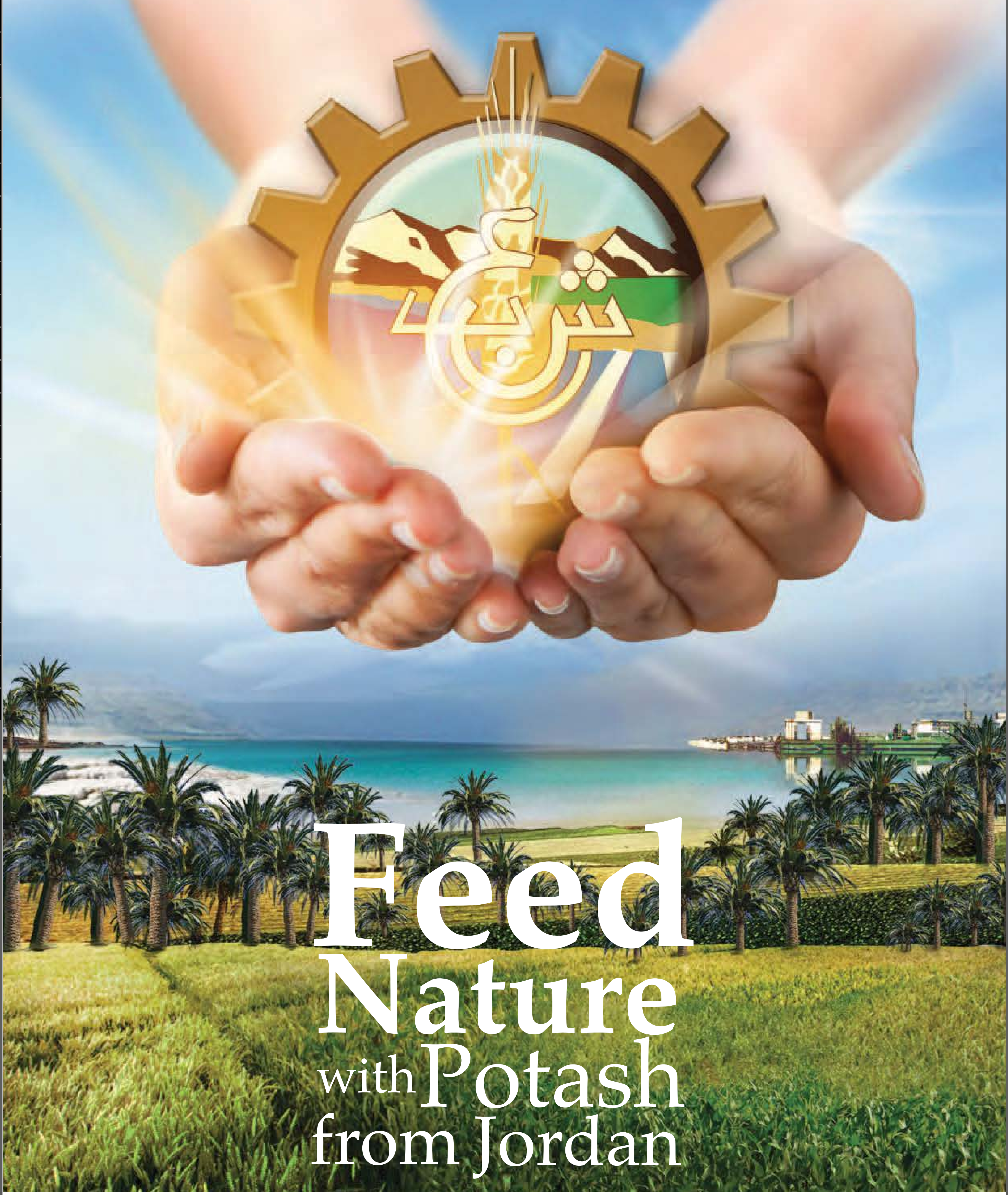


Meet Simon Inglethorpe

In June, on reaching the age of 65, I will step down as Editor of *Fertilizer International* after nearly 27 years in the post and fully 30 years of reporting the continuing evolution of the world fertilizer industry. I am delighted to introduce my successor, **Simon Inglethorpe**. Simon brings first-class experience and expertise to the role, having joined BCInsight Ltd. from Haymarket Media Group, where he was Business Editor at *The ENDS Report*, the UK's leading publication for environmental professionals. A graduate in geology from King's College London, Simon spent a long career as a mineral resource scientist with the British Geological Survey, a role that involved extensive international project work in Africa, Asia, Central America and Europe.

Simon looks forward to taking the helm of *Fertilizer International*. "It is a great pleasure to be taking over from the estimable Mark Evans," he said. "My background in the earth sciences means I do recognise the underlying importance of mineral resources to the sector, particularly phosphates, potash and mineral processing – as well as the rise of shale gas. But there is much more to the fertilizer industry than resources and my experience in business journalism should serve me well as I immerse myself in technology, products, markets and finance.

"Mark forged strong bonds with the readership of *Fertilizer International* and I intend to do the same. I am particularly looking forward to meeting as many of you as possible over the next few months. Ensuring *Fertilizer International* remains the highly-relevant and essential read that subscribers have come to expect under Mark's editorship is a priority. And meeting many of you in person is one way I can help guarantee that *Fertilizer International* continues to be a well-informed, thoroughly-researched publication full of valuable commercial insights and business intelligence." ■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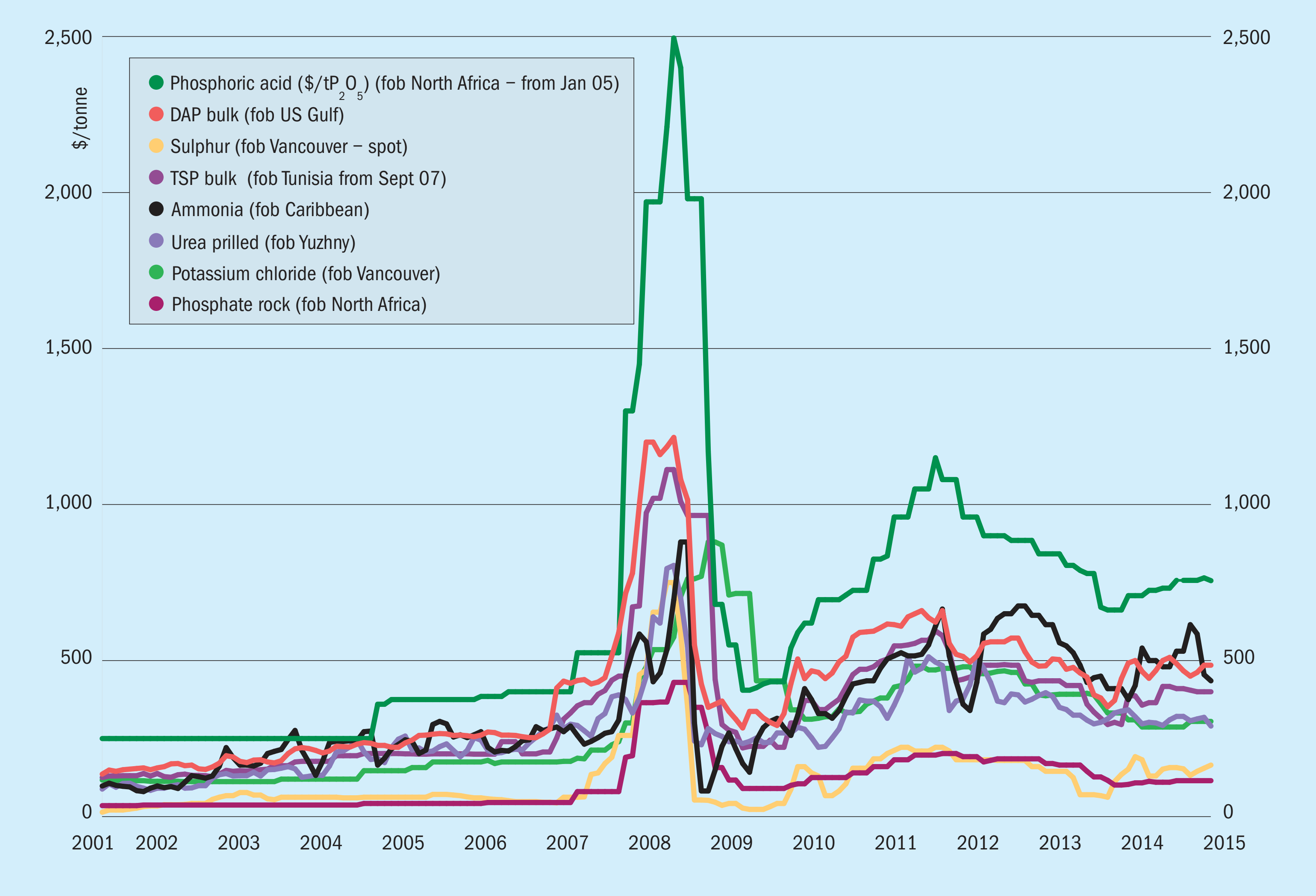
Nature
with Potash
from Jordan

Market outlook

Historical price trends $/tonne



AMMONIA

- Ammonia values slipped in late January, plateauing at around $400/t f.o.b. Yuzhny. Markets remained quiet however during the first half of February.
- Morocco has remained a keen buyer and is reported to have paid between $435-445/t cfr for a recent shipment from Algeria.
- Ammonia buyers in India have held back from making major purchases while they await a clearer picture of the likely price direction. IFFCO is receiving a contract cargo from SABIC under a formula pricing arrangement. The most recent price ideas were $510-520/t cfr.

UREA

- Urea activity was also subdued for much of February. Traders which had concluded aggressive sales based on the prospects for Black Sea availability in the low-$300s/t f.o.b. have yet to recoup their outlays, and late February/early March prices were expected to slip below the $300/t benchmark.
- China has secured large volumes of prilled urea for shipment to India, reducing product availability elsewhere. Prices there were reported to be falling to the $290s/t f.o.b.
- Granular urea netbacks to Middle Eastern suppliers fell sharply, reflecting US market weakness. Suppliers in the region have been faced with returns of around $290/t f.o.b. or lower and are expected to seek higher yields from European markets, where netbacks have been above $305/t f.o.b.
- FSU prilled values have also lost ground as traders aggressively pursued the limited amount available business. Some sales were concluded at prices netting back to $280/t f.o.b.

PHOSPHATES

- Phosphate markets have been characterised by a wait-and-see approach, especially as Indian and Brazilian buyers hold off buying. Chinese suppliers have meanwhile been mainly preoccupied with meeting home market needs. DAP prices out of Tampa thus remained flat at around $485/t f.o.b.
- OCP has been indicating $500/t f.o.b. for new business out of Morocco, but faces competition from Saudi Arabia and Russia, as well as from China when the domestic buying season levels of during March.
- SABIC, Saudi Arabia has followed up two DAP sales to India with a shipment to Pakistan. These deals were all concluded at around $490/t cfr for February and March shipment. KRIBHCO took 250,000 tonnes from Ma'aden in 2014/15 and is expected to raise this uptake to 350,000 tonnes in 2015/16. SABIC has concluded MoUs with Chambal and Zuari for 150,000 tonnes DAP each.
- The Brazilian market has been quiet, leading to wide variations in price expectations. OCP has held firm at $520/t cfr for DAP/MAP deliveries, while Russian indications have ranged between $500-510/t cfr. Buyers' price ideas remain below $500/t. Buying interest is not expected to resume until later in March.

SULPHUR

- Tasweeq, Qatar has announced a March contract price of $164/t f.o.b., a cut of $18/t on the February price and indicating the present downward market direction. Tasweeq's price is well below the $175/t f.o.b. March price announced by Aramco Trading, but some industry analysts suggest that each is too high for the prevailing market interest. China has countered at $170/t cfr, and there is a lack of demand from other regions.
- Moroccan sulphur prices have been pegged in the high-$150s/t cfr, as OCP continued to import steady volumes. Russian contracts with other North African buyers were settled in the low $160s/t cfr.
- Chinese port prices have notched up in response to low stocks and strong phosphate prices. The latest port price indications are Rmb 1,370-1,380/t FCA, Rmb 20-30/t higher than before the Chinese New Year. April contracts climbed slightly from Rmb 1,375/t to Rmb 1,380/t, suggesting that a sustained increase in prices beyond the first half of July is unlikely.

POTASH

- The potash market remains largely inactive, with little change since the Chinese New Year and Brazilian holiday slowdowns. Participants continue to await negotiations over the Chinese and Indian contract prices, while industrial relations issues at ICL's operations in Israel could reduce supply availability.
- Talks continue over Chinese contract terms. Canpotex is reported to be seeking a price increase of around 8%, or $25/t, on the 2014 agreement, but Sinofert is holding out for a rollover, citing high inventories and a decrease in some major potash markets since the start of 2015. One such example is Brazil, where prices have slid by roughly $10-15/t.
- An early conclusion is expected in the contract talks with Indian buyers. Buyers are believed also to be pushing for a rollover on the current $322/t cfr with 180 days' credit, but suppliers are aiming for higher prices, by as much as 10%. ■

Market price summary $/tonne – Late-February 2015

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phosphoric Acid
f.o.b. Caribbean	435	n.m.	f.o.b. E. Europe 127-132	f.o.b. US Gulf	485	n.m	n.m
f.o.b. Yuzhny	395-405	288-293	-	f.o.b. N. Africa	482-530	400	675-840
f.o.b. Middle East	400-430	295-315**	-	cfr India	483-490	-	765*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	285-325	-	cfr US Gulf	70-80	f.o.b. Vancouver	160-170	
f.o.b. Middle East	288-322	-			f.o.b. Arab Gulf	164-180	
f.o.b. Western Europe	-	€440-480			cfr North Africa	130-135	
f.o.b. FSU	276-310				cfr India	190-200+	

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

- While there have been some pockets of optimism, including suggestions that US spring ammonia applications will be strong, ammonia markets overall are expected to remain flat.
- Ample ammonia supply continues east of Suez, with Far Eastern buyers receiving multiple offers for cargoes from with the region and from the Middle East. Demand may increase from mid-March, in line with seasonal fluctuations.
- **Ammonia outlook:** Flat in the short term, but a price floor may soon be reached.
- Urea markets are also expected remain soft, but a further slide in prilled values may be halted in the immediate term, helped by increased interest from Latin American markets.
- On a more positive note, Chinese demand is set to resume following the Chinese New Year and the onset of the spring application season.
- **Urea outlook:** Continuing oversupply is expected to overshadow market expectations in the months ahead.
- There is keen interest over Chinese pricing once phosphate exports resume from April. The increased product availability may prompt a fall in prices, although this could be countered if demand in Brazil and India revives.
- Severe winter weather throughout much of the United States has checked phosphate demand there, but the onset of spring could unleash much pent-up demand. Imports will compete with US suppliers for the available business, so the impact on prices may be muted.
- Russian suppliers are actively seeking alternative markets as European business has proved disappointing. The US market is not offering very attractive netbacks, however, at best suggesting around $470/t f.o.b. Baltic.
- **Phosphates outlook:** Flat values expected to prevail.
- Although Chinese sulphur buyers were likely to have some import requirements in the weeks ahead, market observers were unsure about the potential scale of this demand.
- Russian sulphur supplies have been affected by rail congestion, but sellers expected that river access will become available again after winter ice thaws.
- **Sulphur outlook:** Little prospect for a sustained uplift while phosphate demand remains slow.
- Potash suppliers have conceded to buyers in Brazil by lowering their price target from $380/t cfr to $355-365/t cfr. They hope that no further concessions will be necessary once Indian and Chinese contacts are in place. The depreciation of the Brazilian real, which has fallen by 27% in value during the past six months, is a further obstacle to a revival in Brazilian offtake.
- **Potash outlook:** Continuing market weakness. ■

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PHOTO: ROBERT LUCIAN CRUSITU/SHUTTERSTOCK.COM

Fertilizer Industry financial fortunes

Fourth quarter results suggest that 2014 ended well for many of the fertilizer industry's big players. A pick up in Brazilian demand, strong potash sales and an end-of-year rally in phosphate product prices all benefitted the bottom line in 2014.

The usual flurry of fourth quarter and full-year company results emerged in February. Unsurprisingly, as the round-up of annual results below illustrates, the fortunes of the big fertilizer producers over the last 12 months reflect their different market niches, business models and locations. But some common factors did affect the sector's major players last year. Potash sales volumes in 2014 were at or close to record levels for many producers, for example. A rally in the price of phosphate fertilizers, falling energy costs, the strength of the dollar and strong demand in Brazil also shaped financial fortunes in 2014.

Mosaic finishes strongly

US fertilizer producer Mosaic reported 2014 net earnings of $1.3 billion – flat compared to 2013 – on net sales of $9.1 billion. Higher phosphate and potash sales volumes and lower potash operating costs were offset by lower potash prices. However, full annual earnings of $2.68 per share for 2014 were up by 8% on 2013. Mosaic's financial performance was also boosted by a strong finish to the year with fourth quarter net earnings rising to $365 million, almost triple its $129 million earnings for the same period in 2013.

"While we expected strong fourth-quarter results, demand exceeded our expectations as customers came to the market in force, seeking to replenish empty inventories ahead of an expected strong spring application season in North America," said Jim Prokopanko, Mosaic president and chief executive officer.

Net phosphates sales rose by 4% in the final quarter with higher product prices compensating for lower volumes. DAP selling price, for example, averaged $448 per tonne in the last quarter compared to a price of $381 per tonne in the final three months of 2013. This situation was reversed for potash: record production volumes more than offset lower selling prices and lifted final quarter net sales by nearly a fifth to $763 million.

Mosaic received $2.3 billion net cash from operational activities in 2014 and invested $1.1 billion in Wa'ad Al Shamal Phosphate Company, its Saudi Arabian joint venture with joint Ma'aden and the Saudi Basic Industries Corporation (SABIC).

Mosaic disposed of Argentinian assets, discontinued distribution in Chile and ceased production at its Carlsbad, New Mexico potash mine during the course of last year. The firm also acquired the Brazilian and Paraguayan fertilizer distributor Archer Daniels Midlands. Annual sales of the firm's MicroEssentials range also grew by an impressive 14% in 2014.

Outages affect Agrium

Canadian producer Agrium's 2014 net earnings fell to $720 million ($4.97 per share), down from the $1.1 billion ($7.20 per share) earnings posted in 2013. This was despite an overall rise in annual sales of £315 million to $16.0 billion in 2014.

Fertilizer sales were down $162 million in the fourth quarter of 2014 and net earnings for the period also dropped $48m to $51m. Agrium linked lower potash and nitrogen sales volumes to outages at its Vanscoy Saskatchewan potash facility – which is undergoing expansion – and its Redwater nitrogen facility in Calgary, Alberta. Fourth quarter earnings were also hit by $31 million foreign exchange and derivative position losses.

Chuck Magro, Agrium's president and chief executive officer, said the firm had delivered "solid fourth quarter earnings" despite "some headwinds" in agricultural markets.

"We undertook downtime to refresh and expand our potash and nitrogen facilities this quarter, which impacted wholesale earnings in the short term but will drive higher future capacity and utilization rates," commented Magro. "For 2015, Agrium is focused on executing our strategy… including ramping up production at Vanscoy, completing the Borger nitrogen expansion and continuing to grow retail earnings."

Record sales volumes at Intrepid Potash

Potash sales volumes at Intrepid Potash rose by 32% to hit a record 915,000 short tons in 2014. Sales of its trademark Trio product also increased 48% year-on-year to reach 182,000 short tons. The largest potash producer in the US reported annual earnings before interest, taxes, depreciation and amortisation (EBITDA) of $95.3 million in 2014.

"We achieved record sales volumes this year while pricing was on the rise and our price advantage was at historic highs," said Intrepid's executive chairman, president and chief executive officer, Bob Jornayvaz.

Intrepid's operations generated $127.5 million in cash flow in 2014 with $61.8 million of this going on capital expenditure.

But net income fell to $9.8 million in 2014, down from $22.3 million in 2013, as increased costs offset higher sales volumes and affected margins. The $74 million rise in revenues to $410 million last year was countered by a $91 million leap in the cost of the goods to $304 million. Full year earnings per share of $0.13 last year were also down from $0.30 in 2013

Potash Corp volumes rocket

Annual sales revenues at Saskatchewan's Potash Corporation slipped by 3% in 2014 to $7.1 billion. Net income of $1.5 billion last year also fell from the $1.8 billion reported in 2013. The company's full-year earnings of $1.82 per share for 2014 were also down 11%.

But, as with Mosaic, the firm's performance was bolstered by a strong final quarter. Buoyant 2014 fourth quarter net earnings of $407m, up $177m on the same quarter in 2013, were driven by a record potash sale volume of 2.5 million tonnes.

"Record potash sales volumes, combined with higher realizations across all three nutrients, raised our quarterly earnings near the upper end of our guidance range," said Jochen Tilk, Potash Corp's president and chief executive officer. Total potash sales for 2014 of 9.3 million tonnes were also the second highest in Potash Corp's history.

Nitrogen also performed well in 2014 with Potash Corp reporting a record gross margin of $1.0 billion for the year due to a "robust pricing environment" and higher sales volumes". The 6.4 million tonnes sales volume for nitrogen posted in 2014 was the highest in the firm's history.

Phosphate sales volumes, in contrast, contracted due to the closure of Potash Corp's Suwannee River chemical plant last July and other production constraints. "With fewer tonnes of production available, our sales volumes for both the fourth quarter (0.8 million tonnes) and full year (3.1 million tonnes) trailed the respective periods of 2013," the company said in a statement.

International investments also fared less well in 2014. The $210 million earned last year from investments in Arab Potash Company in Jordan, Israel Chemicals Ltd in Israel and Sociedad Quimica y Minera de Chile SA in Chile fell short of the $276 million earned in 2013.

> **We achieved record sales volumes this year while pricing was on the rise and our price advantage was at historic highs.**

Yara's earnings leap

Income at Yara, the Norwegian ammonia, nitrates, NPK and speciality fertilizer producer, grew by 22% last year. Annual EBITDA earnings rose by NOK 3,008 million to NOK 16,407 million (around $2.2 billion) in 2014. Annual earnings per share also increased to NOK 27.59 compared to NOK 20.67 in 2013.

The year finished on a high point with fourth quarter EBITDA of NOK 4,528 million, almost double the NOK 2,360 million recorded for the last three months of 2013. Yara's average oil and gas costs for the last quarter were also down by nearly a fifth on the same period in 2013.

"Yara reports strong fourth-quarter results with improved margins, reflecting lower natural gas cost in Europe and a stronger US dollar," said Torgeir Kvidal, Yara's acting president and chief executive officer. "Our Brazilian activities continue to perform well, with both higher volumes and margins."

Yara said it also benefitted from higher margins for phosphate products and nitrogen upgrading. Price premiums for Yara's nitrate and NPK products also remained solid in comparison to urea and other commodity fertilizers.

EuroChem volumes stable

EuroChem Group's income has risen by 12% year-on-year. The firm's EBITDA of $1.51 billion for 2014 represent a $164 million increase on the preceding year. Better margins mean this was achieved despite a 7% fall in annual revenue to $5.1 billion in 2014. But profitability has deteriorated with EuroChem moving from $387 million net profit in 2013 to a $578 million net loss in 2014. The Russian-based producer blamed this on the impact of a "significant weakening" of the rouble-dollar exchange rate on its US dollar-denominated debt.

Dmitry Strezhnev, EuroChem's chief executive officer remained bullish: "With substantial raw material and production capacity in Russia, EuroChem's global competitiveness is now stronger than ever."

Combined nitrogen and phosphate sales volumes were stable at 10.6 million tonnes in 2014, with a drop in phosphate volumes mitigated by higher nitrogen volumes. However, lower year-on-year prices caused nitrogen revenues to decline by 3% to $2.9 billion, according to EuroChem. A 6% fall in volumes also dragged phosphate revenues down by 13% to $1.6 billion.

EuroChem says it has invested a total of $2.4 billion in its major Usolskiy and VolgaKaliy potash projects in Russia and estimates these to be 22% and 36% complete, respectively.

PhosAgro ramps up production

PhosAgro's annual sales volume growth was close to 3% in 2014. Nitrogen fertilizer sales volumes grew by 10% to 1.4 million tonnes whereas phosphate sales volumes grew by a more modest 1% to 4.7 million tonnes. The Russian fertilizer company's 2014 fertilizer production of 6.1 million tonnes was also up 4% on 2013.

Growth in Brazil, India and the Russian domestic market created strong demand for PhosAgro products in 2014, the company said in a statement. Better year-on-year pricing also enabled the firm to benefit from higher production and sales volumes, according to chief executive officer, Andrey Guryev. "We saw solid demand for our products this year: Brazil, one of the world's largest consumers of mineral fertilizers, increased imports of phosphate fertilizers by over 10%; India increased imports by 4% year-on-year, though still remaining at the lowest consumption/application rates in the past seven years," he said. ■

Accelerating momentum

EuroChem began the first production of phosphate ore in 2014, producing around 180,000 tonnes.

Clark Bailey, Mining Director of EuroChem talks to FI about the company's latest milestones as it brings two potash mining projects towards fruition in Russia and develops phosphate production in Kazakhstan.

What would you regard as the flagship developments of 2014 throughout the EuroChem portfolio?

It was a year of good accomplishments overall. Sinking the two shafts was finished at the Usolskiy potash complex in Siberia, while the new open pit phosphate mine in Kazakhstan began production. The infrastructure is now in place at the VolgaKaliy potash mine, where we are making fast progress on all three shafts, with all three permanent head frames now in place. The skip shaft No. 1 now extends to 857 m and the hitch with the water seal design has been finalised and installed below the lowest water bearing level and freeze wall level. The production storage area has been started while the huge and very modern electrical sub-station has been fully commissioned. ABB has supplied the sub-station equipment. All surface work at the site is on-going in various stages of progress.

At the Kovdor mine in the Murmansk region, we brought the new apatite line on stream from a new mineral deposit adjacent to the old existing open pit, although all of the processing plant associated with this new deposit will only come on stream later this year.

Finally, we have also increased our resource portfolio and acquired an additional potash mining licence at Usolskiy during the June 2014 auction. Our Usolskiy operations now have a total licence area of 188 km^2, with estimated proven and probable reserves of approximately 2.5 billion tonnes of ore – which conservatively are enough to sustain our operations for 60 years with our current mine plan.

What are your main targets for 2015? Will CAPEX be more or less than in 2014?

The mining CAPEX totalled around $439 million in 2014 just for the potash projects, and we expect to spend a similar sum this year of approximately $1.1 to $1.2 billion for the entire company. This will be mainly spent on the potash projects, with around $460 million earmarked, fairly evenly split between Usolskiy and Volgakaliy. At the Usolskiy site, the main focus will be on the various buildings (administration, canteen, boiler house, mine rescue) and the hoist buildings, head frames and, most importantly, the beneficiation mill. This prepares the way for production in Phase 1 for 2.3 million t/a of potash, with an additional capacity of 1.4 million t/a being added in Phase 2, to give the Usolskiy mine an eventual capacity of 3.7 million t/a.

At VolgaKaliy, shaft sinking will continue, reaching the halite area by early summer with the first shaft. We are also working on the beneficiation plant and product storage building, as well as the administration building and canteen. At both sites, we are working at full speed on the tailings management area.

Are the two potash mines still scheduled to commence production in 2017?

We foresee no significant problems at this stage and are still aiming for the first production in 2017, with the first ore to reach the surface sometime around May 2017.

Would you assess the depreciation of the Rouble currency as being a hindrance to the project developments?

At both mines, most of the equipment which needed to be procured outside Russia was ordered and delivered before the rouble's sharp contraction in the second half of 2014. While 80% of EuroChem's revenues are non-rouble based, around 70% of our costs are rouble-based, a situation which considerably enhances our profitability as well as our competitiveness, since our raw materials costs have fallen sharply in dollar terms. Overall, the weakening of the Russian currency against the US dollar has significantly enhanced the economics of our investment projects in Russia.

In the phosphates sector, you began the first ore production in the Karatau project in Kazakhstan. What is the target production for 2015 and 2016?

We expect to reach our first production, with crushing and screening through to load out by the end of May this year for the phosphate rock mine. This is located at Zhanatas, in the Jambyl region of Kazakhstan. Karatau will be the site for the downstream complex, which we are currently contemplating.

There were a few delays in starting up production, as delivery of the crushers was delayed. Around 180,000 tonnes of ore were produced in 2014 and are currently on the ground at the site. Crushed production is expected to reach around 283,000 tonnes in 2015, and we will ramp up to a capacity of 650,000 t/a of phosphate ore at 28% P_2O_5, before another capacity increase in parallel to the construction and ramp-up of the contemplated fertilizer complex in Katarau. The goal there would be to reach a production level of 1.5 million t/a of phosphate ore.

Any plans for investing in downstream phosphate facilities in Kazakhstan?

Our long-term plan is to go downstream, possibly starting the first downstream production in 2017. A site has been selected and purchased just outside the town of Karatau, due to its proximity to the mine and access to rail. This is approximately 50-60 km from the mine. The rock would be moved by rail between the sites and then onwards by rail to customers.

Do you foresee any opportunities for marketing partnerships when the production of potash gets under way?

It is just our opinion, but Belaruskali seems to be in a good position at present and probably sees no need to get back into partnership with Uralkali. We would not refuse any possible marketing partner, but that partner would need to prove itself as a reliable producer and supplier. We also have our own NPK needs which have to be met first.

Do you plan any increase in NPK capacities in the joint venture with Migao Corporation?

All approvals have now been received from the Chinese authorities for the development of our JV with Migao and the plant is already running a 100,000 t/a NPK line, with a second unit of the same capacity set to come on stream later in 2015. Beyond that, we are considering launching an NK production line, possibly as soon as next year. These are good assets to absorb our potash production when our mines will be running.

If you were to undertake a SWOT exercise for the potash sector for 2015 and immediately beyond, what would your assessment be?

One weakness at present is the softness in the international market price for potash. Regarding threats, one must always be concerned about the threat of flooding at mines, which could disrupt the supply of potash over the longer term. The situations at Solikamsk and Esterhazy are two such examples. On the other hand, any cuts in production as a result of mine flooding can benefit the global potash supply/demand balance.

There are many opportunities to bring new potash production on stream at many locations around the world, especially in Latin America and Asia. However, the production of potash is a very capital-intensive business, so it takes a long time before the first product comes to market. The junior mining companies are facing difficulties in raising funds for their projects. Many of them hope to find richer partners to take their projects forward.

The established potash producers enjoy many strengths meanwhile. They are focused on controlling costs and have sought to minimise their operating costs by making fresh economies, making them better placed for any potential market downturn in the future. Belaruskali now has a strong market presence and is likely to be more influential over the longer term in international markets. One ongoing uncertainty remains that of the subsidy regime in India.

Above: *EuroChem is making fast progress on all three shafts at the VolgaKaliy potash mine.*

Left: *The VolgaKaliy beneficiation mill is now under construction.*

Indian fertilizers usher in a new era

Dr MP Sukumaran Nair, managing director, Travancore Cochin Chemicals Ltd, and former special secretary to the Kerala government's chief minister, asks whether the recent change in government in Delhi heralds a new era for the Indian fertilizer industry.

PHOTO: RAWPIXEL/SHUTTERSTOCK.COM

The two trillion dollar Indian economy looks set to grow at an impressive 8-9% annually under the newly-installed government. But the productive sectors of the economy – agriculture and industry – both need a thorough revamp if the Indian economy is to boost its productivity and regain growth. Wider economic progress on the subcontinent is critically dependent on industrial and agricultural growth being restored.

Economic prospects for the country are also closely linked to other major national challenges such as attaining food security and the revival of manufacturing. The new Indian government has attempted to address these issues in its maiden budget last year. The people of India and the international community are now looking at how Prime Minister Modi will translate this into a pragmatic plan of action.

Ambitious goals on food security boost grain output

Developing the agricultural sector, which provides employment for 65% of the country's work force and contributes 17% to national GDP, is a prime focus. India did attain self-sufficiency in food grain production in the mid-1990s. But per capita availability of food grain subsequently fell back, due to slackening growth and increasing population, returning the country to a situation comparable to that of the 1970s and 1980s.

In response to this, the Indian parliament passed a National Food Security Bill in 2013 making food security mandatory for around two-thirds of the population. The bill expanded a pre-existing food subsidy scheme to cover about 180 million of the country's poor.

They will now receive around 4 million tonnes of food grain every month at a fair price through licensed shops. In effect, nearly 75% of the rural population (630 million) and 50% of urban people (180 million) will be eligible for grain at a cheaper rate in future.

In order to achieve the objectives of the food security bill, India will need to increase its annual grain output – mainly rice, wheat, coarse grains and pulses – from the current 263 million tonnes to 320 million tonnes by 2020. Looking at the trend of the past few years, recent growth in food grain production will not be sufficient for the country to attain mandatory food security and will need to be stepped up. It is also well-established that, on-average, around 55-60% of food production increases are directly attributable to the use of mineral fertilizers to supplement plant nutrient needs.

Grain production and fertilizer production can flourish

The history of agriculture production and the fertilizer industry in India shows that, in the 20 year period between 1980 and 2000, grain production and indigenous fertilizer production flourished together, ably guided by forward-looking policies and a strong political will. This led to self-sufficiency in both food grain production and in the production of urea, the major fertilizer material being consumed. Since then, there has been no investment in the fertilizer sector in the country and the growth in grain production has also slackened and lost momentum. India therefore finds itself in the difficult situation today of being a major fertilizer importing country, with its agricultural productivity also declining.

Indian grain production has slackened.

Fertilizer imports have risen due to the stagnation in domestic production at a time when domestic demand is growing at about 5-6% per annum. The loss of agricultural productivity is also widely blamed on the lack of diligence in applying in fertilizers to our farm lands. The government has tried to address both these issues but with little success. Our per hectare consumption of plant nutrients remains low compared to China and other developing agrarian countries, even though India is the world's second largest consumer, third largest producer and largest importer of fertilizer materials.

A subsidised market distorts application rates

Fertilizers remain heavily subsidised in India. All fertilizer materials, with the exception of urea, are placed under the nutrient based subsidy (NBS) scheme. This allows producer companies to sell at the market price with the government paying a fixed subsidy per tonne of material as a top-up. Urea, in contrast, is sold in India at a government-set price under a separately-administered scheme. The government reimburses urea producers for the cost of production plus a 12% return on net worth. The fixed price for urea is currently INR 5,360 per tonne and the government subsidy rate is INR 11,760 per tonne. The low price of urea, compared to other fertilizer nutrients, has skewed its usage resulting in a drastic upset in the soil nutrient ratio away from the 4:2:1 optimum for NPK. A recent survey indicated that this ratio has been distorted to around 8.2:3.2:1. Unsurprisingly, this has resulted in steep decline in farm yields. Indian farmers are using nearly 5 million tonnes of urea in excess of the actual soil demand as a direct consequence of urea being sold at very low prices. Under the partly-implemented NBS scheme, the prices of phosphate, potassium and complex fertilizers have also skyrocketed and became unaffordable to small and marginal farmers. This has created an alarming situation in certain parts of India's farming land.

Main agriculture-related fertilizer issues

In summary, India is currently faced with a complex array of challenges, as follows:

- **Growing fertilizer consumption:** The current consumption of 140Kg/ha is still low compared to other agriculturally advanced countries and needs adjustment to ensure a stable and sustainable soil NPK ratio.
- **Inefficient fertilizer application:** The soil nutrient requirement is not given adequate importance in the current application of fertilizers. Price and availability have been the primary consideration. The resulting upset in the soil nutrient ratio has led to lower yields.
- **Increasing import of fertilizer materials:** Imports have gone up considerably over the past decade. India is at present the world's largest importer of N,P and K combined. This has also upset the financial balance of the government's budget.
- **Food security bill:** In order to meet the grain demand set out in the National Food Security Bill, the crop productivity of India's farm land has to rise. Among other things, this requires the prudent application and increasing consumption of plant nutrients based on a correct assessment of soil fertility.

Policy prescriptions

The Government has come up with the following multi-pronged strategy to tackle the above challenges:

- **Increase in domestic urea production:** There has been no new investment in urea plants since 1995 with most of the country's plants operating near to their rated capacity. The government has developed a policy to promote new investment in brownfield and greenfield plants to address this. But much-needed extra investment has failed to materialise so far, despite a series of modifications to urea investment policy over the past few years. The supply of natural gas remains a major hurdle. The shortfall in natural gas production from the Krishna Godavari (KG) fields and increases in liquefied natural gas (LNG) costs have largely counteracted government incentives to produce more urea.
- **Balanced use of fertilizer nutrients:** The Government is planning a massive programme for testing the soil nutrient requirements of farm land to achieve more diligent application of fertilizers. The recent budget proposal to distribute soil health cards to farmers is a step in the right direction. However, the exclusion of urea, a major source of nitrogen, has virtually defeated the good intentions of the NBS scheme. This makes a scientific review of urea's exclusion from the NBS, based on recent experiences, almost inevitable.
- **Balanced import programme:** The Indian government – in the wake of increasing fertilizer consumption, rising imports and a large outflow of foreign exchange – has adopted a three-fold approach to this situation. Indian producers are being encouraged to enter into long-term supply contracts with foreign suppliers, set up joint ventures with overseas producers and buy-up fertilizer assets abroad. Addressing policy gaps to get such ventures off the ground and encourage prospective investors is a matter of immediacy for the government.
- **Curbing leakage in the transfer of subsidies:** Fertilizer producers are paid subsidies based on the quantities they send to the market under the current administration of the scheme. But instances of large-scale manipulation of this system have been observed. To overcome this, the government is upgrading information technology to allow the direct transfer of subsidy payments to farmers to be rolled-out nationally. A speedy implementation of this system is warranted.

Future outlook

In the near- and medium-term, imports of fertilizer raw materials, intermediates and finished products are only likely to increase. For a normal monsoon situation, it is reasonable to expect a 5-6% growth in the consumption of applied fertilizers. India's nitrogen fertilizer operating plants are also working at close to rated capacity. Most of these plants have undergone retrofits and revamps to maximise their outputs – so it is not realistic to expect any extra capacity from such plants. That leaves more and more imports every year as the most likely scenario. Even a decision to build new plant capacity today would only yield extra product after four years, meaning that imports will inevitably rise in the near-term.

Shortage of natural gas is the main hurdle for expanding nitrogen capacity. China, facing a similar situation, built a string of ammonia and urea plants based on coal gasification which are operating economically. India has some experience of operating coal-based ammonia plants at Ramagundam and Talcher, although technical problems finally resulted in the abandonment of coal technology and their closure. However, coal gasification technology has moved on since then and become more stable, environmentally-friendly and profitable. The availability of clean coal technology means coal gasification could be a major avenue for the future production of ammonia in India. The country has now developed a total capability from first concept to the design, development, procurement and planning and implementation of world class ammonia and urea plants.

The fertilizer industry enjoys priority allocation of natural gas. Still, the decline in production from domestic fields, especially KG D6, and the prevailing high cost of LNG spot procurement, affects the economics of existing plants and realisation of their full capacities. Expanding the domestic production of natural gas does require more focus. But the import of LNG and its regasification is being explored by government to make up for these natural gas shortages. Currently, four LNG terminals are in operations in the country: Dehej and Hazira in Gujarat; Dabhol in Maharashtra; and Cochin in Kerala. A few others are also planned on India's western and eastern coasts.

But utilisation of LNG capacity at all these terminals remains low, with the exception of Dahej. This is largely a consequence of the lack of viable long-term supply contracts for LNG, as well as wide distortions in the pricing of domestically-produced natural gas and regasified LNG. It is essential that a nationwide pipeline network is put in place to overcome this precarious situation. A rationalised pooling of gas prices, like any other petroleum fuel, also looks inevitable.

Encouragingly, the world's first urea plant based on coal bed methane is being built by Matix Fertilisers and Chemicals in Panagarh, West Bengal. Construction is close to completion, although the supply of feedstock from the Ranigunj coalfields has yet to be established. Such policy indecision risks undermining the huge investment made and could discourage investors forever.

In the phosphate sector, the tremendous increase in the price of products in the overseas market has also affected India, especially after the adoption of its nutrient-based pricing strategy for P & K fertilizers. The free import of rock phosphate and sulphur raw materials has become critical and, consequently, operating margins are declining. Securing access to raw materials may require Indian manufactures to enter into long-term contracts with overseas suppliers, operate joint ventures in countries where these are available, or acquire fertilizer assets abroad for development and production for the Indian market.

Similar joint ventures or asset acquisitions may also be necessary In the case of potash, as India does not have any sources of indigenous supply and the country's whole requirement is met by imports.

Speciality fertilizers and micro nutrients

Agriculture in general, and food grain production in particular, is going through a sea change globally. Precision agriculture fertigation, integrated nutrients supply and administration of plant nutrients based on soil analysis are all becoming accepted as basic tenets of crop productivity improvement.

Secondary and micro nutrients play a vital role in this regard. The soil in certain part of India is known to be grossly deficient in sulphur and zinc, for example. Specially designed nutrient formulations, fortified with micro nutrients, have become essential for sustaining productivity during intensive cultivation.

The United Progressive Alliance (UPA) government of the last ten years meddled with fertilizer policy on several occasions. This proved to be futile every time and investor interest in the fertilizer sector has faded away during the last decade and a half. Fertilizer projects are also highly capital- and energy-intensive. A range of factors have held back the Indian fertilizer industry and limited the impetus for growth. These include insufficient incentives for investment, uncertainty in pricing and the subsidy regime, enormous delays in the disbursement of subsidies and materials becoming more readily available on the international market.

However, the budgetary boost to agriculture and industry is a welcome signal. The extension of gas pipelines by another 15,000 kilometres, a renewed thrust on access to coal bed methane and the thorough revamp of fertilizer policy proposed in last year's budget are all expected to usher in a new era in the development of the fertilizer industry in India.

Working with China's farmers on balanced fertilizer use

Fertilizer production and consumption have grown steadily in China over the past two decades. The Chinese government has educated farmers in modern husbandry methods as part of its efforts to expand national food production. This has led to greater use of chemical fertilizer and improvements in agricultural technology across many parts of the country.

One organization with a long history of supporting China's growing food production needs – particularly the adoption of balanced, site-specific fertilizer use – is the International Plant Nutrition Institute (IPNI). IPNI runs separate regional support programmes covering five continents – China, India, Southeast Asia, Africa, and Central and South America – as part of its overall global strategy. China remains an important part of IPNI's worldwide work due to its huge population and vast geographical size.

"China is a big country and fertilizer consumption is large. We consume about one third of the world's fertilizer supply, so this is an important fertilizer market and fertilizer use here is very important," says Dr Ping He, the current director of IPNI's China programme and a research professor at the Institute of Agricultural Resources and Regional Planning in Beijing, part of the Chinese Academy of Agricultural Sciences.

"China has a big population so food security and balanced fertilizer application is important as well: how to increase fertilizer usage efficiency, including how to improve soil fertility, how to obtain better crop yields from limited arable land – and how to protect the environment," adds Dr He.

IPNI's involvement in China dates back several decades to an earlier Potash & Phosphate Institute (PPI) and Potash & Phosphate Institute of Canada (PPIC) programme launched under Dr Sam Portch in the 1980s. PPI/PPIC's original China programme carried out much-needed research

In an exclusive interview, **Dr Ping He** of the Chinese Academy of Agricultural Sciences talks about her role at International Plant Nutrition Institute and its important work in China.

on the country's soil types and crop needs. A large field trial programme enabled farmers to view at first hand the beneficial effect of balanced fertilizer application.

IPNI's subsequent activities and strategy in China have evolved in response to agricultural sector developments – particularly the changing fertilizer education and training needs of the country's farmers.

"Since 2007 we have focused more on fertilizer science in our research and field trial work in China," Dr He explains. "In the past we focused mostly on P and K, now the focus includes N. We are also looking more at the environment, which is a global trend, and the impact from fertilizer use.

"Misuse of fertilizer and its relationship with the environment are important issues in China. Inappropriate use, especially of N and P, has resulted in an imbalance and consequently low fertilizer use efficiency in some areas of the country."

Regional variations

Agriculture development varies in different parts of China due to a numberof factors. Although the level of agricultural development generally reflects overall economic development in the region, geography and climate also play an important role, according to Dr He. Agricultural in northern and eastern China is more developed than in western China, for example, with southern China also being more agriculturally advanced than western provinces.

"The problem for agriculture in western China is the water shortage, so the government is promoting irrigation schemes there," says Dr He. "If more water is available there will be greater agricultural production potential in the western region.

"In southern China there is a lot of water for agriculture as there are a lot of rivers. A very big government project already has started to transfer water from the south to northern and western China by rivers and canals."

Changing demographics

One issue that is influencing INPI's work in China is the changing demographic profile of the country's farming sector, including farm size, organization, management and the type of the staff employed.

"One of the challenges is – who will farm in future? Farms are increasing in size as the government is promoting large-scale, efficient farms," says Dr He. "Labour costs are increasing, but farm profits are not very high. Farmers' cooperatives rent the land to operate large scale farms – there are subsidies for this. The first subsidies were for cereals, cash crops and fruit.

"These subsidies are for the whole of China and can cover the energy cost of operating big machinery. Subsidies also may be based on the land size involved.

"The amount of arable land in China is about 0.1 hectare per capita. This figure is very low, so land ownership is fragmented and farmers' profits are low."

Rising labour costs are a growing issue for China's farming sector due to the growing number of farmers who are choosing to move to cities in search of higher paid jobs. This, in turn, pushes up farming costs by causing wage rates in rural areas to rise. Farms are also becoming increasingly automated as they attempt to to reduce the amount of labour needed.

"Labour costs are high, so when we decide to organize a field trial and need labour for samples, we have to pay more than previously. If farmers leave the land to work in the construction or service industries, they can earn more than from farming," says Dr He.

Science-based technology on bigger farms

One very clear and discernible trend in China's agricultural sector over the past two decades has been the increase in the size of individual farms. Farms have grown in size by renting land from others, such as absentee farmers who have left to work in cities or retired farmers whose children have left home to become migrant workers. IPNI has modified its fertilizer technology support programme to accommodate larger farm sizes.

"There have been some changes in our China programme because of the change from small to large scale farming," says Dr He. "It's easier for big farms to apply science-based technology, so we hope in future to see new technology being used by the big farms and that fertilizer use efficiency will be improved.

"Precision agriculture and site specific nutrient management can be used for large area farms. Our China programme is focused on how to improve nutrient use efficiency for many crops including wheat, rice, maize, and now soy bean.

"In southern China these include cash crops such as bananas, sugar cane, and rape seed for cooking oil. In north-western China these crops include potatoes, cotton and water melon."

Nutrient expert consulting meeting with co-operators.

Free fertilizer application help

Small farmers still have an important role to play in ensuring stable food supplies in China, despite the trend towards large farms. One of IPNI's largest projects in China is the newly-launched **Nutrient Expert** fertilizer recommendation system. IPNI is using the system to provide small farmers in a number of countries with better access to accurate, site-specific fertilizer application advice.

"We use Nutrient Expert to make recommendations for small farmers where tools for fertilizer testing are not available," Dr He explains. "We are also doing Nutrient Expert in India, South Asia, Southeast Asia and Africa.

"The idea is to develop local technicians and fertilizer distributors to calculate recommended fertilizer application amounts for farmers."

IPNI has collected a large amount of data to support its nutrient application development programme from its 20 years of experience working with agricultural universities, soil institutes, fertilizer suppliers and farmers growing a wide variety of crops across China.

"We only need the site information from the farmer, such as the fertilization history, how much fertilizer is applied, the target crop, the land area used, the crop yield, and the attainable yield," says Dr He. "Nutrient Expert will calculate the fertilizer rate, the place of application and the application timing.

"This service is free as IPNI is a non-profit organization. Nutrient Expert software can be downloaded from the internet, then we can train the cooperative technicians by webinar or onsite training."

The Nutrient Expert project is a work in progress. IPNI plans to make new versions of Nutrient Expert freely available as its capability expands and improves. It plans to add fertilizer application recommendations for new crops to the software in addition to those already covered.

"We did field experiments and validation over a five year period in China," says Dr He. "After we were confident, we released the information to the public.

"In 2013 we released Fertilizer Expert Version 1.0 in China, covering wheat and maize. Currently we are working on soya bean and rice recommendations for the next Fertilizer Expert version for China."

Dr He adds: "Maybe we can release the soya bean version in 2015. We need at least three years of field research validity, but we will not stop working on these, and will regularly update them."

Correcting chemical nutrient overuse

IPNI's work is helping correct some unwanted new trends in fertilizer use in China – particularly the overuse of chemical nutrients.

Although single-source nutrient application is advantageous for scientific research, in practice, most farmers prefer easier-to-use compound fertilizers, usually combined with a single-source top dressing. Many rice and wheat farmers, for example, use compound fertilizers such as 15-15-15, 16-16-16 or 17-17-17 and then top dress with urea, according to Dr He.

"There is an increasing trend for compound fertilizers to be used – farmers prefer compound fertilizers for almost all crops," says Dr He. "Farmers want one application containing all nutrients, but the ratio is not always correct for their crop and soil.

"The problem is that farmers often cannot calculate the right nutrient ratio. They just follow their neighbour or the general farming industry recommendations and this can cause over-fertilization – for example, with 15-15-15, you can over apply P."

IPNI's Nutrient Expert application helps ensure proper use of fertilizers by enabling soil and fertilizer technicians and companies selling fertilizers to calculate the correct ratio of nutrients that farmers should be using – tailored to their particular crop and farm soil conditions.

"IPNI research uses single fertilizers to calculate how much nutrient to use. But when they use Nutrient Expert farmers can select compound fertilizers or a single source fertilizer and compensate for their own specific conditions," says De He.

"IPNI developed Nutrient Expert to improve recommendations for nitrogen and phosphorus use in intensified systems where maybe they are not balanced with potassium. Inappropriate nutrient use mostly occurs in intensified agricultural areas in China, but in western China nutrients generally are not over-applied."

Nutrient management and younger farm managers

The fertilizer market situation currently facing the agricultural sector is quite different to the state of affairs 30 years ago when IPNI first started work in China. Nutrient deficiencies still exist but are different to those of the mid-1980s when most of China's agrarian sector was managed under the commune farming system.

"Previously there was a very large potassium deficiency but, with the PPIC programme, balanced nutrients have been promoted," comments Dr He. "Science and international cooperation have improved nutrient management in China."

> **"IPNI has developed four Rs protocols for fertilizer to be used at the right time, in the right place, using the right sources and in the right amount.**

Changes to Chinese farming since the early 1990s have also led to a new generation of farmers and farm managers arriving on the scene. They also need to be supplied with fertilizer application recommendations and information about balanced nutrients.

"Many farmers are older people," Dr He explains. "There are young farmers as well but they are more like land managers.

"The older farmers need help as they are people who work in the fields. The younger land managers who rent farms also need help with fertilizer application and other farming technology."

Nutrient expert field validation in Jilin Province.

Dr He adds: "Commercial technical information is important to young farm managers and older people working in the fields. The government is doing a soil testing programme through the Ministry of Agriculture's provincial level organization.

"This includes scientists working with soil and fertilizer technicians for crop specific recommendations for rice, cereals and other cash crops."

The four Rs of nutrient stewardship

In addition to Nutrient Expert, another of IPNI's international programmes which has recently been introduced in China is the **4R Nutrient Stewardship** system aimed at agricultural scientists and technicians.

"Fertilizer often is not applied at the right time, in the right place, with the right sources and in the right amount so we developed IPNI's four Rs fertilizer management system," Dr He explains. "IPNI has developed four Rs protocols for fertilizer to be used at the right time, in the right place, using the right sources and in the right amount.

"We have developed four Rs programme brochures for different crops and have just published four Rs booklets in English, Chinese and some other languages. These booklets are designed for soil scientists and technicians."

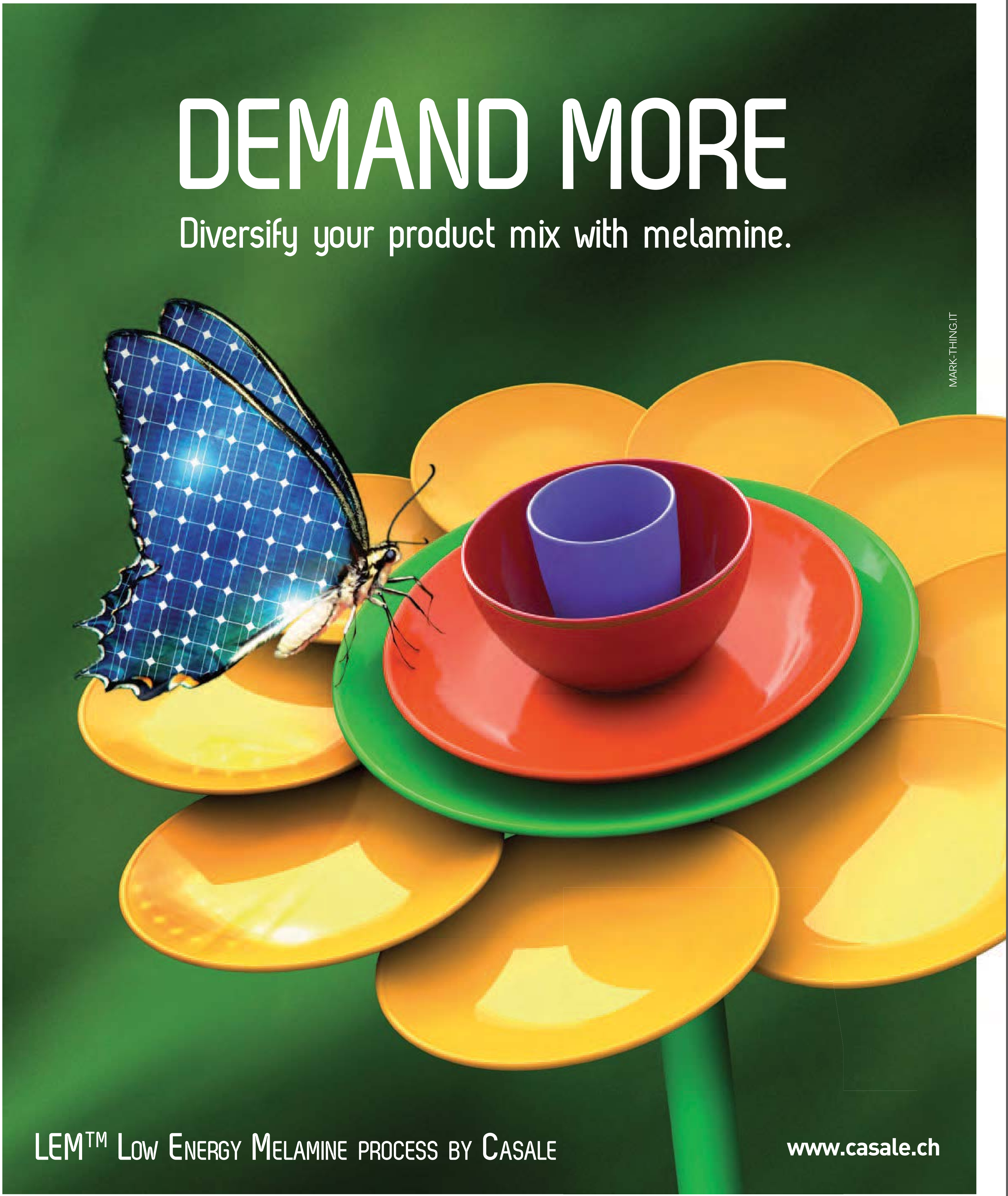
IPNI is using a variety of existing approaches and new media to reach out to farmers, fertilizer suppliers, soil technicians and agricultural scientists.

"With farmers we use videos and brochures at present. But we will also develop a mobile phone SMS messaging system under IPNI's Nutrient Expert programme in the next few years as it will be more convenient for farmers to access this information," Dr He explains.

The China fertilizer programme is one of IPNI's largest single-country programmes due to the vast volume of fertilizers consumed nationally and the enormous size of China's agricultural sector.

"China is responsible for about one third of the world's total fertilizer consumption, so balanced nutrition is very important," Dr He concludes. "However, the today's challenges are different to those before.

"In the past, there was a nutrient imbalance through insufficient use. But now there is fertilizer overuse – so we focus on nutrient efficiency and environmental issues."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The alternatives to natural gas

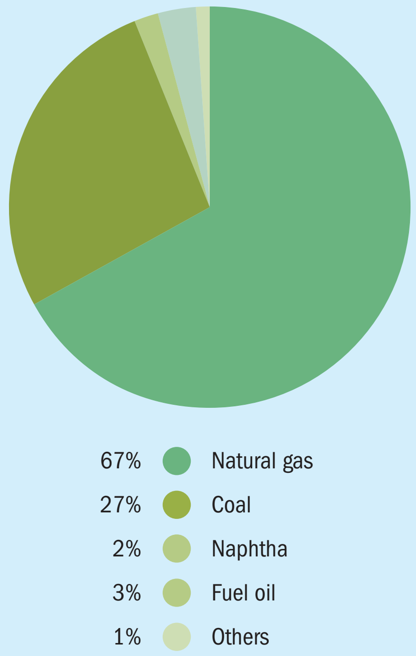
Recent developments in the gas, coal energy and other sectors and their potential impact on fertilizer production capability are outlined.

Table 1: **Natural gas production, consumption and reserves** (2013)
Billion cubic metres (bcm)

	Production	Consumption	Net balance	Reserves
World total	**3,370**	**3,350**	**+20**	**185,000**
United States	688	737	-49	9,300
Russia	605	414	+191	31,000
Iran	167	162	-5	33,800
Qatar	159	26	+133	24,700
Canada	155	104	+51	2,000
China	117	163	-46	3,300
Norway	109	4	+105	900
Saudi Arabia	103	103	-	8,200
Algeria	79	32	+47	4,500
Indonesia	70	38	+32	2,900
Egypt	56	51	+5	1,800
UAE	56	68	-12	6,100

Source: BP, via Nitrogen+Syngas

Fig 1: **World ammonia capacity by feedstock** (2012)



Source: IFA, via KBR

In its medium-term outlook for fertilizers' and raw materials' global supply (Michel Prud'homme [May 2014].), IFA notes that feedstock for the production of ammonia continues to evolve in favour of natural gas and coal. In addition, there are niches for a variety of less conventional feedstocks, including coke oven gas, petroleum coke, naphtha, biomass and gasified municipal waste. The shares of these niche feedstocks are forecast to remain static of the next five years, accounting for a forecast 7.6 million t/a of world ammonia capacity in 2019, but they may become more significant in the longer term.

Table 1 shows production, consumption and reserves of the major gas producing and consuming countries around the world. In terms of reserves, Russia and the Middle East (led by Qatar and Iran) enjoy the largest reserves. On the production side, output from the United States continues to increase, overtaking Russia as the world's largest producer in 2009. The United States also holds a substantial lead as the largest gas consumer and still runs at a slight net deficit. There has been a notable ramp up of production capacity in Iran and Qatar, while Egypt's rising consumption (especially in the wake of increased ammonia and urea capacity) means that the country could before long become a net gas importer: supplies of natural gas to the country's ammonia and urea complexes have already been disrupted by sporadic gas shortages.

China has also seen a major increase in gas production, including from unconventional sources, but this has failed to keep pace with the country's burgeoning demand.

Russia is the world's largest exporter of gas, via pipeline to Europe, while Qatar is the second largest, mainly comprising LNG. Overall, the Middle East and North Africa are the largest export regions, while Asia is the largest net consumer. Egypt has been a net exporter, but rising domestic demand will see its own exports dry up. Algeria has some spare gas capacity and is engaged in expanding the downstream production of ammonia. (*Global gas markets*, **Nitrogen+Syngas** No. 333 [January-February 2015].)

Chinese gas consumption is rising the fastest of any major nation, having doubled between 2008 and 2013. The country imports around 52 bcm/year, about half by LNG and the remainder via pipeline from Turkmenistan. China is also stepping up its production of unconventional gas, including sour gas and coal bed methane. There is also rising shale gas production.

Despite the increased gas output, demand continues to outpace domestic supply, and while coal continues to be relatively cheap, it remains a preferred fuel for much of the country's syngas production.

Natural gas remains the first choice

For the moment, natural gas will remain the predominant feedstock used in the production of ammonia from the Haber-Bosch process. IFA estimates that this feedstock will contribute 66% of global ammonia capacity in 2016, equating to 165 million t/a of total ammonia capacity. Virtually all new projects in South America, Europe, Africa and South Asia will be based on natural gas. The main exceptions are in India and Australia, where several projects based on coal or coal bed methane have been mooted.

Between 2013 and 2018, 80% of all new ammonia capacity will be based on natural gas. The remaining 20% will be based on coal and other feedstocks, occurring mainly in China and a few other Asian countries. (Fig. 1) Coal and petroleum coke are expected to represent 30% of the feedstock for ammonia in 2018, equivalent to 73 million t/a of ammonia capacity. China is forecast to contribute 95% of this coal-based ammonia capacity. Out of the 25 new ammonia plants expected to be completed within the next five years in China, 22 will be based on coal.

Ammonia plants have become ever more efficient in their use of feedstocks. The production of ammonia synthesis gas, consisting of pure hydrogen and nitrogen, is the largest single contributor of the production cost of ammonia, accounting for a typical 70% of the total. Advances in the technology for the generation of synthesis gas have enabled net energy consumption to be reduced, from approximately 88 GJ/t ammonia in the days of coke-based water-gas generators to approximately 28 GJ/t ammonia today in the use of natural gas in a steam reforming unit.

Ammonia plant capacities have also increased, with single-train units now capable of achieving well in excess of 2,000 t/d. The gas consumption for a stand-alone ammonia plant of this size is approximately 20 million Btu/t of ammonia product, based on the lower heating value (LHV) of the feed gas. For a feed gas with LHV of 917 Btu/scf, a 2,000 t/d ammonia plant requires approximately 63 MMscf/day of feed gas. If the entire ammonia product is converted to urea, the gas consumption will increase to approximately 36 million Btu/t of ammonia product. For an ammonia/urea complex with a capacity of 2,000 t/d ammonia, the feed gas consumption will be approximately 79 MMscf/day. A gas field of at least 0.7 tcf is required to support this gas consumption over a project life of 20 years.

The quantity of gas required for a single-train ammonia plant is small when compared with LNG, gas-to-liquids (GTL) and methanol plants. As the future trend in ammonia plants is towards ever larger capacities, going beyond 3,000 t/d, such plants will be located with easy access to low-cost gas supplies.

The coal alternative

Since natural gas has one of the highest proportions of hydrogen among all fossil fuel feedstocks, it is one of the most suited raw materials for ammonia production, However, synthesis gas produced from coal presents a feasible alternative feedstock for ammonia production, and until the recent downturn in global energy prices, there had been increasing interest in harnessing coal-derived gas feedstock. Coal as feedstock for hydrogen production is predominantly used in China and is generally characterised by high energy consumption and CO_2 emissions.

It has been estimated that there are over 847 billion tonnes of proven coal reserves worldwide. (*Coal Gasification Technology for Ammonia Plants*, B. Anantharaman et al, KBR Inc. Paper presented at **Nitrogen+Syngas 2012**.) These reserves are estimated to last around 115 years at current rates of production. By contrast, gas reserves are equivalent to around 55-60 years at current production levels. The largest coal reserves are in the United States, Russia, China and India.

KBR is one of several companies to have developed technology for ammonia production from the coal gasification route. The process description is summarised as follows:

- Coal preparation: dried, pulverised coal is fed to the pressurised gasifier unit. The coal feed fluidises as it enters the gasifier.
- The air separation unit supplies pure O_2 to the gasifier and pure gaseous N_2 to the ammonia synthesis loop.
- In the coal gasification stage, partially dried, pulverised coal, O_2 and steam are fed to the gasifier. Coal gasification reactions take place in the resulting fluidised bed. Steam is added to the gasifier, both as a reactant and as a moderator to control the reaction temperature at about 980°C.
- To maximise the production of H_2 for making ammonia, carbon monoxide is reacted with steam catalytically in a water gas shift reactor to form CO_2 and H_2.
- To recover heat and remove mercury, shift effluent is cooled and syngas free of condensate is passed through a mercury removal guard bed of activated carbon.
- In the acid gas removal unit, the bulk of the acid gases in syngas are removed. After sulphur polishing, the recovered CO_2 can be sent to a urea plant.
- Elemental sulphur can be removed from the H_2S stream from the overhead of solvent stripper in a sulphur recovery unit.
- Syngas leaving the acid gas removal unit is sent to the nitrogen wash or pressure swing adsorption unit to recover hydrogen at more than 99.5% mol purity.
- The remaining components in the syngas, along with the unrecovered H_2 concentrate in the tail gas, are sent for reforming. The H_2 from the nitrogen wash unit is mixed with high-purity N from the air separation unit in a 3:1 molar ratio.

KBR estimated the financial and operating costs of a 2,000 t/d coal-to-ammonia plant, assuming a cost of coal of $20/t (equivalent to $1/mmBtu) and an electricity cost of $100/mWh. Based on prices prevailing in 2012, KBR estimated a cost of ammonia production that corresponded to an internal rate of return of 15% at $215/t. This demonstrated that a coal-to-ammonia plant is economically viable while ammonia prices are in excess of around $350/t.

China historically has developed a considerable nitrogen fertilizer industry based on coal gasification to produce ammonia. Initially, this was for ammonium bicarbonate production and later urea. (*Unconventional feedstocks for syngas production*, **Nitrogen+Syngas** No. 329 [May-June 2014].) The Gasification Technologies Council (GTC) indicates that of the ten largest gasification plants in existence, five are in China, while of the 20 largest plants currently under construction all but three are in China. China previously used older gasification technology which required the use of more expensive anthracite coal, but is now switching to newer technologies which are able to use cheaper bituminous and sub-bituminous coals.

Other countries have also considered coal gasification as a way of valorising their

Linc Energy's UCG demonstration plant in Queensland, Australia.

large coal reserves, but India – perhaps the country in the most similar position to China – has lagged behind in development. In one notable project, Rashtriya Chemicals and Fertilizers (RCF), Coal India Ltd. (CIL) and Gas Association of India Ltd. (GAIL) are jointly developing a coal gasification facility. The project envisages the reopening of an idled urea fertilizer plant in Talcher, Odisha state, converting it to produce 1.2 million t/a of urea and ammonium nitrate through coal gasification. CIL will supply about 5 million t/a of coal for the project. The target date for commissioning the plant is 2017.

In Australia, Liberty Resources announced plans for an integrated complex in Denison, Queensland that will use in-situ coal gasification to produce 1 million t/a each of ammonia and urea. It set up a subsidiary, Urea Corporation of Australia Pty., to pursue the project. Marubeni was reported to have contracted for the output. A production site at Injune, central Queensland has been mooted, and the project scope has incorporated preliminary costs associated with an ammonia and CO_2 gas pipeline to a urea plant located at the port of Gladstone. This project was announced in January 2013. Following the planned acquisition of an IT company in late 2014, Liberty Resources indicated that it was intending to sell Urea Corporation of Australia.

Coal gasification projects have gained some traction in the United States. In September 2014, the Middle Eastern fertilizer and petrochemicals developer and investment conglomerate Egypt Kuwait Holding Co. (EKH) announced plans to develop a nitrogen complex in Idaho, at an estimated cost of between $2-2.3 billion. The complex is expected to have the capacity to produce 1.3 million t/a of ammonia, urea and UAN. Reports suggest that EKH already has an investor in the Egyptian nitrogen producer, AlexFert. The latter company's potential interest reflects the current uncertainty over long-term feedstock availability in Egypt, where shortages of natural gas have interrupted domestic ammonia production.

In one of the biggest projects of its kind, Dakota Gasification Company (DGC) has awarded the contract for detailed engineering and procurement services to IHI E&C International for its planned production of urea at the Great Plains Synfuels Plant, near Beulah, North Dakota. The proposed plant would produce 1,100 s.ton/d of urea and is planned for completion in 2017. The Beulah facility currently uses coal gasification to produce natural gas, which in turn is consumed to support a 391,000 s.ton/a ammonia plant.

In April 2014, DGC signed a construction contract and licence agreement with Stamicarbon. The contract covers the construction of the urea melt, granulation and diesel exhaust fluid (DEF) production facilities at the Beulah site, using Stamicarbon's technology. The Great Plains Synfuels Plant is the only commercial-scale coal gasification plant in the United States that produces ammonia and associated downstream products.

Coal's main disadvantage as a feedstock is that it has low ratio of hydrogen to carbon, particularly compared with natural gas, and so emits a larger proportion of CO_2 when oxidised: in syngas generation, coal emits about 50% more CO_2 than natural gas. As a way of avoiding carbon emissions, collection and disposal of the CO_2 has been suggested, in the form of carbon capture and storage (CCS). It has been suggested that coal gasification lends itself more easily to CCS, as it is easier

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68

Aerial view of the Air Products' renewable energy facility.

to capture the CO_2 when it is entrained in a process gas flow rather than when it is burned.

Underground coal gasification

Underground coal gasification (UCG) gasifies the coal in situ at the actual seam, drilling down into it and blowing air or oxygen into the seam, using the pressure of groundwater to supply process steam and contain the reaction. Earlier attempts to apply the technology enjoyed very limited success, the process proving variable and hard to control. Recent developments in horizontal drilling and advanced process control have sought to address these issues, and proponents of UCG argue that it produces a ready-made deposit space for carbon capture and storage, while the overall coast of the process is reduced by the elimination of the above-ground gasification reactor. Three UCG pilot plants were built in Queensland, Australia during the 2000s. In Australia, which is rich in coal reserves, Linc Energy has refined the UCG process for cleaner gas, using a Fischer-Tropsch reactor. This reactor contains a catalyst to transform the clean gas into liquid hydrocarbons. Linc Energy is now developing UCG projects in Poland, South Africa, the United States (Alaska and Wyoming) and China, but cash flow issues are reported to have led the company to diversify into conventional coal and tight oil production to provide revenue streams. The sole commercial UCG plant in operation is run by Yerostigaz in Uzbekistan, supplying gas to a nearby power station. Linc Energy acquired Yerostigaz in 2007.

Petcoke gasification

The Coffeyville refinery in Kansas, United States produces ammonia and other downstream products from petroleum coke. Coffeyville Resources Nitrogen Fertilizers (CRNF) is a wholly-owned subsidiary of CVR Partners LP and directly owns and operates the CVR Partners nitrogen fertilizer plant. The facility produces ammonia and UAN fertilizers and is the only operation in the North America that uses a petcoke gasification process to make hydrogen. It produces about 5% of total UAN demand in the United States. In 2014, CRNF produced 388,900 s.tons of ammonia, of which 28,300 net tons were available for sale, and 963,700 s.tons of UAN.

Global supplies of petroleum coke are around 140 million t/a and there was growing interest in harnessing this feedstock source for chemicals production in the United States when gas prices were rising in the early 2000s. However, the subsequent fall in prices caused by the exploitation of shale gas resources led interest to wane.

Biomass and municipal waste

The possibility of using biomass as a gasification feedstock has gained wider interest, prompted by concerns about carbon emissions from other processes. However, biomass presents problems which do not arise with other gasification technologies. In particular, the energy density of biomass tends to be low, requiring much effort to be expended in gathering and concentrating it. Biomass may also contain significant amounts of water, which can make the gasification process less efficient and requires more heat energy input.

The so-called "energy crops" used in biofuel manufacture, such as corn or sugar for ethanol, and rape or palm oil for biodiesel manufacture either use food crops or require land which might otherwise be used for growing food crops, and this has prompted warnings of food price inflation and food scarcity in some of parts of the world when demand peaks. Gasification can overcome this problem as it can use residues from food production and non-edible plants or plant parts, including cellulose, and those do not necessarily compete for agricultural resources.

To date, successful uses of biomass gasification have tended to use feeds from existing industrial processes, notably in pulp and paper manufacture and wood processing. Many of these installations have been just pilot plants or demonstration units for the technology and have tended to rely on significant tax breaks or injections of public money as part of green energy schemes. Given the high cost of gathering and preparing the biomass means that some form of tax credit or other grant will remain necessary to prompt any investment in biomass feedstock projects.

Local municipal authorities tackle large volumes of household waste, a large proportion of which cannot be recycled and must be sent to landfill. However, fewer sites are available for landfill and there is increasing environmental concern over methane escaping from established sites. Many authorities have looked at incineration as a way of disposing of waste while recovering some energy value from the waste. Now gasification is becoming of increasing interest as an alternative to incineration, being much more efficient as well as recovering up to twice the amount of energy per tonne of waste (at around 1,000 kWh instead of 550 kWh). An entrained process stream also makes gas clean-up easier, allowing the removal of heavy metals, such as mercury, which are known hazard of waste incineration.

Globally, usable tonnages of municipal waste have been estimated at more than 2 billion t/a. Air Products is currently building a renewable energy facility at Billingham, Teesside, UK, which was once the home for much of ICI's ammonia and fertilizer production. The facility will comprise two plants with the capacity for 350,000 t/a and will use advanced gas plasma gasification energy-from-waste technology licensed from AlterNRG. The facility will generate approximately 49.9 mW of electricity per plant, while diverting over 350,000 t/a per plant/year of non-recyclable waste from landfill.

While natural gas and coal are the established feedstocks for ammonia and syngas production, other energy sources are being developed that may become economical alternatives in the longer term. Even while global energy prices are at a low ebb and present, many countries continue to seek a reduced dependency on imported energy or hydrocarbons. The renewed focus on coal gasification is being led by China and also Australia, and other Asian countries (including India, Vietnam and Indonesia) are also likely to be interested. The impetus to harness alternative feedstocks is therefore likely to continue, and ammonia technology licensing companies are certainly showing interest. ■

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47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68

Innovations boost plant efficiencies

Developments in urea plant design have been driven by the construction of large-scale single-unit grass-roots facilities, together with the application of new materials with improved corrosion resistance and mechanical strength, revamps of existing facilities, as well as developments in granulation and cooling/conditioning technology.

While a world-scale grass-roots urea plant will today cost comfortably in excess of $1-2 billion, many established producers continue to seek enhanced capacity and efficiencies from their existing operations. Specialist technology suppliers have continued to find innovative ways of boosting plant capacity and reliability, at relatively low capital costs. Casale S.A. is a world leader in the revamping sector, and its Split Flow and Full Condenser technologies provide an advanced and proven way to boost CO_2 stripping plants, while Casale's Vortex Granulation technology has been developed most recently to boost the capacity of urea prilling plants. (*Split Flow and Full Condenser and Vortex Granulation Technologies*, Stefano Reggiori, Casale S.A. Paper presented and **Nitrogen+Syngas 2014**.)

These Casale technologies were recently installed in a Chinese urea plant, the first such application in China. The CO_2 stripping urea plant was originally designed with a capacity of 1,500 t/d and was latterly operating at an average 1,740 t/d. Casale's remit was to raise this capacity to 2,610 t/d, using its proprietary technology, incorporating Casale-Dente High-Efficiency Trays™, Split Flow Loop™, Full Condenser™, MP Split Flow Section™ and Vortex Granulator™ technologies.

In addition to the planned increase in capacity, Casale's remit included:

- Increasing the CO_2 conversion in the urea reactor

Fig 1: **Casale plant revamping scheme**

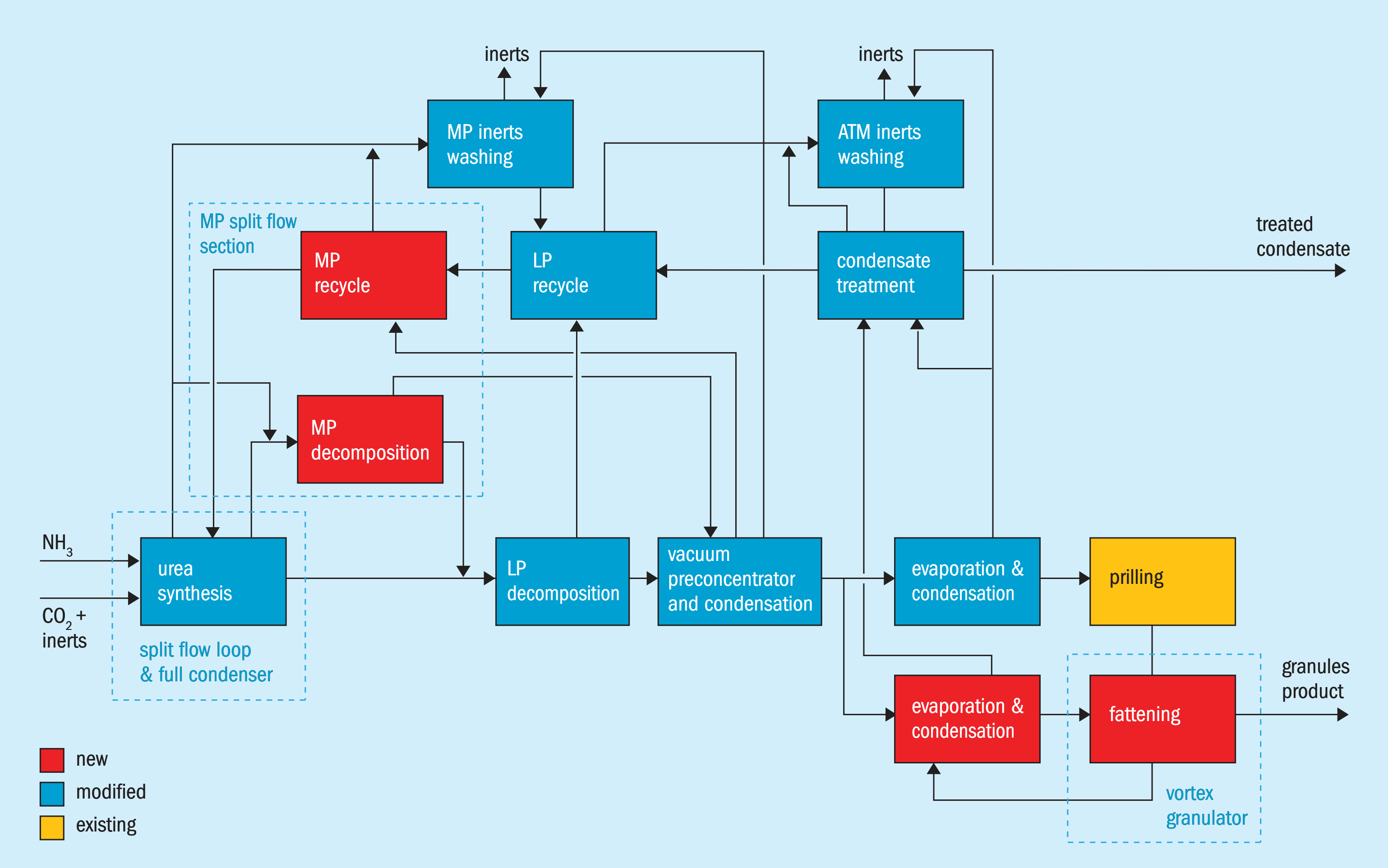
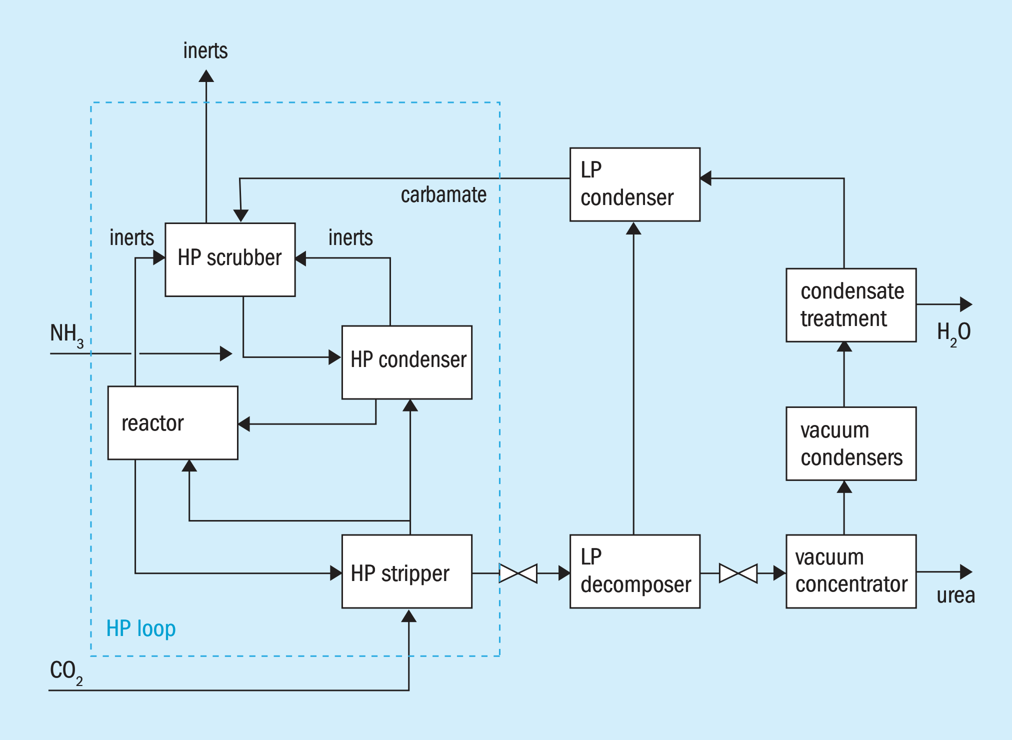


Fig 2: **CASALE Split Flow Loop™ process block diagram**



- Minimising the overall specific energy and utilities consumption
- Increasing the quality of the final product
- Guaranteeing the highest operational flexibility.

The principal modifications to the urea plant to meet these project remits comprised:

- Implementation of Casale's Full Condenser and Split Flow Loop technologies to upgrade the CO_2 stripping urea plant section from 1,740 t/d to 2,610 t/d.
- Improving the performance of the urea reactor by installing Casale-Dente High-Efficiency Trays.
- Debottlenecking the HP synthesis loop by implementing the MP Split Flow Section.
- Incorporating the Casale Vortex Granulator™ as part of the debottlenecking project.

Fig. 1 shows the plant revamping scheme. The high-pressure (HP) synthesis loop capacity and performance have been improved via the application of Casale's technologies, thus minimising the new HP equipment required. The main equipment of the loop (reactor, stripper and carbamate condenser) has been reused, with just minor modifications. The trays in the existing reactor were replaced with a new set of Casale-Dente high-efficiency trays. The HP stripper was modified to fit the equipment for the new load and to provide a new split flow loop configuration. The existing HP carbamate condenser was modified to incorporate Casale's full condenser technology to enhance performance and fit the equipment to provide the new split-flow configuration. Heat recovery from the HP scrubber was implemented by installing a new first-stage vacuum evaporator upstream from the existing one, thus minimising the steam consumption in the latter one.

After revamping, a new HP ammonia centrifugal pump was installed, while the increased CO_2 flow requirement prompted the replacement of the old CO_2 compressor. A hydrogen converter was added to remove the hydrogen contained in the CO_2 feedstock. To cope with the new carbamate solution capacity, a new HP carbamate centrifugal pump was added.

In the MP split flow section (Fig. 2), the capacity increase is exploited by implementing a new decomposition section, installed in parallel to the existing HP stripper, operating at about 18 bar g. The urea solution coming from the reactor is split into two streams: the majority is fed to the existing HP stripper while the remainder is sent to the new MP split flow section. Condensing the NH_3 and CO_2 recovered at medium pressure allows the recycle to the synthesis section of a carbamate solution with lower amount of water than the one condensed at low pressure. The lower water content increases the performance of the urea reactor.

The new MP split flow section is completely independent and has been provided with a new MP decomposer with separator, an MP pre-condenser that through vapours heat recovery pre-concentrates the 70 wt% urea solution, and an MP condenser with a closed loop circuit. The urea solution coming from the reactor is fed into the MP decomposer, where it is concentrated to about 65 wt%. The MP decomposer is a shell-and-tubes exchanger, and the steam condensing, shell-side, provides the required heat for decomposing the unreacted CO_2 and NH_3.

The inerts containing O_2 and coming from the HP scrubber are injected inside the tubes for passivation. At the outlet of the MP decomposer, vapours are separated from the concentrated urea solution inside the separator. The solution coming from the MP decomposer joins the solution exiting the HP stripper to feed the existing LP section. The released vapours are mixed with the recycle liquid carbamate solution coming from the existing LP section via the new MP carbamate pumps. The mixture is sent to the MP pre-condenser, where the condensation heat is utilised to concentrate the urea solution to more than 75 wt%. The heat recovery implementation allows a 3.5 bar g steam saving to be obtained.

The inert gases leaving the top of the MP condenser contain some ammonia, which are collected in a packed bed column for scrubbing, thus maximising the recovery in this section. The condensed carbamate liquid solution is pumped back to the HP synthesis loop, either by the new HP carbamate centrifugal pump or by the three existing HP reciprocating pumps. The scrubbed inert gases are sent to the MP absorber column for final washing.

Enhanced recycling capacity

In the LP section, decomposition and recycling capacity has been enhanced. Urea solution, both from the HP stripper and MP decomposer, are fed into the new LP separator vessel, where the gas/liquid separation is achieved. Only the liquid phase is sent to the existing rectifying column, where the liquid distribution is improved by new Casale design internals of improved efficiency. The liquid from the new LP separator enters the top of the rectifying column, which in turn enters the recirculation heater for further decomposition. The vapours from the top of the recycling column, together with the vapours from the new LP separator, join a stream of CO_2

from the compressor that has been added in order to guarantee optimum condensation into the LP condenser.

In the vacuum pre-condensation and condensation sections, performances have been increased for both load and in implementing the MP vapours heat recovery. The urea solution coming from the rectifying column is fed to the MP pre-condenser, where the condensing heat of the MP vapours (from the MP decomposer) allows the concentration of urea solution to more than 75 wt%. The new MP pre-condenser has been designed to match the energy-saving target, allowing heat recovery from released MP decomposer vapours. The flash separator has been designed for the increased vapour load. Additional condensing capacity has been provided in this section.

In the vacuum evaporation and condensation sections, the design capacity of the old evaporation section remained unchanged at 1,700 t/d, while the extra production (910 t/d) is handled by the new, independent evaporation, vacuum and condensation section, which has been installed close to the vortex granulation unit.

In order to implement the HP scrubber cooling water loop heat recovery, a first vacuum evaporator was replaced by a unit consisting of two exchangers in series. The lower section is heated by means of hot cooling water coming from the HP scrubber cooling loop, where a part of the heat is recovered for concentrating the urea solution. The upper part is heated by means of 3.5 bar g steam. The final concentration is up to 99.7 wt%. The urea melt is sent to the prilling tower.

Vapours are condensed into the existing vacuum condensers: dilute process condensate is used for atmospheric vent washing before being collected with the process condensate and sent to the condensate treatment section. The additional urea solution coming from the urea solution tank is processed in a dedicated new evaporation section, with a capacity of 910 t/d. The urea solution from the urea solution tank is sent, together with the recycle from the fattening unit, to the new first evaporator and then to the second new evaporator, where urea concentration of 99.7 wt% is reached. The solution from the second evaporator is fed to the vortex granulator, where the solution is sprayed on the prills used as seeds for obtaining the final product.

Inerts washing and waste water treatment

A new MP absorber has been installed to tackle the increased flow of inerts. In the condensate treatment section, the process water produced in the urea plant is treated in order to obtain water containing 1 ppm of urea and ammonia, making it suitable to be used as boiler feed water, before it is discharged from the urea plant. A new distillation column has been installed in order to achieve the required process condensate quality. The upper part of the column removes most of the NH_3 and CO_2 using vapours coming from the lower part. The stripping medium is 3.5 bar g steam. The water from the chimney tray in this column feeds the existing hydrolyser, thus reducing the urea content in the treated water to 1 ppm.

Vortex granulator

The fattening unit produces urea granules, starting from urea prills as a seed and urea melt at 99.7 wt% as the coating medium. This operation is performed in the Casale Vortex Granulator™. In order to spray on to a large number of solid particles simultaneously with no agglomeration, it is necessary to keep the prills spaced out. Fluidisation is the only method to avoid contact between particles over a long period of time. The fluid bed incorporates both a rotational and forward motion to enable all the particles in the bed to receive the same quantity of sprayed urea melt and the residence time is the same for all particles.

The prilling tower at the plant was not altered, and its capacity remained at 1,700 t/d. Urea melt for the prilling tower is provided by the existing evaporation section. The extra 910 t/d urea plant production is concentrated into the new evaporation section to obtain urea melt that is sprayed on the total amount of prills in the vortex granulator in order to obtain higher-diameter granules product. Because of space limitations at the site, two granulators working in parallel have been installed. Final cooling is performed in a common fluid bed cooler installed below the granulators.

Enhancing plant reliability

Toyo Engineering Co. has been improving the process and reliability of urea plants, paying attention to material development and the reduction of passivation air. (*Life-cycle Solution to Enhance Reliability of Urea Plants*, M. Takahashi et al. Paper presented at **Nitrogen+Syngas 2014**.) The high corrosiveness in the synthesis section in urea plants means that materials exposed to synthesis solution are subject to corrosion and degradation. This has prompted Toyo to develop a super duplex stainless steel, *DP28W*™. This was first applied at a urea plant in Trinidad, where it is employed in HP equipment, including liner plates, tubes and internal parts. After over three years of service, the components incorporating *DP28W* stainless steel were inspected. No abnormal corrosion relating to active corrosion or accelerated corrosion was observed.

After commencing extensive application of *DP28W*, it has also been used for tubes of HP equipment instead of conventional duplex stainless steels or austenitic stainless steels. This was also found to have performed well in service, with no abnormal corrosion.

Reactors can be refurbished with *DP28W* in total recycle urea plants. One urea producer replaced a titanium-lined urea reactor with one incorporating *DP28W*, after the weld metal of the titanium had become corroded, with consequent leakage. The refurbished plant has been operational for some eight years now, and the *DP28W*-lined reactor has shown excellent corrosion resistance, including in the weld joints.

Urea reactor design evolution

Saipem SpA licenses urea HP equipment technology under the Snamprogetti™ brand, comprising the urea reactor, carbamate separator, urea stripper and carbamate condenser. The design of this equipment continues to be enhanced. Snamprogetti has lately paid particular attention to enhancing the design of HP urea equipment, in particular the urea reactor, with the goal of improving its fundamental contribution to the efficiency and reliability of the plant overall. (*Design Evolution of the Urea Reactor*, Alberto Serrafero et al, Saipem SpA/Snamprogettti Urea Technology. Paper presented at **Nitrogen+Syngas 2014**.)

In the urea reactor, the ammonia and CO_2 react to form ammonium carbamate, a portion of which dehydrates to urea and water. The NH_3-to-CO_2 ratio used in the Snamprogetti process is 3.2 to 3.5, combined with a temperature of 186-189°C and a pressure of approximately 156 bar, which permits a conversion yield in the reactor of up to 63-65%. The reactor works as a bubble column: the internal structure consists of a variable number of trays with a dedicated design in order to improve the fluid dynamic path of the NH_3 and CO_2 reactants and the carbamate, urea and water products.

Severe conditions in temperature and pressure and very aggressive corrosion media impose a careful mechanical design on this equipment: the resistant body is made in carbon steel, while the internal part in contact with the process fluid is lined with 25/22/2 Cr/Ni/Mo, fully passivated to ensure effective protection against corrosion.

The latest Snamprogetti technology is incorporated in the new Matix Fertilizer complex in West Bengal, India. The urea plant has a capacity of 3,850 t/d. The reactor has a shell internal diameter of more than 2.5 m and a height of 45 m. The reactor is fabricated from high-strength carbon steel and is lined internally with 25/22/2 Cr/Ni/Mo material.

Equipment management

It is important to undertake regular inspections of urea plants for corrosion and evaluate the technical condition of the equipment. Solutions found to eliminate operational problems serve as the basis for further improvement of the design and material of the equipment. (*Equipment management: effective solutions*, Aleksandr Chirkov, NIIK (R&D Institute of Urea), paper presented at **Nitrogen+Syngas 2014**.)

One recent innovation that was devised in the wake of stringent plant inspections is the use of liquid dividers in a top chamber of the stripper. The long-term effectiveness of the stripper (which is a falling film heat exchanger) depends on the melt distribution on the tube sheet that affects uniform film formation in heat exchanging tubes. Earlier configurations incorporated a stripper with a half-ring liquid divider. However, inspections showed that the melt distribution level was uneven. The ring-type liquid divider offers a significant improvement in efficiency, providing a uniform distribution of the melt.

Enhancing scrubbing efficiency

As particulate emission regulations become ever more strict, Stamicarbon and EnviroCare International have teamed up to develop high-efficiency scrubbing technologies, which remove submicron dust with a high collection. This scrubber technology is integrated with Stamicarbon's second-generation fluid bed granulation technology. (*High-Efficiency Scrubbing Technology for Urea Fluid-Bed Granulator Exhaust Gas*, Wilfried Dirkx, Hans van den Tillaart, Stamicarbon, and Brian Higgins, EnviroCare International. Paper presented at **Nitrogen+Syngas 2014**.)

The final stage in the urea production process is the finishing process, which yields a solid product. The most favoured finishing technology is the fluid-bed granulation process, in which urea melt is solidified into granules in the granulator. In order to remove the heat of the crystallisation released during this solidification, large amounts of cooling air are fed to the granulation unit. The air leaving the finishing section typically contains ammonia and significant amounts of urea dust.

The removal of urea dust is challenging, since the amounts of off-gas (mainly air) is large, with an airstream of around 750,000 Nm^3/h. Typically, 3 wt% of the produced urea is carried out of the granulator by the fluidising air. A significant fraction of this urea dust is submicron. Modern emissions standards require high dust removal efficiencies of around 99.9%, with all particulate to be captured as well as 80-90% of the submicron dust. At the same time, a relatively low scrubber pressure drop is required, in order to reduce the size and power consumption of the fan. Due to the large amount of urea present in the off-gas from the granulator, it is also economically necessary to capture and return this urea to upstream processes for reuse.

Traditional particle abatement devices are mainly designed and optimised to treat particles with sizes above 1 μm and are far less efficient in collecting submicron particles, especially between 0.2 and 1 μm. Conventional tray scrubbers have been the primary particle capture system for urea granulators, but Stamicarbon and EnviroCare have sought to develop improved scrubbing technology.

The new EnviroCare scrubber design contains six stages that progressively treat and clean the off-gas. Make-up water is introduced downstream, contacting the cleanest gases first. The water is then recirculated many times, working its way upstream until it comes into contact with the dirtiest gases. By the time the water is extracted, it has been allowed to cycle up in concentration with urea and/or ammonia salts. This applied scrubber technology enables emissions of 10 mg/Nm^3 or lower to be obtained. With an additional integrated Wet Electrostatic Precipitator, even lower emissions can be achieved. Fig. 3 shows the six stages of the new design, which comprises:

- A concentrated urea quench
- Diluted urea quench
- Conditioning trays
- *MicroMist*™ venturi tubes
- Acid treatment for NH_3 capture
- High-efficiency mist eliminator stage.

Ensuring optimum quality with effective vacuum systems

Urea prills and granules often suffer quality problems (such as low-strength figures, adverse dust and caking behaviour). High moisture content is a frequent cause of these problems. The moisture content of the final product is largely determined by the moisture content in the urea melt feed, and thus the design, operation and maintenance of the evaporation section is critical. (*Managing the Optimum Moisture Content – Key to Assure the Optimum Urea Product Quality*, Alvaro J. Cadena and Mark Brouwer. Paper presented at **Nitrogen+Syngas 2014**.)

The prilling process starts with superheated urea melt droplets, which solidify slowly from the shell to core and after complete solidification, will cool further until the prills reach the bottom of the prilling tower or even further during storage. Moisture content is the key determinant of the prills' caking and crushing strength. Urea melt is fed into a prilling tower typically containing 0.3 wt% water and has a water vapour temperature of 35 mbar, at a temperature of 140°C. In the prilling tower, the melt droplets are in contact with air, which is flowing upwards and which typically has a water vapour pressure of about 62 mbar. The amount of water hardly changes during its travel upwards.

The situation changes when the shell of the prill droplet starts to solidify. When urea melt with a concentration of 99.7 wt% cools down below the saturation point, it forms solid urea (100 wt% urea) and a liquid (mother liquor) phase with a relatively low urea concentration. At 120°C, the mother liquor has a urea concentration of 95 wt%, at 100°C some 88 wt% and at 80°C some 80 wt%. Prills with 0.3 wt% moisture content thus contain 6 wt% mother liquid phase

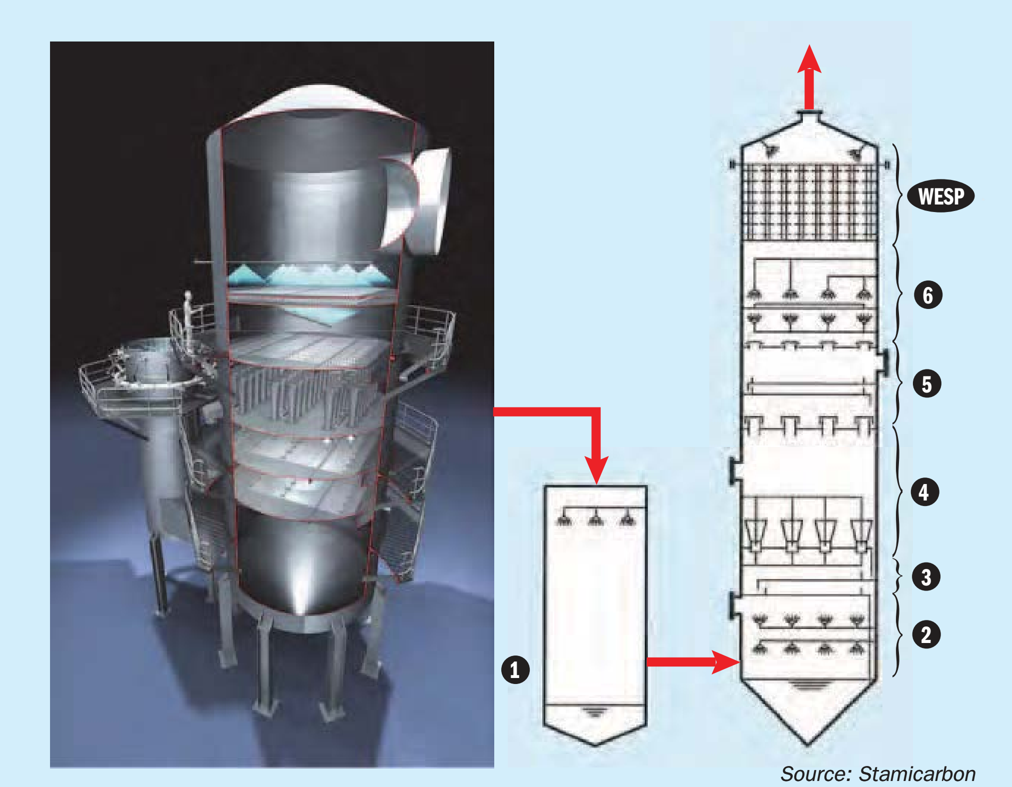
with 5% water and at 80°C contain 1.5 wt% mother liquid phase with 20% water. During the cooling process, urea from the mother liquor precipitates as urea crystals on the internal and external surfaces.

As the prill cools from its shell to its core while falling downwards, the water vapour pressure of the prill shell reduces while the water vapour pressure of the core is still relatively high. Urea crystals are formed in the porosities of the prill shell during the cooling process, reducing the possibility of mass transfer via diffusion. The lower shell temperature also reduces the diffusion processes itself. The shell thus forms a barrier for the moisture mass transfer process.

In the prilling process, because a limited amount of water can be transferred from the prill into the air, it is important to minimise the water content in the urea melt in order to ensure a good final prill quality.

The heat and moisture mass transfer in a drum or fluid bed granulation follows comparable principles. The mass transfer process of moisture from the granule to air is slow. The design water content in the urea melt must be maintained in order to assure a good granular quality. Proper design and operation of the vacuum system in the evaporation section is also critical to the quality of prills and granules. Special attention to the original parameters is required to maintain vacuum levels: steam, cooling water, fouling and increased load all have the potential to adversely affect the quality of the final product.

Fig 3: **Representative scrubber cutaway view with six stages indicated**



Source: Stamicarbon

Greater energy requirement

Increased loads in existing urea plants lead to increased loads in the HP carbamate condenser. To meet these increased loads, a greater amount of energy to remove in the HP carbamate condenser is required. It is very important, when installing a vacuum system, to specify the minimum steam pressure that will be available.

Steam quality is also an important consideration and should be dry and saturated, without any entrained moisture present. Poor quality steam threatens the operation of the ejector by reducing energy and capacity, and it may also promote erosion in both the steam nozzle and diffusor. Slight superheat is beneficial to ensure dry steam conditions. However, too much superheat has a negative effect on steam flow.

In a two-stage evaporation process, cooling water temperature affects the overall performance of the vacuum system. It is a key component in the calculation of Log Mean Temperature Difference (LMTD), which dictates the condensing capability of the vacuum condensers. LMTD will be adversely affected, affecting the performance of the vacuum condenser. The negative impact of higher water temperatures is more severe on the pre-condenser of the first stage evaporator vacuum system and on the first inter-condenser of the second-stage evaporator vacuum system, as their LMTDs are normally low as a result of lower condensing temperatures.

As the vacuum condenser loses its capacity to condense, the vapour pressure begins to increase within the vacuum condenser, and the condenser's operating pressure consequently rises. The performance of the upstream ejector begins to fail, with a resulting adverse cascading effect. Fouling is another consideration when designing a new vacuum system. It has a multiple effect, reducing the heat transfer rate and the flow of cooling water. Besides fouling on the cooling water side, the evaporation section in a urea plant experiences fouling on the process side.

Highly concentrated urea melt at low pressures and high temperatures partly dissociates in ammonia and isocyanic acid (HNCO), which are both gases. At cold spots, however, ammonia and HNCO combine again to form urea, while further polymerisation to biuret and triuret can occur. These polymers form in the evaporator separators and inlet lines to the vacuum system and create higher temperature drops. It is difficult to dissolve these polymers in water and flushing with concentrated urea is currently the best solution, together with proper tracing and insulation to avoid cold spots. On the ejectors and vacuum condensers, additional water flushes are typically installed to remove any urea and carbamate fouling in this equipment. Operating at a higher melt temperature to achieve desired concentration is not recommended, as the biuret content can rise unfavourably, resulting in a lower-quality prill.

Careful design needed

The vacuum system in a urea plant, comprising ejectors and vacuum condensers and based on unique performance characteristics and interactions, requires careful consideration of the design parameters and adequate provisions to prevent costly operational difficulties, while at the same time providing sufficient flexibility in plants to enable them to exceed their nameplate capacities. Specialised equipment manufacturers can provide vacuum package systems that can ensure the proper balance of ejector and condenser design. ■

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47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68

Every nutrient matters

An assessment of best management practices for optimum nutrient efficiency.

As a cereal grain, rice is the most widely consumed staple food for much of the world's population, especially in Asia. It is the agricultural commodity with the third-highest worldwide production, after sugarcane and maize.

Rice cultivation is well-suited to countries and regions with high rainfall and is labour-intensive to produce and requires ample water. The crop can be grown practically anywhere, even on a steep hill or mountain area, using water-controlling terrace systems. The traditional method for cultivating rice is flooding the fields while (or after) setting the young seedlings. This method requires sound planning and serving of the water management systems. While flooding is not mandatory for the cultivation of rice, all other methods of irrigation require higher effort in weed and pest control during growth periods and a different approach for fertilising the soil.

In 2012, FAO estimated that 162.3 million ha were used for rice cultivation and the total production was about 738.1 million tonnes. The average world farm yield was 4.5 t/ha. Rice farms in Egypt were the most productive, with an average yield of 9.5 t/ha, while Australia and the United States were also amongst the highest-ranking producers, with average yields of 8.9 t/ha and 8.3 t/ha respectively. Yields in China average 6.59 t/ha, while the global average is 4.3 t/ha. Table 1 shows Top 20 rice producers by country.

Rice is vital for the nutrition of much of the population in Asia, as well as in Latin America and the Caribbean and in Africa. Developing countries account for 95% of the total production, with China and India alone responsible for nearly one-half of the global output.

World production of rice has risen steadily from about 200 million tonnes of paddy rice in 1960 to over 609 million tonnes in 2009. Rice production was transformed from the 1960s onwards with the development of high-yielding varieties, forming the basis of the Green Revolution that brought the world a greater measure of food security. The application of fertilizers helped bolster the move away from rice as a subsistence crop and towards rice as a key cash crop in many regions.

Particularly in Asia, rising populations make it necessary to increase food production and productivity. Because areas of new land are limited, this means intensification on existing agricultural land. Nutrient inputs will therefore have to rise, perhaps by as much as three times above present average levels. Some countries in Asia already appear close to the point where additional fertilizer brings little additional yield: Japan, South Korea and Taiwan are all estimated to be applying the theoretical maximum. In other countries, actual fertilizer application rates are low and well below those recommended, or are else applying imbalanced nutrient levels.

As well as average levels of fertilizer consumption per hectare, it is important to assess fertilizer inputs/output balances. Studies of nutrient balances for rice and other major crops in several Asian countries have shown a negative balance, with more nutrients removed in the harvested crop and lost in other ways – for example, in Indonesia, Burma and Vietnam. These studies have also found that, while there is a positive balance for nitrogen, there is a negative balance for the other primary nutrients (as in Bangladesh and the Philippines), while Thailand has a negative potassium balance.

Table 1: **Top 20 rice producers by country** 2012

Million tonnes	
China	204.3
India	152.6
Indonesia	69.0
Vietnam	43.7
Thailand	37.8
Bangladesh	33.9
Burma	33.0
Philippines	18.0
Brazil	11.5
Japan	10.7
Pakistan	9.4
Cambodia	9.3
United States	9.0
South Korea	6.4
Egypt	5.9
Nepal	5.1
Nigeria	4.8
Madagascar	4.0
Sri Lanka	3.8
Laos	3.5

Source: FAO

Specific nutrient needs

Rice is predominantly grown under wetland conditions, and it is important to understand the unique properties of flooded soils for better management of fertilizers for this crop. When a soil is flooded, the following major chemical and electrochemical changes take place:

- Depletion of molecular oxygen
- Chemical reduction of soil
- Increase in pH of acid soils and a decrease in pH of calcareous and sodic soils
- Reduction of Fe^{3+} to Fe^{2+} and Mn^{4+} to Mn^{2+}
- Reduction of NO_3^- to NO_2^-, N_2 and N_2O
- Reduction of SO_4^{2-} to S^{2-}
- Increase in supply and availability of N, P, Si and Mo
- Decreases in concentrations of water-soluble Zn and Cu
- Generation of CO_2, methane and toxic reduction products, such as organic acids and hydrogen sulphide.

These factors have a significant influence on soil nutrient transformations and availability to rice plants. (*Nutritional Recommendations for Rice*, Haifa Chemicals Ltd.) Nutrient mobility also influences symptomology. N, P, K and Mg are mobile nutrients, for which deficiency symptoms appear in the oldest (lower) leaves first, because their mobile nutrients move to the youngest leaves, which act as sinks. The immobile nutrients comprise Ca, Fe, Mn, Zn and S. Deficiency symptoms appear in the youngest (upper) leaves first, because these nutrients become part of the plant compounds.

Rice straw being gathered after the harvest in Chiang Mai province, Thailand.

The importance of nitrogen

In flooded paddy fields, ammonium (NH_4^+) rather than nitrate (NO_3^-) tends to be the main source of N for rice. In recent years, research as focused more on the partial NO_3^- nutrition of rice crops, and test results have shown that lowland rice is exceptionally efficient in absorbing NO_3^- formed by nitrification in the rhizosphere. The growth and N acquisition of rice are significantly improved by the addition of NO_3^- to nutrition solution with NH_4^+ alone.

Nitrogen increases plant height, panicle number, leaf size and number of filled spikelets, which largely determine the yield capacity of a rice plant. Farmers generally use split applications for N. In lowland areas, rice losses of applied N occur through ammonia volatisation, denitrification, leaching and run-off. The recovery of fertilizer N applied to rice rarely exceeds 30-40%. Fertilizer N use efficiency in lowland rice may be maximised through a better timing of application to coincide with the stages of peak requirement of the crop, and the placement of N fertilizer in the soil. The use of controlled-release N fertilizer can also improve use efficiency.

Agronomists advocate the early application of N (65-100% of the total N rate) as ammonium N (NH_4^+) on to dry soil, immediately prior to flooding at around 4- to 5-leaf growth stage. Once early N is applied, flooding should be completed as quickly as possible, preferably within five days of the N application. The flood incorporates the N fertilizer into the soil, where it is protected against losses via ammonia volatisation and/or nitrification/denitrification as a long as a flood is maintained. The flood should be maintained for at least three weeks to achieve maximum uptake of the early-applied N.

N is the most limiting nutrient for rice production in many countries. Rice plants require N during the tillering stage to ensure a sufficient number of panicles. The critical time for N application is typically about midway between 14 days after transplanting or 21 days after sowing and panicle initiation. The least N losses due to leaching or volatisation occurred when the only application was close to the flooding time.

N fertilisation improves yields. Field trials showed responses of 28.4 and 18.9 kg rice per kg N for rates of 25 and 50 kg/ha respectively. Yield increases are affected by variety, soil N supply capacity, amount of radiation during the reproductive phase and management practices, such as weed control and plant density.

Urea is generally the N fertilizer of choice. Sufficient N should be applied preplating or pre-flooding to assure that the rice plant needs no additional N until panicle initiation. When additional N is required, it should be top-dressed at either of these plant stages or whenever N deficiency symptoms appear. Based on site-specific nutrient management (SSNM) concepts, a rice crop typically requires about 50 kg/ha N for each tonne in additional grain yield, usually split into three applications. High pH soil conditions can increase N volatility when urea is used as the N source.

Phosphorus for grain yields

P nutrition is critical for producing maximum grain yields, especially in the early vegetable growth stages, when it promotes strong early plant growth and the development of a strong root system. P also promotes tillering, root development, early flowering and ripening. The symptoms of P deficiency are often not immediately apparent, although plants can appear stunted and dirt-dark green, with erect leaves, relatively few tillers and decreased root mass.

P fertilizer recommendations for rice are currently based on soil testing for available P and soil pH. P availability to rice is optimum when the pH is below 6.5. For upland crops, P availability is usually optimal when the soil pH is between 6.0 and 6.5. In acid soils, (pH<6.0) the P is associated with Fe and Al compounds that are slowly available to the plant. P availability increases following the establishment of the permanent flood, due to the chemical changes that occur to the iron phosphate.

In soils where pH>6.5, P is primarily associated with Ca and Mg. Not all calcium and magnesium phosphate compounds are slowly available to plants since their availability declines as pH increases. As a result, P is usually not limited on acidic soils. By contrast, the availability of calcium phosphates tends to be low after flood establishment in alkaline soils (pH>6.5).

Under flooded conditions, P is released to the soil solution as Fe^{3+} phosphate compounds, which become reduced and convert to Fe^{2+} compounds under low oxygen conditions. On soils low in active Fe or low

Oryza sativa, commonly known as Asian rice.

Fig 1: **Rice paddy production in Asia**

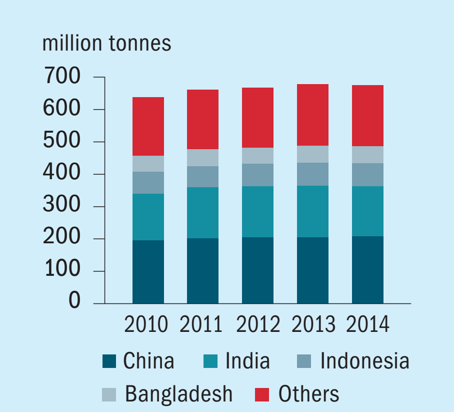
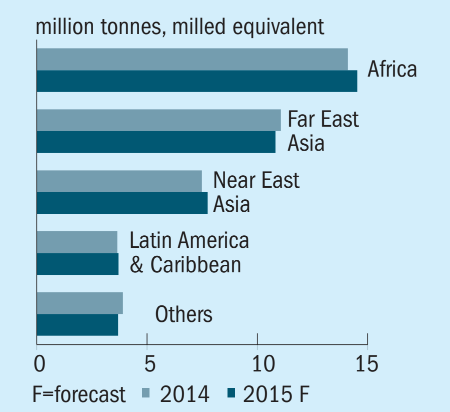


Fig 2: **Rice imports in 2014 & 2015**



Global rice production dips slightly in 2014

FAO estimates that global rice production in 2014 totalled 744.7 million tonnes, a dip of 0.2% on the 2013 level. The lower total reflected a 0.1% contraction in both plantings and yields to 162.9 million ha and 4.57 t/ha respectively – brought about by unfavourable weather conditions. Substantial production declines were indicated in India, Indonesia and Thailand, but the weather had a less severe impact in Bangladesh, China and Vietnam, where production gains were expected. A recovery in global rice production is expected this year, with notable increases in plantings in Indonesia, while production in Africa and North America has shown a positive trend.

FAO forecasts a world trade in 2015 of 40.5%, implying a small 0.6% growth from the 2014 estimate. On the demand side, the expansion reflects expectations of continued increases in imports by countries in Africa and Latin America, but deliveries in North America and Europe are seen as falling, while stabilising at high levels in Asia. Among the leading exporters, Thailand is expected to remain predominant, achieving record deliveries. China, Pakistan and the United States are also expected to ship more.

FAO projects world rice utilisation at 500.5 million tonnes (milled basis), around 1.9% above the 2013/14 estimate. About 83% of utilisation would correspond to food intake, while the feed would absorb 3% of the total, and remainder would be mainly for seeds and non-food industrial use. For the first time in a decade, global rice utilisation is expected to surpass production, leading to a 3.8 million tonnes' drawdown of global rice stocks in 2015 to 177.5 million tonnes. Despite the decline, world reserves are expected to remain high, with the stocks-to-use ratio estimated at 34.8% in 2014/15, down from 36.2% a year earlier, but sufficient to cover more than four months of requirements. ■

in total P, sufficient P may not be available. On high pH soils (>7.0), with an abundance of Ca, the Ca-phosphate compounds may not release adequate P to the soil solution.

Soil pH is a better predictor of rice response to P fertilisation than soil test P. Flooding rice soils generally moderates the pH towards a neutral pH condition, thus promoting soil-available P. When soils are flooded, reducing conditions mobilise P from ferric iron (Fe^{3+}) and Al phosphates to more labile forms and increases P mineralisation from soil organic matter, both acting to satisfy the crop's requirement.

A rice crop can remove 0.35 kg P_2O_5 per 50 kg rice per ha. P is best applied pre-plant or pre-flood at rates determined via soil tests and yield expectations. When needed, P fertilizer should be soil-applied when land is prepared for planting. Agronomists advise that all P should be applied before planting in both water-seeded and dry-seeded rice.

Potassium – the linchpin nutrient

Modern high-yielding rice varieties absorb K in greater quantities than any other essential nutrient. In farmers' fields across Asia, total K uptake rates of a crop yielding 5 t/ha are in the range of 100 kg/ha, of which more than 80% are concentrated in the straw at maturity. For yields greater than 8 t/ha, total K uptake may exceed 200 kg/ha.

Effective K nutrition in rice promotes tillering, panicle development, spikelet fertility, nutrient uptake in N and P, leaf area and leaf longevity, disease resistance, root elongation and thickness, and tolerance to diseases and pests.

Recommended K rates are rarely sufficient to balance K removal rates under common commercial conditions. Many intensive rice systems therefore run under negative K balances – a situation that may be exacerbated when straw is removed from the field. K deficiency also occurs on poorly-drained soils. Low K content is often associated with Fe toxicity, which is common on acid sulphate soils.

Grain yield response per kg K_2O applied is higher in the dry season than in the wet season crop, averaging 10 kg grain/kg K_2O in the dry season and 8 kg grain/kg K_2O in the wet season. Field trials have shown that K fertilisation typically increase yields by 20%, with a mean response of 10.6 kg rice per kg K_2O applied. Proper K fertilisation is critical for maximising rice grain yields. K is very mobile within the plant. The application of sufficient fertilizer K also increases the efficient use of N fertilizer. Field tests show that the application of additional K can boost the recovery efficiency of N fertilizer to 37% of the applied N.

K is absorbed in great quantities by rice, especially by high-yielding cultivars, and fertilisation at 70 and 100 kg/ha K_2O significantly increases panicle development and yield. K deficiency symptoms include stunted plants, droopy and dark green upper leaves, yellowing of the interveinal areas of the lower leaves, which eventually turn brown. K deficiency increases the incidence of physiological disorders, including brown leaf spot and stem rot.

The rice plant requires about 40 kg/ha K_2O just to achieve a plant that can produce a yield target of 6.5 t/ha in the wet season and 25 kg/ha K_2O to attain a plant that can produce a yield of 5.5 t/ha in the dry season. The optimal nutritional balance is achieved with an uptake of 14.7 kg N, 2.6 kg P and 14.5 kg K per tonne of grain yield. Total K_2O requirements for these yields are 153 and 121 kg/ha respectively. Although broadcasting and incorporating the whole K application at the time before planting or pre-flood is generally recommended, split applications are also common in some areas. It is recommended to apply all K before planting in both water-seeded and dry-seeded rice.

Applying secondary nutrients

Sulphur plays an important role in the biochemistry and physiology of the rice plant, mainly in chlorophyll production, protein synthesis and carbohydrate metabolism. S deficiency is however widespread in many rice-producing regions, including the Indian sub-continent, Brazil and South East Asia. S deficiency symptoms are very similar to N deficiency symptoms, producing pale yellow plants which grow slowly. In contrast with N, however, S is immobile in the plant, so that yellowing will first appear in new leaves rather than older leaves. S deficiencies can generally be avoided by applying a minimum of 112 kg/ha of ammonium sulphate $(NH_4)_2.SO_4$ between pre-plant and the 2-3 leaf plant stage. This treatment will provide 23 kg/ha of N and 26 kg/ha of S. Calcium sulphate (gypsum) is another widely-applied treatment.

Calcium is important for the build-up and functioning of cell membranes and the cell wall strength. Ca-related disorders tend to be caused by unfavourable growing conditions, rather than by inadequate supply of Ca to the roots. Deficiencies can develop under waterlogging, soil salinity, excess K or ammonium supply and root disease.

Ca moves in the plants' transpiration stream and is deposited mainly in the older leaves. Deficiencies are found in the youngest leaves and growing points. Ca deficiencies are relatively rare in irrigated rice systems but are common in acid, strongly-leached soils in uplands and low lowlands. Ca is an important nutrient throughout the rice crop's growing cycle.

Micronutrient deficiencies

These typically do not occur on acid- to slightly-acid clay soils (pH = 5-6.5), but on silt and sandy loam soils, as well as other high-pH soils (>7.5) are subject to various micronutrient deficiencies. Soils with high-available P and low organic matter are subject to Zn deficiency, which is the most widespread micronutrient disorder in rice. Waterlogged soils are particularly susceptible to Zn deficiency. In plants, Zn is critical to many physiological functions and of all micronutrients, Zn is required by the largest number of enzymes and proteins. Zn pathways have important roles in photosynthesis and sugar formation, protein synthesis, fertility and seed production, growth regulation and defence against disease.

Soil-applied Zn in water-seeded rice should be applied just before flooding or with $ZnSO_4$. If a soil test indicates Zn deficiency before planting, 8-11 kg/ha Zn should be broadcast-applied as 22-34 kg/ha $ZnSO_4$ before planting or into the water after flooding. If Zn deficiency symptoms occur after rice emergence, a Zn chelate can be applied at 0.5-1 kg/ha. DAP, ammonium sulphate and $ZnSO_4$ are often used as a fertilizer blend applied to rice.

Boron (B) is important for cell-wall biosynthesis and affects structure and plasma membranes' integrity. Optimum pre-plant B contents for some soils is 0.25-0.5 kg/ha. In order to achieve this, a broadcast application of 0.75 kg/ha B is recommended. This can be achieved by the application of 6.8 kg/ha of commercial Borax $(Na_2B_4O_7.10H_2O)$, containing 11% B, or 4.3 kg/ha of commercial boric acid (H_3BO_3), containing 17.5% pure B.

The symptoms of iron (Fe) deficiencies include yellowing or chlorosis of the interveinal areas of the emerging leaf. The entire leaf later turns yellow before finally turning white. The severity of Fe deficiency increases with pH. Rice has a greater Fe requirement than that of other plants. In flooded rice paddies, Fe deficiency

Aerial view of terrace rice fields in Yunnan Province, China.

is more likely to be found in calcareous and alkaline soils low in organic matter, and in soils irrigated with alkaline water. A high concentration of calcium carbonate in the soil or irrigation water is likely to make Fe deficiency of rice more severe. Fe deficiency can be corrected by applying a foliar spray of 2-3% $FeSO_4$ solution.

Manganese (Mn) toxicity in rice appears as brown spots on older leaves, often accompanied by Al and P deficiency. It rarely occurs in lowland paddy rice, but may occur of the soil contains very large amounts of easily reducible Mn. The solubility of Mn increases in aerobic soils as the pH drops below 4.5. Silica has been found to alleviate Mn toxicity by decreasing the uptake of Mn. Liming is a common remedy for Mn toxicity, while the application of $CaSO_4$ and $FeSO_4$ can also be helpful.

Rice suffering from aluminium (Al) toxicity shows interveinal white or yellow discoloration of the tips of older leaves. The roots of affected plants are stunted and deformed. Al toxicity in wetland rice is observed in most acid sulphate soils during the initial phase of flooding. It is usually associated with Mn toxicity and P deficiency, when it may hinder the uptake by rice of P, Ca and K. Al toxicity can be corrected by liming to raise the soil pH.

Best fertilisation practices

Foliar fertilisation overcomes the limitations of soil fertilisation, including leaching, insoluble fertilizer precipitation, and antagonism between certain nutrients. Foliar feeding has proved to be the fastest way of curing the nutrient deficiencies and boosting plant performances at specific physiological stages. With plants competing with weeds, foliar spraying focuses the nutrient application on the target plants. Foliar feeding not only replenishes plant nutrients but also acts as a catalyst in the uptake and use of certain macronutrients.

The leading fertilizer produces have developed specially-formulated foliar feeding fertilizers tailored for use on rice crops. Haifa Chemicals has launched *Haifa Bonus*, a foliar formulation developed to enable the spraying of highly-concentrated solution without scorching the foliage. The formulations consist of pure, fully-soluble nutrients only. The formulations are available in various N-P-K-Mg-Zn ratios and include *Haifa Bonus+Zn™*, which has proved effective in prompting enhanced chlorophyll and photosynthesis.

The Haifa *Multicote®* range of polymer-coated CRFs is available in many formulations, with release longevities of between 2-16 months.

Haifa has also launched the *CoteN®* range of polymer-coated controlled-release fertilizers (40% N) for use on rice. Tests have shown that *CoteN* applied before flooding prompts higher grain yield and improved N recovery efficiency, achieving recovery efficiencies as high as 80%. A special non-floating *CoteN* has been devised for paddy rice, being heavier than the regular product. It has a four-month release longevity. One base-dressing application enables avoiding top-dressing application and prevents N losses by leaching. Tests have shown that the continuous supply and reduced losses of N enable a reduction of up to 20% in N fertilizer application rates.

Tessenderlo Chemie has developed the *K-Leaf™* range of potassium sulphate fertilizers tailored for rice cultivation. Rice is extremely sensitive to salinity as a seedling and during early plant development. Under saline conditions and for foliar application, the use of K_2SO_4 leads to better yields. In tests in Egypt and other locations, foliar-applied *K-Leaf* was found to boost yields by between 6-28%.

Yara International has launched the *YaraMila Actyva* NPK fertilizer range, which has been specifically developed for use on rice and maize. The P is in three forms so that supply to the plant is continuous. The orthophosphate form enables easier absorption by the plant, while the polyphosphate content maintains the P uptake at the next stage. The last form is dicalcium phosphate. *YaraMila Actyva* is more effective than urea, avoiding the latter product's nutrient losses to atmosphere, nor does it make the soil acidic. Formulations include added sulphur, ammonium sulphate, magnesium oxide and zinc.

SFP has developed the *Nutri-Sphere-N* additive for granular or liquid N fertilizer that creates an active zone of protection around the fertilizer granule to reduce volatisation and nitrification, thus leaving more of the nutrient in the soil for plant uptake. *NutriSphere-N* increases N availability and can increase yield potential by up to 10-15%.

NutriSphere-N is biodegradable, water-soluble, making it suitable for application on rice, providing greater N fertilisation efficiency and optimised.

SFP has also developed *AVAIL™* coating to enhance the performance of phosphate fertilizers. *AVAIL SD* is a liquid phosphate fertilizer-compatible formulation for side-dress applications and is particularly suitable for use on rice.

Mosaic has developed the *MicroEssentials®* range of N-P-S fertilizers, with added micronutrients. These are fused into one nutritionally-balanced granule, providing uniform nutrient distribution, increased uptake and season-long availability. *MicroEssentials SZ* incorporates Zn and has been tested on rice at various US locations. Rice yields increased with the higher rates of Zn. ■

March-April 2015

phosphates & potash INSIGHT

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Global phosphate outlook: a difficult balancing act

Global demand for phosphates is expected to grow steadily over the medium-term. We examine whether the expansion in capacity planned over the next three years will match growing demand or be surplus to requirement.

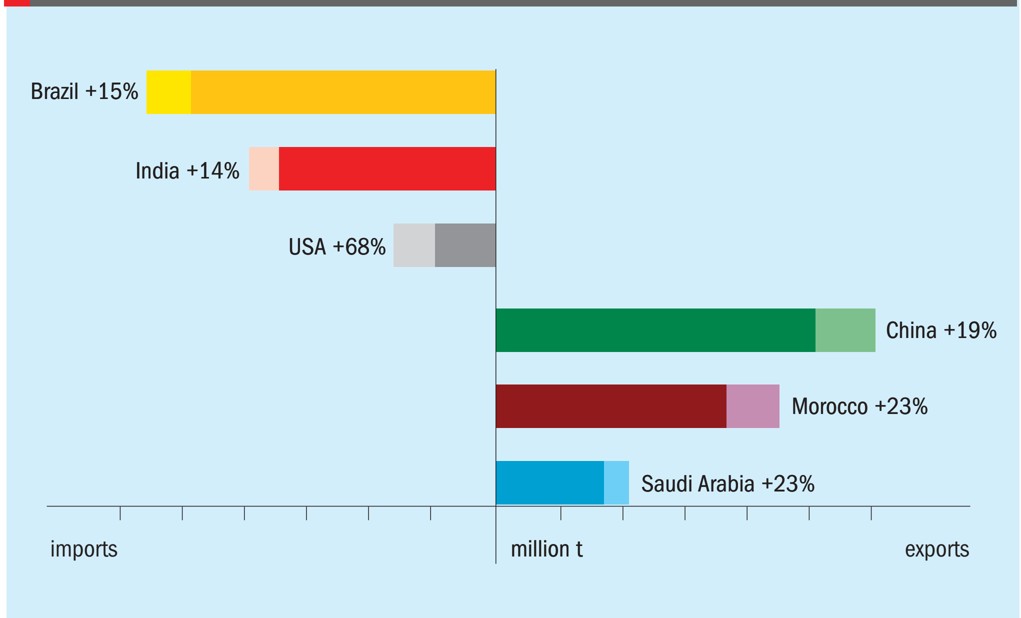
As recently as last October, US fertilizer giant Mosaic was predicting record-breaking global phosphate shipments in 2015, despite underlying worries about the knock-on effect of crop price weakness on fertilizer sales. "Yes, there's ups and downs, dips and valleys, but the trend is unrelenting," commented Mosaic's chief executive officer Jim Prokopanko. "It is upward."

Mosiac and analysts CRU are forecasting a 2.5% increase in world phosphate product shipments this year to reach 65.4 million tonnes. That is up 1.6 million tonnes on 2014 shipments of 63.8 million tonnes.

Demand for phosphate products surged last year, driven by record United States (US) imports, a rising requirement from Brazil and a rebound in the Indian market. This demand was mainly met by increased exports from China, Morocco and Saudi Arabia (Fig. 1). The switch in Chinese exports to more distant destinations, in response to lower-than-expected Indian demand, was a notable trend in 2014. Phosphate imports to India remain at half the level of their 2010 peak, with China now exporting almost as much to Brazil (1.02 million tonnes) last year as it did to the subcontinent (1.08 million tonnes). China also exported 238,000 tonnes to the US in 2014 compared to virtually nothing in 2013.

But will the export market continue to flourish as Ma'aden ramps up its phosphate production capacity in Saudi Arabia and OCP increases its output of finished products in Morocco? Unfortunately, the unpredictable nature of fertilizer markets means that recent trends are not necessarily a reliable guide to the future fortunes of the sector. What is clear, though, is that the prospects for the phosphate industry over the next few years will largely depend on world demand continuing to grow, and having sufficient supply capacity in the right place to meet this. But reliably forecasting supply and demand over the medium-term, although not impossible, is a complex and uncertain business.

Fig 1: Key 2014 global phosphate imports and exports with annual increases



Potential double digit supply growth

The production of phosphate fertilizers begins with rock phosphate extraction (Fig. 2). Based on the most recent International Fertilizer Association (IFA) figures, global mining capacity for rock phosphate stands at around 246 million tonnes with production running at 193.5 million tonnes and traded volumes at 26.2 million tonnes. According to CRU, the number of mining projects in the pipeline means rock phosphate capacity has the potential to rise 95 million tonnes by 2018 – an almost four fifths increase – whereas demand is only projected to rise by 17 million tonnes over this period. Many proposed mine expansion projects will not proceed because of the potential oversupply in CRU's view (*Hopes Renewed*, **Fertilizer International**, No. 460 [May-June 2014]).

IFA also expects only half of the projected rise in rock phosphate capacity to translate into increased supply. It predicts a more modest 18% growth in phosphate

Fig 2: **Raw materials, intermediates and products**

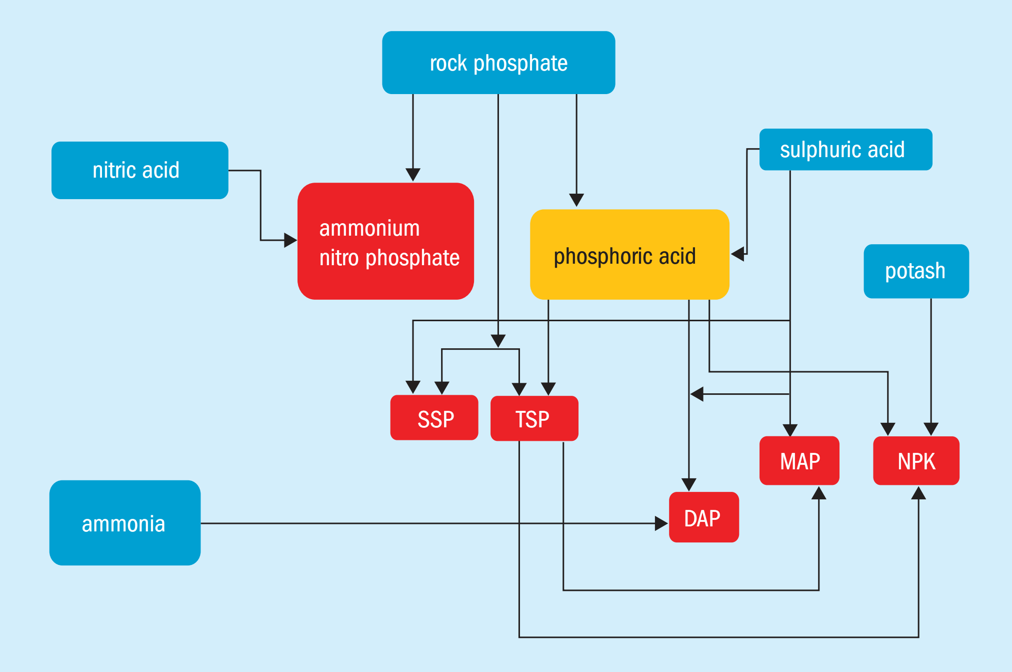


Table 1: **World phosphate rock production and trade**

Million t rock	2011	2012	2013	2018
Production	190.6	196.5	193.5	
Trade	31.1	30.2	26.2	
Supply			218	258
Capacity			246	313

Source: IFA

Table 2: **World phosphoric acid potential supply/demand balance**

Million t P_2O_5	2014	2015	2016	2017	2018
Supply					
Capacity	55.6	57.67	58.62	60.41	61.51
Potential supply	46.71	48.14	49.33	50.80	52.03
Demand					
Fertilizer	37.33	38.18	38.98	39.74	40.49
Non-fertilizer	5.59	5.88	5.95	6.15	6.28
Distribution loss	0.86	0.88	0.90	0.92	0.94
Total demand	43.77	44.94	45.83	46.81	47.71
Balance					
Surplus	2.93	3.20	3.50	3.99	4.32
% of supply	6	7	7	8	8

Source: IFA

rock supply over the medium term – rising from 218 million tonnes to 258 million tonnes between 2013 and 2018. Nearly 20 million tonnes of extra phosphate rock supply is likely come from African countries such as Morocco and Tunisia. Supply from Saudi Arabia and Jordan should also expand by 9 million tonnes with China contributing an additional 7 million tonnes (Table 1).

The supply of the phosphate industry's main intermediate material, phosphoric acid, could also rise by as much as 5.32 million tonnes (11%) over the medium-term. A total of 30 new phosphoric acid units are scheduled to become operative between now and 2018, according to IFA. In particular, large additions to capacity are expected in Morocco, Saudi Arabia, China and Brazil. This means that overall global phosphoric acid capacity may well outstrip fertilizer demand leading to a growing supply imbalance.

IFA predicts the worldwide phosphoric acid surplus will grow by 1.39 million tonnes over the next four years from 2.93 million tonnes in 2014 to 4.32 million tonnes by 2018 (Table 2). Phosphoric acid surpluses are likely to rise from 6% to 8% of supply over this period.

CRU separately estimates that 47 phosphoric acid plants could be developed globally over the next five years, with 13 of these likely to be "probable and firm" prospects.

Processed phosphates capacity

Diammonium phosphate (DAP), monoammonium phosphate (MAP), and triple superphosphate (TSP) are the industry's main saleable end products. Global capacity for such phosphate fertilizers is forecast to grow by 5.1 million tonnes (12%) over the next five years to 47.7 million tonnes – with expansion of DAP capacity likely to account for 80% of this (Table 3). Around 22 new phosphate production units in 10 countries are planned over this period, with China accounting for seven to eight of these and a further seven coming from Morocco and Saudi Arabia.

IFA expects a "massive addition" of new phosphate fertilizer capacity to come on-stream in both Morocco (+1.8 million tonnes) and Saudi Arabia (+1.5 million tonnes) by 2018. In Morocco, OCP, the world's largest producer of rock phosphate and phosphoric acid, looks set to expand its current annual MAP and DAP production capacity of 3 million tonnes at Jorf Lasfar by 60% to 4.9 million tonnes by 2018. It is planning to add 4 million tonnes of capacity between 2014 and 2016 and a further 6 million tonnes of capacity between 2016 and 2020 as part of a two-phase expansion of its Jorf phosphate hub complex.

Saudi Arabia's production capacity for phosphate fertilizer is expected to ramp up to 7.4 million tonnes over the next two years. Ma'aden expects construction of a new 2.6 million t/a capacity DAP unit and a 0.76 million t/a NPK capacity unit at Ras Al Khair on the gulf coast to be completed by the end of next year. The $7bn Umm Wa'al project in the north west of the country will also have the capacity to produce 90,000 t/a sodium tripolyphosphate (STPP) and 250,000 t/a of monocalcium phosphate (MCP) and dicalcium phosphate (DCP)

1 47 | 2 48 | 3 49 | 4 50 | 5 51 | 6 52 | 7 53 | 8 54 | 9 55 | 10 56 | 11 57 | 12 58 | 13 59 | 14 60 | 15 61 | 16 62 | 17 63 | 18 64 | 19 65 | 20 66 | 21 67 | 22 68 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46

Table 3: **Global processed phosphates capacity**

Million t P_2O_5	2013	2014	2015	2016	2017	2018
DAP	27.00	27.65	28.93	29.73	31.03	31.03
MAP	11.22	11.28	11.29	11.29	11.29	11.97
TSP	4.43	4.42	4.47	4.47	4.47	4.74
Total	**42.65**	**43.35**	**44.69**	**45.49**	**46.79**	**47.74**

Source: IFA

Table 4: **Key DAP and MAP capacity developments**

Million t P_2O_5	2013	2014	2018	2013-2018 change
DAP*				
China	8.1	8.1	9.0	0.9
Saudi Arabia	1.4	1.4	2.9	1.5
Morocco	2.4	2.8	4.2	1.8
India	3.5	3.7	3.7	0.2
Total DAP				**4.4**
MAP				
Brazil	0.3	0.3	0.9	0.6
China	7.1	7.1	7.3	0.2
Total MAP				0.8
Total				**5.2**

**Option to change to MAP-TSP production.* *Source: IFA*

Table 5: **World phosphate demand.**

Million t P_2O_5	2011	2012	2013e	2014f	2018f
Demand	41.6	41.9	41.8	42.2	45.9

Source: IFA

– and could enter production within two years. A $4.1bn finance package for the project, a joint venture between Ma'aden, Mosaic and Saudi Basic Industries Corporation (SABIC), is due to be agreed by the end of June.

A number of projects slated for completion by 2018 could see Brazilian phosphate fertilizer production capacity increase to 4.4 million tonnes, a 1.1 million tonnes increase on 2013. Vales Fertilizante's Patrocinio [Salitre] project and Anglo American's Catalao project combined are expected to add 680,000 tonnes to Brazilian MAP capacity and 260,000 tonnes to TSP capacity. Canadian-owned MBAC also plans to boost single super phosphate (SSP) production at its central Brazil Itafos Arraias site from 345,000-375,000 tonnes to 470,000-500,000 tonnes over the next two years. However, IFA expects Brazil will need to maintain fertilizer imports at 2-2.5 million tonnes over the next five years to meet a predicted 3.5% increase in annual fertilizer demand.

China has continued to export massive tonnages of phosphate fertilizers since 2007 due to its surplus capacity and excess production – despite the imposition of seasonal export taxes. Exports of DAP, for example, reached a record 3.8 million tonnes in 2013 with MAP exports close to 0.7 million tonnes. IFA expects exportable surpluses to remain in the region of 5-5.5 million t/a over the next three years. A new flat rate export tariff of around $16 per tonne comes into force in China this year. CRU expects the effect of the policy change to be largely neutral, although it is likely to mean Chinese exports are more evenly spread throughout the year and may make marginal producers less competitive.

DAP and MAP capacity is set to expand further in China with seven new phosphate fertilizer units expected to come on-stream in Sichaun, Hubei and Xinjiang provinces before 2018. These should add 0.9 million tonnes to China's 9 million tonnes DAP capacity and expand its existing 7.1 million tonnes capacity for MAP by 0.2 million tonnes. Continued Chinese expansion is predicted despite long-standing overcapacity and the financial losses posted by more than half of the country's fertilizer producers in 2013 (Table 4).

Medium-term demand – up a fifth on pre-recession levels?

A limited resurgence in world phosphate demand is expected over the next four years, following a period of stagnating sales between 2012 and 2013 linked to falling import demand from India for DAP and rock phosphate.

IFA predicts world phosphate demand will grow at a modest annual rate of 2% between 2014 and 2018. It expects overall global phosphate demand to grow by 3.7 million tonnes (9%) from 42.2 million tonnes to 45.9 million tonnes by 2018 (Table 5).

Historically, global phosphate consumption dropped by more than 10% in 2008/09 but recovered almost entirely the following year. If IFA is correct, world demand for phosphate will eventually surpass pre-recession levels by around a fifth over the next three to four years.

India and China's entwined fortunes

The phosphate market relies heavily on international trade with two major import regions in particular – South Asia and Latin America – determining demand. IFA expects Asia and Latin America to collectively account for around three quarters of increased demand to 2018.

The market for DAP – the main internationally-traded phosphate fertilizer – illustrates current trade imbalances, with the US, China, Russia and Morocco exporting most of the traded volume and India alone accounting for around half of global imports. India's role as a major import market for excess Chinese phosphate production makes the trade between the two countries a key supply/demand relationship internationally (Figure 3).

Subsidy changes and more stable, moderate prices are likely to see Indian phosphate demand back on a growth trajectory during the last half of this decade, predicts

Mosaic. It is forecasting a 2.3% annual growth in demand from the subcontinent between 2010 and 2020. This equates to a 3.0 million tonnes increase in demand, from 11.1 million tonnes to 13.8 million tonnes, in India over the decade. Domestic DAP production will remain stable over this period at circa 4 million tonnes, meaning DAP imports would need to rise to around 10 million tonnes by 2020.

Demand uncertainty

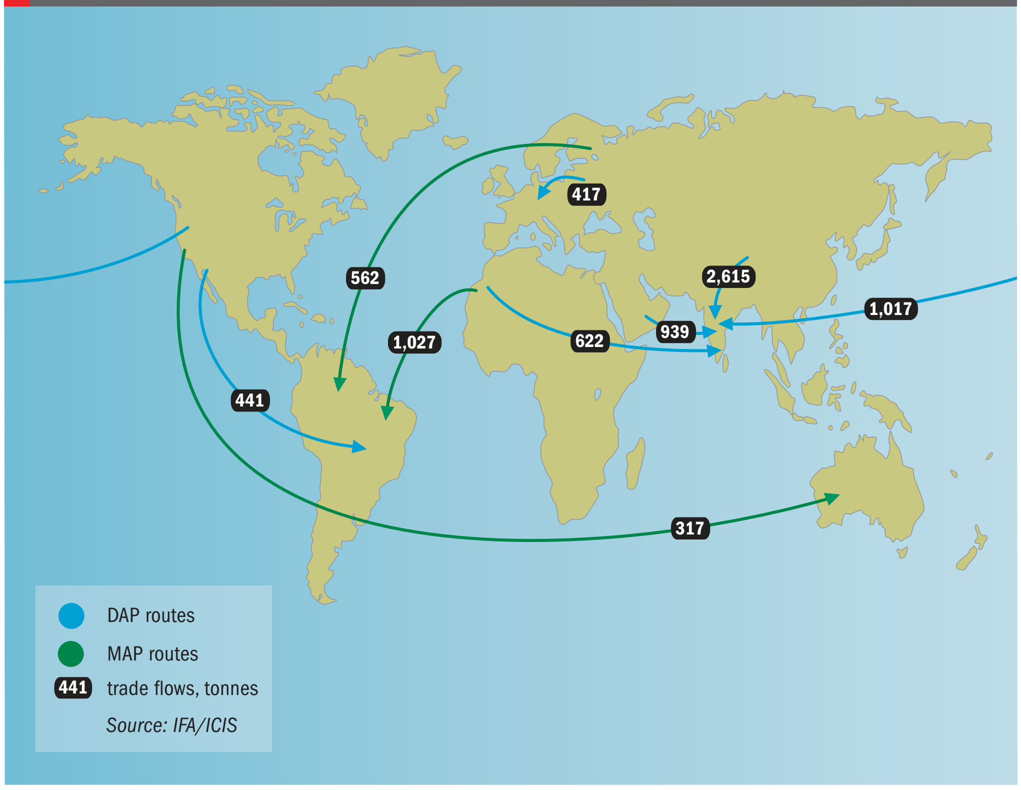
Accurately forecasting global phosphate market imbalances over the medium term is highly problematic due to myriad uncertainties on the demand side. IFA's central forecast of 45.9 million tonnes for 2018 world phosphate demand comes with a health warning attached – and could vary anywhere between 44 and 48 million tonnes due to a host of unpredictable factors. The performance of the world economy, possible weather-related crop shortfalls, unexpected changes to fertilizer subsidy regimes and new policies on nutrient use efficiency could all confound current expectations.

Major factors such as agricultural commodity price falls, changes to phosphate trade flows, the oil price collapse and the strong dollar all influenced the phosphate market in 2014. Looking ahead, the fortunes of the phosphate market this year will partly hinge on agricultural commodity price trends and whether the predicted rise in demand from India comes through. Mosaic, for example, is banking on take-up by India for more than half its forecast increase in 2015 shipments.

"Demand is the big unknown," agrees Juan von Gernet, a senior consultant and phosphate team leader at CRU, although he is confident about the ability to forecast demand over the medium/longer term. "Demand numbers do change in every quarterly supply–demand balance CRU puts out but we do have a good handle a few years out. There can be considerable quarterly fluctuations but the medium term outlook for demand is OK."

In terms of global phosphate supply, the main game-changing development is the end of China's massive 15-year capacity expansion programme and the prospect of Morocco and Saudi Arabia stepping in to supply the bulk of projected demand during the last half of this decade. CRU expects to see a consolidation and shake-out in Chinese phosphate production over the next five years. The future of the country's big producers looks secure but many mid-tier and smaller phosphate producers will face closure due to their higher costs.

Fig 3: **Global trade in MAP and DAP 2014**



The US has lost 1 million tonnes of production capacity following recent supply shocks. Mississippi Phosphates, the country's third largest phosphate, producer, ended DAP production at its 771,000 tonne capacity Pascagoula plant in December following bankruptcy. A further 215,000 tonnes of US phosphate capacity was also lost last July when Potash Corp closed its Suwannee River operation.

Tracking future additions to capacity is relatively straightforward, according to CRU. "On supply, most companies budget for this investment – in many cases more than $1bn is allocated for a new integrated project, which requires considerable foresight. This means we can take a decent view on capacity," comments CRU's Juan von Gernet. He also points out that many companies took the decision to invest in new capacity five to seven years ago when fertilizer prices were high and the market fundamentals strong. Short-term fluctuations in market prices can affect project viability though, warns von Gernet, with new capacity mothballed or delayed once prices fall below long-run marginal costs (LRMC) – which is the cost of bringing an additional tonne of new supply to the market.

The commercial rationale for investing in what seems like needless extra capacity – given that supply imbalances looks set to increase up to 2018 – looks questionable. But Oliver Hatfield, an analyst and director at Integer Research, believes there are two explanations for the continuing investment in extra phosphate production.

"Investment in commodities tends to shift between phases of under and over investment. It's what makes them cyclical. The other [factor] is that the role of the state is influential in key countries which are significant for supply and demand – China, India, Morocco etc. – so decision-making is sometimes influenced by factors beyond pure medium-term financial profit," he said.

Investment in production can be based on a strategic decision to gain market share or be due to the need to replace and retire older, less efficient phosphoric acid and processed product capacity. The former is the most likely explanation, in Hatfield's view. "There is some strategic investment taking place relating to market share. Replacement/retirement, much less so," he concludes.

What is reassuring about current phosphate supply and demand predictions is the good level of agreement between independently arrived at forecasts. CRU, for example, is predicting a 5 million tonnes growth in global supply over the next five years and an 8-9% growth in demand, almost identical to IFA's assessment. ■

Phosphates 2015
welcomes you to Florida

CRU Events will convene the 2015 Phosphates Conference and Exhibition at the Tampa Marriott Waterside Hotel between 23-25 March 2015.

Tampa, Florida, in the heart of the US phosphates sector, is the setting for *Phosphates 2015*, the annual international meeting for the global phosphates industry. This year's three-day conference offers a typically wide-ranging and highly topical mix of subjects. Leading phosphate producers, traders and engineering, technology and equipment providers from across the globe are all expected to attend.

Tuesday's programme covers topics such as industry innovation and the state of play of the North American, Brazilian and Chinese phosphate markets. Phosphorus sustainability, phosphate rock price trends and the outlook for nitrogen and sulphur raw materials will also be put under the spotlight. Attention on the Wednesday turns to the demand for phosphate from feed, food and industrial markets, world freight and the influence of weather on demand.

The latest developments in beneficiation and process technology are also showcased in technical sessions on the afternoons of both days. A preconference site visit to Mosaic's Four Corners mine in nearby Bradley has also been laid on for delegates on the Monday.

PROGRAMME OF PRESENTATIONS

TUESDAY 24 MARCH

SESSION 1: GLOBAL AND REGIONAL OUTLOOKS

- **Keynote address: Phosphate Industry Innovation**
  Rick McLellan, Senior Vice President Commercial, The Mosaic Company
- **Suppliers at the gate: The CRU View on the global phosphate outlook**
  Juan von Gernet, Team Leader – Phosphates, CRU
- **Capital Markets: Perspectives on the Phosphate Sector**
  Glenn Gatcliffe, Managing Director, Global Metals & Mining, Fertilizers, BMO Capital Markets
- **Out of the Haze: Demystifying the Chinese phosphate market**
  Isaac Zhao, Senior Consultant – Phosphates & Sulphur, CRU
- **Outlook for Sustainable Use of Phosphate Fertilizers in Brazil**
  Luiz R G Guilherme, PhD, Full Professor, Soil Science Dept., Universidade Federal de Lavras; Technical Consultant, ANDA, Brazil
- **North American Outlook**
  Dr. Michael Rahm, Vice President Market and Strategic Analysis, The Mosaic Company
- **The North American Partnership for Phosphorus Sustainability**
  James Elser, Regents' Professor & Parents Association Professor (Ecology, Evolution, and Environmental Science); Distinguished Sustainability Scientist, School of Life Sciences, Arizona State University

SESSION 2: RAW MATERIALS OUTLOOK

- **Rocky road – where will phosphate rock prices end up?**
  Alberto Persona, Consultant – Phosphates, CRU

- **Panel discussion: From minor to miner: Exploring the challenges and opportunities for juniors up and down the Phosphate value chain**
  Chris Tziolis, Executive Director, Rum Jungle; Roderick Smith, CEO, Cominco Resources; Ralph Rushton, Director & Business Development, Focus Ventures. Moderator: Peter Heffernan, Managing Consultant, CRU Consulting
- **The supply outlook for raw materials: Nitrogen and Sulphur**
  Sheena Patel, Senior Consultant, CRU Consulting

WEDNESDAY 25 MARCH

SESSION 3: FEED, FOOD AND INDUSTRIAL MARKET OUTLOOKS

- **Perspective from an Asian Producer – Phosphoric acid industry; Food and Industrial demand**
  Ajay Mahajan, President, Aditya Birla Chemicals
- **Feed outlook: Discussing global feed phosphate demand and constraints and opportunities in the feed market**
  Clay Hackney, Manager International Sales, PotashCorp
- **Agricultural markets and phosphate demand**
  Wayne Welter, Market Analyst, J.R. Simplot
- **Exploring the opportunities provided by precision farming and specialty fertilizers**
  Julia Presnova, Vice President Strategic Intelligence & Marketing, Prayon
- **Examining threatening and favourable global weather conditions, and the subsequent impact on fertilizer demand**
  Drew Lerner, President and Senior Agricultural Meteorologist, World Weather, Inc.
- **Transportation and logistics challenges**
  Speaker to be confirmed

TECHNICAL SESSION TIMETABLE

TUESDAY 24 MARCH

16:30 **Exploring technologies that enable beneficiation of poor and harder to treat phosphates**
Dr. Michael W. Baker, Manager Minerals Beneficiation & Chemical Technologies, Tenova Bateman Technologies

16:55 **Floatation schemes of phosphate ores worldwide**
Guoxin Wang, Global Director, Mining Chemical Technologies, ArrMaz Products

17:20 **Potential of thermal fluidized bed processes for removal of impurities from Phosphate Rock**
Ludwig Herman, Senior Consultant Energy, Outotec

17:45 **Process Technology, test results and plant integration for the removal of Mg from high Dolomite Phosphate Rock**
Dr Patrick Zhang, Research Director – Beneficiation & Mining, Florida Industrial and Phosphate Research Institute; Curtis Griffin, Phosphate Fertilizer Specialist, PegasusTSI Inc.

WEDNESDAY 25 MARCH

14:30 **Phosphoric plant cooling water treatment process**
Speaker to be confirmed, Hatch

14:50 **New process for removing iron from Phosphoric Acid**
Stephen Hilakos, Process Engineer, Jacobs

15:10 **Reduction of impurities in Phosphoric Acid**
Faustino Prado, President, Prado Technology; Samuel Sweat, Senior Consultant, Phosphates, Prado Technology. ■

The US keeps up its excellent work

The United States is acknowledged to have pioneered modern phosphate production but is facing new challenges as its output declines. We profile seven organisations determined to cement the country's reputation as a global centre of excellence for the phosphate industry

Mineral statistics can be deceptive. US phosphate production peaked at 54.4 million tonnes in 1980, accounting for 37% of world production that year. Production has slid inexorably since then to an estimated 27.1 million tonnes last year, only 12% of global production. That figure is dwarfed by the 100 million tonnes of phosphate rock produced by China in 2014 and also eclipsed by Morocco's latest 30 million tonne annual production volume.

Yet the US remains a global heavyweight. Phosphate extracted from 11 mines by five firms in four states still generates $2.4 billion worth of processed products annually and employs 2,100 in mining and beneficiation. Florida and North Carolina account for four fifths of domestic phosphate rock output with Idaho and Utah making up the final fifth.

The US also remains a leading international exporter of phosphate fertilizers and, thanks to the industry's long history, has built up an extraordinarily strong and sophisticated manufacturing supply chain. More than 95% of US mined phosphate goes straight to phosphoric acid production. This is then transformed into liquid and granular fertilizers and animal feed, adding value along the way and further boosting the domestic economy. International trade is almost as important a revenue-generator as sales to the domestic market. Nearly half of domestically-produced US phosphoric acid ends up being exported, as either granular diammonium phosphate (DAP) and monoammonium phosphate (MAP) or merchant-grade phosphoric acid.

Some industry analysts may take production figures at face value and argue that the US phosphate industry is locked into a slow but inevitable decline, compounded by underlying factors such as depleted resources, increasingly stringent environmental regulation and international competition. But the US industry's depth and breath of expertise, and track record of technological innovation, still gives it a competitive edge globally. The following seven profiles help explain why the US phosphate sector still punches above its weight – and continues to capture new markets for its products and services.

Troubleshooting and problem solving

One pivotal organisation that has long played a role in helping the US phosphate industry innovate, develop and grow is the **Florida Industrial and Phosphate Research Institute (FIPR)** (*Removing impurities from phosphoric acid*, **Fertilizer International**, No. 464 [January-February 2015]). The institute has a history stretching back over four decades and is currently part of the Florida Polytechnic University.

"In the Institute's 36 years of operation, it has made great strides in addressing the most vexing problems both within the phosphate industry and in the environment and communities it occupies," says Brian Birky, FIPR's interim executive director.

This has included research on process water treatment, phosphogypsum management, land reclamation, resource recovery and energy and water conservation.

The institute's current remit allows it to offer consultancy services and to enter into contracts with the private sector,

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68

US federal and state bodies and foreign companies and governments. Having the freedom to expand internationally and "work on industry issues from around the world" has been an important change for FIPR, says Birky: "The Institute is authorized to promote the application, patenting, and commercialization of its technologies, knowledge, and intellectual property. For example, the Institute is now conducting studies funded by companies in Central and South America, Asia, and Europe."

Dolomite flotation, on-line spectrometry and dewatering technology have been three particular fruitful areas of FIPR research that have helped the US phosphate industry to innovate, cut costs, improve efficiency and reduce its environmental impacts.

FIPR has been instrumental in helping the industry develop a successful mineral processing method for removing magnesium from phosphate. This is a particular problem because nearly 50% of phosphate ore in the Southern Extension in central Florida is currently unusable due to high levels of magnesium contamination in its lower zone. Thanks to FIPR-funded research, Mosaic is on the verge of constructing a dolomite froth flotation plant to process and upgrade phosphate from this lower zone.

FIPR originally funded the laboratory development of a froth flotation method for processing high-dolomite pebbles in the late 1990s. This used a phosphoric acid/sulphuric acid mixture as a phosphate depressant and a proprietary reagent as a dolomite collector. Follow-up pilot tests by Jacobs Engineering in 2001 demonstrated the technical and economic feasibility of this flotation technology. The total operating costs of processing highly-dolomitic Florida pebbles in this way were estimated at $15.6 per short ton of product. "Even counting for inflation and price increases, this operating cost is extremely competitive today – because phosphate rock is selling for about $150 per ton," says Patrick Zhang, FIPR's beneficiation and mining research director.

Mosaic subsequently carried out an engineering and design study for a dolomite flotation plant but suspended the project due the concern about the cost of treating process waters containing phosphoric acid. Mosaic and FIPR are currently working together to solve this problem by evaluating a new dolomite collector that avoids using phosphoric acid as a phosphate depressant. The research is promising and there is a high probability that Mosaic will proceed with the construction of dolomite flotation plant in the very near future, according to FIPR.

FIPR has also long championed the potential of on-line chemical analysis for improving the performance of phosphate beneficiation plants. A breakthrough came when FIPR began working on laser induced breakdown spectroscopy (LIBS) with Dr Michael Gaft of Israeli firm Laser Distance Spectrometry. This collaboration resulted in the development and commercialisation of the world's first LIBS on-line analyser for wet minerals. Mosaic now uses two LIBS analysers for quality control purposes at one of their beneficiation plants and is saving several million dollars annually as a result. FIPR has also funded and successfully tested an industrial LIBS prototype for analysing quarry faces and mined materials. "Remote, instant analysis of mine faces would truly revolutionize phosphate mining and beyond," comments Zhang.

FIPR recently completed a pilot project on the use of 'deep cone paste' dewatering technology. This involved treating phosphatic clay with an anionic polymer, mixing this with sand and pumping the resulting sand/clay mixture into the feed box of a deep cone thickener. A cationic polymer is then added so that the sand/clay mix thickens into a high-solids paste. "This is the most successful project on phosphatic clay dewatering ever undertaken by FIPR or any other organization. It offers the best hope for phosphatic waste disposal without or at reduced impounding," says Zhang.

Dewatering is a particular economic and technical challenge for the Florida phosphate industry, where clay is typically removed from rock phosphate before upgrading by froth flotation. This generates around one tonne of clay waste per tonne of phosphate end-product. Separated clay slurry with a solids content of about 3% is pumped into large settling ponds. These can occupy around 40% of mining areas and limit the options for land use after reclamation.

FIPR believes deep cone paste technology has the potential to save the industry tens of millions of dollars annually. The technology could also make obtaining new mining permits easier and leave more land available for high value uses. Pilot tests results suggest that using deep cone paste for dewatering instead of conventional settling ponds could benefit a typical Florida phosphate mine by $15.2 million over its 25-year life.

Online LIBS Analyzer Installed on a moving belt.

Disruptive innovation

Use of the Wet Acid Process (WAP) to produce phosphoric acid has long been the mainstay of phosphate fertilizer manufacture globally. Florida-based **JDC Phosphate** is intent on changing that by developing and championing a rival technology, the Improved Hard Process (IHP). Successful commercialisation of IHP is a potential phosphate industry game-changer in its view.

IHP takes it name from Dr Robert Hard of Occidental Research who in the early 1980s solved a melting problem that had plagued previous attempts to produce phosphoric acid in a rotary kiln. The process was subsequently improved upon by Joseph Megy, a former colleague of Hard's, and combines low-grade phosphate ore with petroleum coke and silica to produce 70% phosphoric acid through a high temperature reduction reaction.

JDC Phosphate has built a 12,000 t/a IHP demonstration plant at Fort Meade, Florida, to validate the technology and prove its viability (*A non-sulphur route to phosphoric acid*, **Sulphur**, No. 348 [September-October 2013]). IHP could cut phosphoric acid production costs by 30% or more, according to the company. The process also produces inert pellets which the firm plans to sell as a lightweight concrete aggregate called J-ROX.

JDC Phosphate currently holds two US patents for IHP with two further patents pending. Financial backers have invested $42m in the venture to date and include Texas-based Agrifos Fertlizer, trading company Mitsui, Australian mining company Minemakers, the Florida Opportunity Fund and Portuguese venture capital business Espirito Santo Ventures.

Conventional phosphoric acid production by WAP requires a high-quality phosphate ore and involves mineral processing to upgrade P_2O_5 content and remove impurities. WAP also produces phosphogypsum waste which requires management and disposal. IHP, in contrast, can consume lower grade phosphate ore and has less stringent quality requirements. It has several potential cost advantages and other benefits in comparison to WAP, such as the extension of mining reserves and waste avoidance.

JDC Phosphate is running its demonstration plant on 'high magnesium pebble' rejected by Mosaic's Hardee Mine and other reject ore. This feedstock was selected as it is very similar to the lower zone phosphate deposits of the Hawthorne formation in central Florida which are currently left largely un-mined due to their high magnesium content. "IHP's requirements for rock phosphate quality are much less compared to conventional WAP," says JDC Phopshate's chief executive officer, Tip Fowler. "The raw material consumed by our process contains 3.7% magnesium oxide on average compared to the maximum 1% content WAP is able to tolerate."

IHP could "literally triple phosphate reserves in Florida" in Fowler's view by opening up an extra 1.2 billion tonnes of low-grade ore for exploitation. He adds: "The demonstration plant has shown that all the key features and different components for success do work. We've converted gases to phosphoric acid at high yields, achieved a stable kiln temperature avoiding hot spots and melting and controlled dusting inside the kiln."

Fowler is confident that JDC Phosphate is close to demonstrating that IHP is feasible. The firm plans to run its demonstration plant semi-continuously during the second half of this year with a new dust scrubber fitted. These trials are likely to be a critical as they could finally provide the engineering data needed to design a full-scale IHP operation. Their successful completion would allow JDC Phosphate to seek a partner and select a location for a much larger 100,000-200,000 t/a capacity IHP plant, potentially in Senegal, Peru, Australia or Florida. It could, however, take three years to obtain the necessary permits and build such an operation.

A license agreement with JDC Phosphate also gives Minemakers the right to develop an IHP project at its Wonarah phosphate mine in Australia's Northern Territory.

Spearheading international expansion

Consulting and engineering company **KEMWorks** is based in Lakeland, Florida, and specialises in project development for the global phosphate industry. Since its formation in 1995, KEMWorks' has transformed its business in response to the contraction of the US phosphate industry and has gone from being primarily domestic to becoming more than 75% overseas-based at the present day.

KEMWorks has helped develop a number of notable international phosphate projects, including Cominco Resources' Hinda project in the Democratic Republic of Congo and the Wonarah project for Minemakers in Australia. The company is also involved in the Farim phosphate project being developed by Swiss firm GB Minerals Ltd in the northern part of central Guinea-Bissau in West Africa. This high-grade sedimentary phosphate deposit consist of a single, continuous phosphate bed with measured and indicated resources of 92.6 million tonnes at 27.7% P_2O_5 grade.

> **Increasingly exacting emissions standards and the need to achieve superior plant energy efficiency are creating a highly-competitive marketplace.**

GB Minerals describes Farim as the world's highest grade greenfield phosphate rock project, and believes is will eventually deliver a premium product containing up to 36% P_2O_5. KEMWorks was able to reduce the capital cost of the project's beneficiation plant by simplifying its flow sheet after carrying out laboratory beneficiation test work in Florida. It is currently working with Lycopodium in Canada on the project's bankable feasibility study.

KEMWorks has also helped US firms switch from phosphate to other forms of fertilizer production. Agrifos (now Rentech Nitrogen) looked at alternatives to phosphate fertilizers in 2009 when it was forced to stop operating its gypsum stack in Pasadena, Texas. It was KEMWorks know-how and engineering expertise which enabled the existing DAP/MAP granulation plant to be converted to ammonium sulphate production. The converted plant now produces up to 2,100 tonnes of ammonium sulphate a day by combining sulphuric acid produced on site with imported ammonia.

The experienced team assembled by engineering, procurement and construction specialists **PegasusTSI, Inc.** (PegasusTSI) has been involved in more than 75 large-scale fertilizer projects around the world. The Tampa-based firm has built up a wealth of experience on phosphoric acid and granular phosphate fertilizer production and fluosilicic acid recovery.

Notable international assignments include a 2012 contract to convert the feed system of the Pakistan Maroc Phosphore phosphoric acid complex in Jorf Lasfar, Morocco, from dry rock to slurry. This enabled the plant to accept feed transported from Khouribga along OCP's 192Km slurry pipeline. Also in Morocco, PegasusTSI is involved in the design of OCP's new Daoui wash/flotation plant as part of a project to upgrade and improve its performance. The firm also completed a prefeasibility study for MBAC's $393 million Santana phosphate project in Para State, Brazil, in 2012. The indicated resource estimate suggested sufficient reserves (average P205 grade 12.1%) for an estimated 30-year mine life, with production of 500,000 tonnes per annum of single superphosphate (SSP) possible. In the US, PegasusTSI have built a $50 million, 84,000 t/a phosphoric acid plant expansion for SF Phosphates and a turnkey dicalcium phosphate (DCP) granulation plant for JR Simplot, both at Rock Springs, Wyoming.

Factors such as exacting emissions standards for air, water and solid waste and the need to achieve superior plant energy efficiency are creating a highly-competitive marketplace, says PegasusTSI's business development specialist, Baccar Ennayal. "PegasusTSI's team of engineers and designers remain at the leading edge of these challenges. The recent imposition of yet more stringent environmental regulations on operating plants in the US has allowed us to provide cost-effective solutions to reducing emissions through in-plant abatement as well as end-of-pipe treatment strategies."

Process innovation and diversification

K-Technologies, Inc. (K-Tech) of Lakeland Florida is specialist provider of innovative process technologies to the minerals and chemicals industries (*More added value* *from phosphates*, **Fertilizer International**, No. 463 [November-December 2014]). Its expertise includes the use of advanced separation processes such as continuous ion exchange (CIX) and continuous ion-chromatography (CIC) in chemical and environmental applications.

CIX is used for minor element removal (MER) from phosphoric acid during DAP production due to its ability to separate out deleterious elements such as iron, aluminum and magnesium. The company's technology is also being used to meet growing demand for high-purity fertilizers such as the clear-liquid, water-soluble MAP.

"K-Tech is not an equipment supplier or engineering company," emphasises chief executive officer and company president, Tom Baroody. "We design the overall process package and develop detailed design criteria, generally in partnership with specialty engineering companies and equipment suppliers in order to produce a complete project package."

K-Tech's expertise can benefit the US phosphate industry in several ways, says Baroody. "As conventional ore reserves decline, our MER technology can be used to allow mining of lower grade ore reserves that in Florida underlie the conventional ore seam. These ores are high in MER, particularly magnesium, and could be developed in many instances without disturbing additional land surface area."

The firm also believes its technology could be used to harvest almost all of US fluoride requirements by separating silicofluoride from phosphogypsum pond water systems at active phosphate operations in Florida. This would have the added benefit of mitigating or eliminating the cost of treating the fluoride in these ponds.

CIX/CIC technologies generally allow the recovery of target elements such as REEs and uranium from phosphoric acid at a 25-50% lower cost than is achievable through either conventional mining or by using other recovery methods such as solvent extraction.

K-Tech believes its separation technology could help the US phosphate industry diversify and strengthen its position in the global marketplace.

"A phosphate company with vision could become a major diversified industrial supplier to US. and worldwide markets for fluorides, silica, uranium, and rare earths, and could offer an entire new line of water soluble high analysis fertilizers, in addition to its current line of products," concludes Baroody, adding: "This could be done while their ore reserve base is expanded. As a result, such a company could become self-sufficient instead of relying on increasing imports of phosphate rock – and all of this can be accomplished in a cost-effective, environmentally-friendly manner."

K-Tech is also currently working with Texas Rare Earth Resources on a project to extract and purify individual heavy rare earth elements (REEs) from a rhyolite ore-body in the state.

Integrating process chemicals with process design

Florida-headquartered **ArrMaz** is a global supplier of process chemicals to the fertilizer industry (*Minimising fertilizer losses in transportation, handling and storage*, **Fertilizer International**, No. 464 [January-February 2015]). Its products include collectors, dust control and anti-caking agents, defoamers, flocculants, filter and granulations aids and colouring agents. It supplies these custom formulations via an international network of outlets in the US, Brazil, China, France, Morocco and Saudi Arabia.

Part of ArrMaz's business is supplying chemicals and additives for phosphate mining and downstream processing. Engineering and process design consultancy are now "hugely important elements" of this, according to chief marketing officer, Jeff Walker. On new phosphate projects, ArrMaz works directly with project principals, their advisors and engineering, procurement and construction contractors.

"It's amazing how frequently the process designs for processing a particular ore and converting it into phosphoric acid and fertilizer fail to fully consider the impact of those designs on process chemicals, and vice versa," says Walker. "The assumption is often that the process chemicals are simply out there and that a sustainable, economic, abundant supply is a given."

He continues: "We try to advise clients that the reality can frequently be otherwise, and that changing the design of a process – even to one with higher capital cost – is easily worth considering if it's a much better match for more economical process control chemicals that are easier-to-handle and readily available. Especially if these are more forgiving of inevitable surprises, such as the variability of the phosphates to be processed."

Walker concludes that it is in everyone's best interest to bring in know-how and a "deep understanding" of process chemicals to a project at an early stage, to ensure that process design, engineering and construction are carefully coordinated with process reagents.

Improving phosphorus availability

Sarasota-based fertilizer additive manufacturer **Eco Agro Resources** first opened for business in 2013 (*New frontiers for super-charged nutrition*, **Fertilizer International**, No. 463 [November-December 2014]). It markets two nitrogen stabilizer products for urea granules and urea ammonium nitrate (UAN), both incorporating its proprietary PENXCEL technology. N YIELD blocks the urease enzyme and improves the take-up of the fertilizer by soil during the first weeks after application. Recently introduced sister product N-BOUND contains a nitrification inhibitor which blocks the organisms that cause the oxidation of ammonium to nitrate in soil.

Eco Agro Resources has now turned its attention to production of a phosphate fertilizer additive, PHOS GAIN, with large-scale commercial tests planned in North and South America during 2015. PHOS GAIN uses the same proprietary PENXCEL technology to prevent metals such as aluminium, iron, and magnesium from locking up phosphorus in the soil, so it remains available to plants. Chief executive officer, Andrew Semple, explains more: "The technology in PHOS GAIN was first used to enhance performance of oilfields. But we developed a unique, water-free formulation that allows the active ingredients to work more efficiently in protecting phosphorus."

Eco Agro Resources is fast-tracking the development of its fertilizer stabilisers and enhancers in response to growing environmental concerns over the release of nitrogen and phosphorus from farmland into streams and lakes. The successful conclusion of commercial tests should allow PHOS GAIN to be launched on the market later this year, in time for the 2016 growing season.

The company's technology provides growers with effective agronomic products that also help protect the environment, says Semple. "We all share the same goals in agriculture – to help feed the world and to protect the land for future generations. Those goals can be met with technology, education and adoption of improved practices, and allow us to continue to provide nutrients for growing crops while protecting our water resources," he concludes. ■

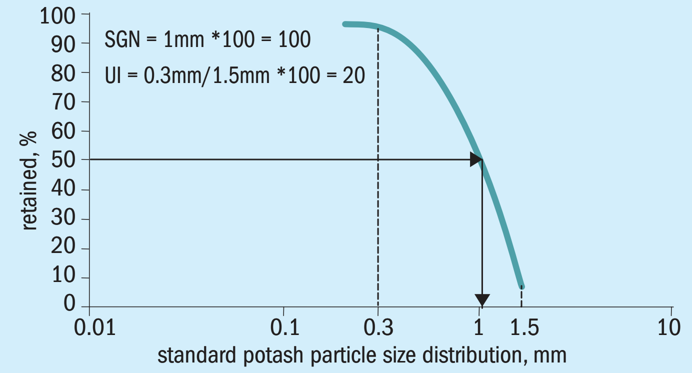
Meeting the needs of an exacting market

A typical potash production process.

PHOTO: APM SOLUTIONS

The production of marketable potash from the basic ore may comprise a series of processes, including crushing and pre-screening, milling, flotation, salt leaching from the flotation concentrate, drying, granulation and refining. Developments in potash processing technology are described.

Fig 1: **Calculation of the SGN number and UI index**



Most of the world's potash is extracted from evaporites by underground or solution mining. Another important source is brine from land-locked water bodies, as in the Dead Sea, Salar de Atacama and the Great Salt Lake.

Like most industrial minerals, potash is sold based both on its chemical composition and size distribution. Fertilizer-grade potash is typically marketed with a chemical composition of 60% K_2O minimum. Various potash fertilizer products are marketed based on their size distributions. The most common are granular, coarse, standard and fine. All four have the same chemical composition, but differ on their particle size distribution specifications. The coarser products are sold at a premium. (*Potash Processing in Saskatchewan – A Review of Process Technologies*, Carlos Perucca, AMEC Engineering & Construction Services Ltd.).

Particle size of fertilizer products is characterised by the two parameters of Size Guide Number (SGN) and the Uniformity Index (UI). SGN is defined as the particle size in millimetres, of which 50% by weight of the sample is coarser and 50% finer, times 100. The UI is the particle size of which 95% of the material is retained, divided by the particle size at which 10% of the material is retained, multiplied by 100. Fig. 1 shows the calculation of the SGN number and UI index.

In order to increase the concentration of KCl to 95%, three different beneficiation techniques are mainly applied in the potash industry: flotation, thermal dissolution-crystallisation (or hot leaching) and electrostatic separation.

The salt minerals in potash ores are intergrown with other salt minerals to varying extents. The most important minerals are sylvinite, sylvite mixed with halite, and kieserite. The ore most be sufficiently reduced in size, so that individual components are liberable, before the minerals can be separated and the useful components recovered. Potash salts are relatively easily size-reduced by grinding. In the crystallisation process, KCl is extracted and must therefore not be occluded inside other materials, which implies a size limit of 4-5 mm. (*Extraction, beneficiation and grinding of potash salt*, CPM LCA Database.) For flotation and electrostatic separation, liberation of the minerals must be complete, with the individual grains consisting of as much as possible of pure minerals.

In Canada, about 70% of the total potash and almost 90% of fertilizer-grade KCl is produced by froth flotation, sometimes supplemented by heavy media separation. Crystallisation is used mainly to produce industrial grade and speciality fertilizer grade (white muriate) potash. Fig. 2 shows the flotation route to obtain fertilizer-grade KCl.

For German sylvinite ores and hard salts, beneficiation is achieved by grinding to a maximum grain size of 0.8-1.0 mm. For the coarser sylvinite ores as found in Saskatchewan, a size reduction to <9 mm would give an adequate liberation.

Comminution, scrubbing and desliming

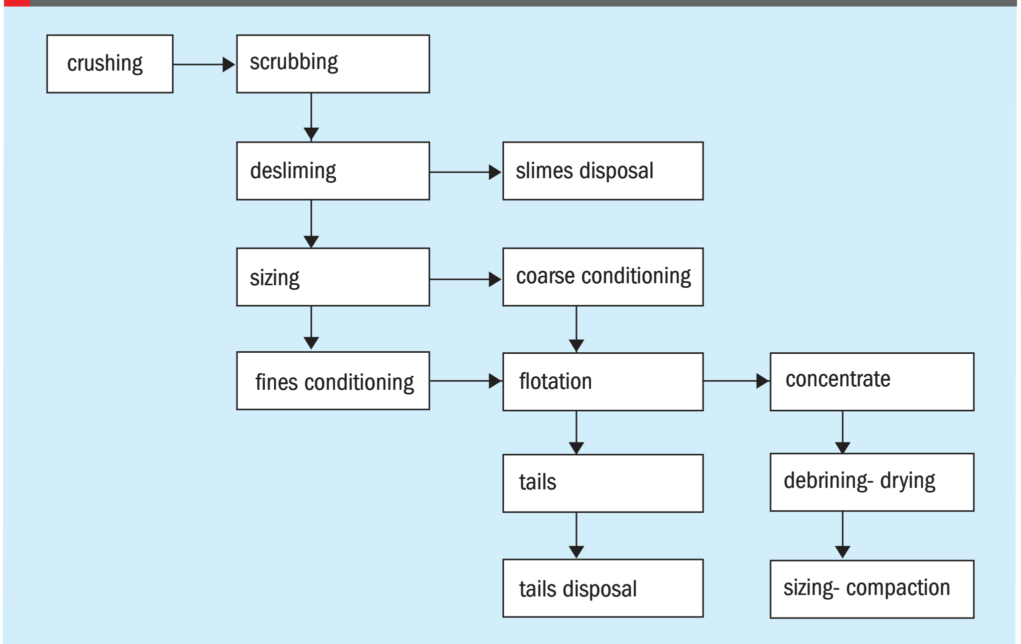
The sizing of the mill feed ore is a compromise between maintaining the KCl in as large a size as possible, obtaining a good liberation from the sodium chloride and facilitating the scrubbing of the insolubles released during the process. The run-of-mine ore is produced by continuous miners and is usually processed underground through a jaw crusher to reduce the largest lumps to the 150-200 mm range to minimise transportation problems underground and during skipping to the surface.

Potash ore is considered to be a soft rock. The simplest comminution circuits are single-stage dry crushing, using impactors in closed circuit with vibrating screens. More refined circuits comprise double-stage wet crushing in combination with wet screens and hydrocyclones. Dry crushing plants are simpler to operate, but present problems with dust collection. Wet crushing plants are cleaner, the screening is more efficient and allows for improved rejection of insolubles.

Rougher flotation tails are usually re-crushed in a secondary wet crushing stage. Rod mills were used for this purpose in older circuit designs, but recent installations (including the retrofitting of existing plants) have used rotating cage impactors. These are cheaper to operate, use less space, offer higher capacity and generate less fines. In most potash ores, there are liberated insoluble minerals which can be released by scrubbing the ore with saturated brine after crushing. During this stage, fresh water is added to the ores to dissolve magnesium chloride.

Scrubbing is usually accomplished in a series of highly agitated cells, normally

Fig 2: Schematic block diagram of a conventional potash flotation plant



at high percent solids (60-70% solids in a KCl-NaCl saturated brine), designed to liberate the insoluble attached to the potash particles. Two-stage scrubbing is common in mine areas with high insoluble ores. After scrubbing, separation of the insolubles may be done with cyclones, siphonsizers, teeter-bed separators, or wet screens, while the secondary separation is usually undertaken with hydro-separators, cyclones and thickeners.

Desliming by flotation of insoluble slimes from the ore may be undertaken in two stages. This method has the advantage of reduced capital expenditures for desliming equipment, but incurs higher reagent costs. In this method, a flocculant is added to the -100 mesh fraction to increase the size of the slime particles prior to flotation. Slimes flocculants are conditioned with a collector and floated in two stages in conventional flotation cells. The desliming stage is considered critical, as a virtually slime-free product is necessary to feed the potash flotation stage, in order to minimise reagent costs and to ensure good potash recovery.

Conditioning

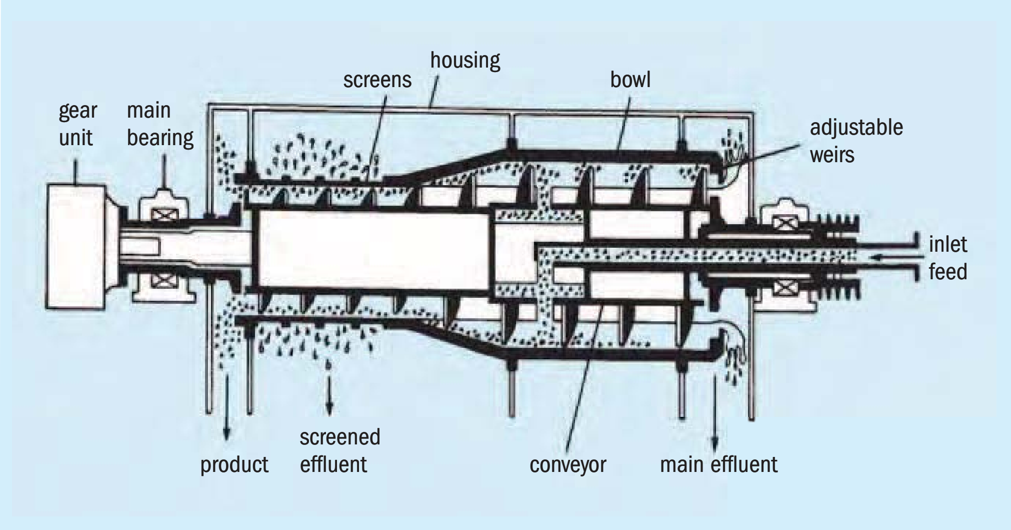
Coarse material is conditioned separately from fine material in order to optimise reagent usage. Both coarse and fine material are conditioned with a depressant and a potash collector. An extender oil is added to the coarse conditioner while alcohols and glycol frothers are normally used to promote the froth.

Some conditioning is required for tailings scavenger circuits where large particles require an optimum application of reagents, or flotation is preceded by secondary grinding to liberate the middling-sized material. The cleaning, re-cleaning and centrifuge scavenging circuit require no further reagent applications.

Polyelectrolytes (usually referred as slime depressants) are applied to reduce the harmful effect of clays on sylvite flotation. The main mechanism involves blocking off the clay surfaces for amine adsorption. Collector conditioning is thus always preceded by conditioning with the polyelectrolyte modifier.

Some operations employ heavy media separation using magnetite and cyclones. This process produces a separation of the run-of-mine at a very coarse size, typically about 12 mm into three streams: tailings, product and middlings. The latter are subsequently ground and subjected to conventional flotation, together with the fines generated in the initial crushing stages. Reagent costs are lower than with conventional flotation.

Fig 3: **Schematic diagram of a screen-bowl centrifuge (Bird Machine Co)**



Flotation, centrifuging and drying

Flotation essentially relies on the fact that fresh mineral surfaces can be induced to adopt either a hydrophobic or hydrophilic attitude in the solution through conditioning with specific surface chemicals. Air bubbles are then introduced into the solution and mineral particles, if they are hydrophobic, attach themselves to air bubbles and float up to the top of the flotation vessel, where they can be mechanically removed. Common collectors are hydrochloride and acetate salts of aliphatic amides with a carbon chain length of 12-24. Frothers are often added before the slurry enters the flotation cell.

The flotation process offers advantages over other processes, in particular the crystallisation process, in that total energy consumption is generally lower and maintenance and equipment depreciation charges are generally less than for other comparable processes.

Since potash ores contain water-soluble solids, flotation has to be carried out in saturated brine, a highly concentrated electrolyte system. The properties of an aqueous flotation system at such a high electrolyte concentration are very different from dilute aqueous solutions employed in conventional flotation processes. Coarse and fine material is floated using conventional flotation cells, ranging from 100- to 300 ft^3. Rougher concentrates are sized at around 0.84 mm (20 mesh), which is usually the final premium product. Material smaller than 0.84 mm is sent to the cleaner flotation stage to separate the entrapped fine salt.

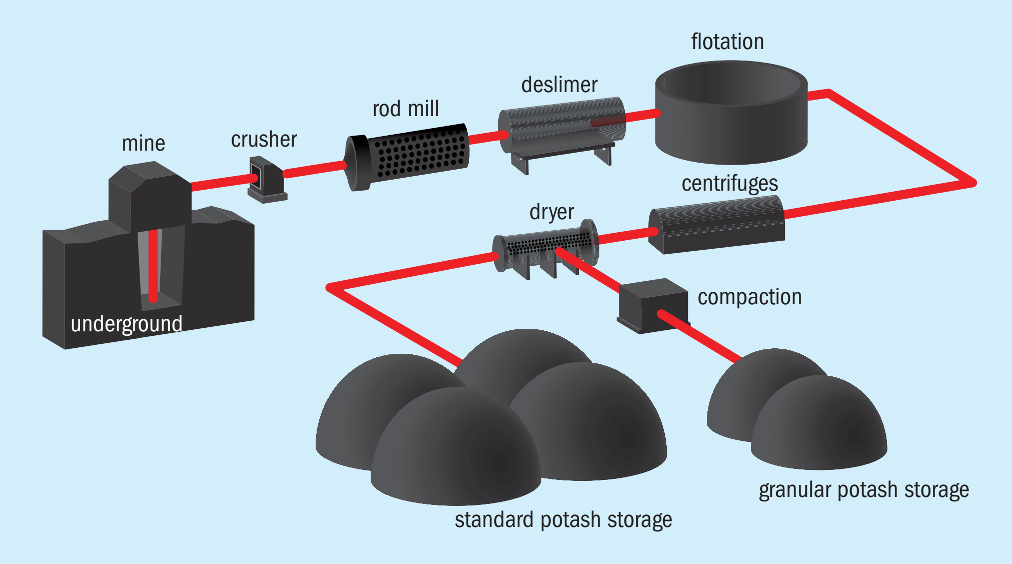
Potash rougher flotation tails usually consist of a coarse fraction (>1.41 mm, 20 mesh) that include liberated and non-liberated KCl particles that do not float, due to detachment caused by turbulence in addition to buoyancy limitations. The rougher tails also include a fine fraction (<1.41 mm) that consists of fine salt with no potash left. Potash rougher tails are screened on sieve bend screens. The -1.41 mm fraction is disposed of as tails and the +1.41 mm material is re-crushed and floated in conventional or column cells. Concentrates from rougher and scavenger potash flotation and re-cleaner flotation can be centrifuged, using screen bowl-type centrifuges down to 4-5% moisture. Flotation tails are thickened in hydrocyclones and pipelined to tailings ponds.

Potash flotation plants are designed to deal with very coarse material when compared with conventional sulphide flotation plants. In addition, brine equilibrium is temperature-dependent, which causes crystallisation when temperature drops or goes into solution as temperature increases. In order to cope with pumping problems derived from plugged lines and sanded-out pumps, potash processing plants are usually designed with a back-up set of pumps for each pump application. Water flush lines are also common and plentiful.

Screen bowl centrifuges are usually used to de-brine the flotation concentrates. In additon both co-flow gas-fired rotary and fluid bed dryers are common. (Fig. 3) Dryer exhaust gases are subjected to cyclonic dust recovery, usually followed by wet scrubbers. Electrostatic precipitators may be used for final gas clearing. Low pressure wet scrubbers can be effective when combined with tall stacks.

Potash obtained by flotation is usually standard- or fine grade, although some

Fig 4: **The potash production process**



coarse product may also be produced. In order to produce coarse and granular sizes, a compaction plant must be installed.

For the drying stage, rotary or fluid bed dryers may be employed. The design of the fluid bed dryer has been steadily improved over the years, and a modern fluid bed can process many types of bulk solid materials at a wide range of moisture levels and operating temperatures. The heat and mass transfer between the drying air and the material being dried is highly efficient, giving the fluid bed dryer a short residence time. It is also easy to operate, being able to run in batch or continuous mode, and has fewer mechanical components and a smaller footprint than other dryer designs.

A fluid dryer operates according to the phenomenon of fluidisation: this occurs when air or another gas of sufficient velocity is passed upwards through a bed of bulk material, suspending the material and causing the potash particles to move in random order. In this type of dryer, where the fluidising air is hot, this fluidisation effect provides extremely rapid heat and mass transfer between the air and the material.

In operation, the fluidising fan provides the motive force for the air that will fluidise the material. This fluidising air flows from the fan through ductwork to the combustion chamber, where the air is heated. The hot air flows from the combustion chamber to the fluid bed dryer's air distribution plenum, then flows upward through an air distribution plate (with a series of holes), evenly distributing the airflow upward into the dryer's drying chamber. A conveyor or rotary airlock valve at the feed inlet controls the wet feed to the drying chamber, where the material falls into a fluidised bed above the air distribution plenum.

In the fluidised bed, the potash particles rapidly move about in random order. Each particle is fully exposed to the hot fluidising air, which quickly transfers heat to the particle and promotes fast drying. As a result of the fluidisation effect and the direct contact between the particles and hot air, the bed forms a mixture of almost homogeneous temperature and moisture.

After drying, product is screened on double-deck rotary screens into coarse (8 x 20 mesh), coarse (14 x 48 mesh) and fine (35 x 100 mesh). Compactors are fed with a well blended, hot material (>130ºC), previously dedusted. High-pressure rolls compact the feed into flake, up to 16 mm thick. The flake is then crushed in impactors and screened into the premium coarse and granular products. Typical efficiency of a well-operated compaction plant, measured as the conversion factor (tonnes of final product as a percentage of tonnes of feed to the plant) is around 30%.

Coarse and granular products can be mixed with a small amount of water and dried again in a glazing circuit, with the objective of filling cracks inside the particles and to eliminate sharp corners to reduce dusting problems during shipping and handling. Coarse and granular products can be easily blended with other fertilizers for tailor-made formulations, while standard- and fine-grade products are most widely used in Asian markets.

Crystallisation

Crystallisation is the process used to obtain industrial-grade KCl of up to 62.5% K_2O. The basis of the dissolution-crystallisation method of beneficiation is that KCl is much more soluble in hot water than in cold, whereas sodium chloride is only slightly more soluble at 100°C than at 20°C.

The process consists of mixing the potash with hot water while agitating at 100-110°C to selectively dissolve sylvite from halite. Undissolved sodium chloride and insolubles are later removed in a clarifier. Clarifier overflow is fed to the crystallisation circuit, comprising several vacuum units. Both gravity flow and pumping are used to transfer liquor between stages while the solids are pumped out. Inside the crystallisers, the brine liquor is cooled down to 20°C and high-purity KCl is obtained by differential crystallisation.

Crystallisation is also used as a side process to recover potash fines generated during crushing and scrubbing. These are usually too fine to be efficiently compacted and so are upgraded by crystallisation to a standard-size material.

Electrostatic separation

Electrostatic separation is a dry technique in which a mixture of minerals may be differentiated according to their electrical conductivity. For potash minerals, which are not naturally conductive, the separation must be preceded by a conditioning step that induces the minerals to carry electrostatic charges of different magnitude and, if possible, different polarities. In Germany, researchers have developed a process for dry beneficiation of complex potash ores. Particle size, conditioning agents and relative humidity are used in the electrostatic separation zones to separate ore into three fractions. The components are separated in stages, using up to four stages, and the particles pass from one stage to another. This process consumes less energy than conventional wet separation processes, avoiding the need to dry out the beneficiated potash as well as avoiding associated problems of tailings disposal.

Common beneficiation practices

In Canada and the United States, flotation is predominantly used, with the exception of two solution mines. Some plants operate small hot leaching facilities, in which product fines are recrystallised or KCl is extracted and crystallised from the flotation residues and clay slurries. In Germany, the hot leaching/crystallisation process predominates. Electrostatic separation has also gained ground. In Spain and the United Kingdom, flotation has been used exclusively for the separation of KCl from sodium chloride. FSU potash producers rely generally on the hot leaching process, but newer plants have adopted the flotation process, except when potash ores contain high levels of clay or when MgCl levels exceed 30%.

Where potash is produced from brines (as in Great Salt Lake and the Dead Sea), brines are concentrated in multiple-effect evaporators, and crystals of the final product are grown in multi-stage vacuum crystallisers. The brine may also be concentrated by solar evaporation.

Environmental aspects

In addition to the consumption of energy, the main environmental problem with potash ore processing is the disposal of waste. When processing potash ore to saleable product, three types of waster product are generated:

- Liquid and solid salt tailings
- Insolubles or slimes
- Dust.

Salt tailings are generally the main environmental concern and the composition of the waste depends on the type of ore treated. Waste from sylvinite processing consists mainly of halite, while waste from the treatment of hard salts comprises halite and kieserite. Halite and carnallite are the main wastes from the treatment of carnallitic ore. Concentrated salt is a toxic waste that does not decay and requires dilution to be non-toxic.

Until relatively recently, the main methods for disposing of waste were:

- Stacking
- Backfilling
- Pumping into the ground
- Discharge into natural water systems.

New plants have been required to eliminate most of these practices. In the case of stacking, measures must be taken so that salt solutions run off the deposited material and not harm the environment when they are absorbed in the ground. If the ground underneath the stack is not impermeable, layers of clay or plastic sheets must seal it. In Germany, the solid waste is formed into steep conical heaps to reduce the amount of run-off formed by rainfall and to minimise the required ground area. If mining methods are suitable and certain geological requirements are met, solid waste can be backfilled in the mines. This is the main method of waste disposal in the German potash mines, and the method is also practised in some mines in Canada.


PHOTO: ERIEZ FLOTATION DIVISION

An Eriez flotation unit.

Leading equipment suppliers

Rexnord is a leading supplier of critical mechanical and conveyance systems tailored for the specific needs of the potash industry. Recognising that the processing mill is one of the central operations, the company supplies a comprehensive range of equipment. This includes gear drives, bucket elevators, drag and flight conveyors, bearings, chains and couplings. Rexnord's range of equipment for ore processing includes power transmission product lines, the *Falk V-Class*™ gear drive.

The demanding environment of potash ore processing demand reliable high-performance gear drives: they must be able to withstand shock loads, providing enhanced torque capacity to withstand the heaviest loads. A long seal life, solid thermal performance and increased operating life are enhanced by cooler operating temperatures. The Rexnord range is supported by drag and flight conveyors for the ore that are tailored to handle dusty and abrasive potash materials. Rexnord also offers bearing and gear-end caps, coupling guards and high-performance breathers to protect critical performing components from the heavy salts, dust and contamination in potash mining.

The **Eriez Flotation Division (EFD)** of Eriez Manufacturing Co., Canada is a leading supplier of column and non-conventional flotation cells to the international potash industry. The company has developed the *CavTube*® flotation column for typical flotation feed. EFD has also developed the *HydroFloat*® for treating coarser feeds up to 3 mm. This latter device differs from intensive mixing devices, such as mechanically-agitated cells. Using an aerated fluidised bed, the mixing is reduced, along with both particle detachment and buoyancy restrictions. In bubble-particle systems, collision occurs in mechanical cells by their relative movement within turbulent vortices or at their boundaries. This turbulent regime is counter-productive for the recovery of coarse particles by flotation. As velocities of both bubbles and particles during the attachment are slower under quiescent conditions in the *HydroFloat* system, the contact time is generally higher. The probabilities of both collision and adhesion are therefore improved when compared to the mechanically-agitated process.

With the Eriez *HydroFloat* system, the height-to-diameter ratio is significantly different than with mechanical units. As a result, control and consistency of flow is more critical, and the *HydroFloat* unit requires much less floor space to operate. The Eriez unit also offers mechanical advantages, including improved recoveries and concentrate grades. Power costs are typically up to at least 40-50% lower than the equivalent mechanical flotation circuit. In addition, with no moving parts, maintenance is minimised.

The long-established US company, **Heyl & Patterson** supplies the *Renneburg* range of dryers and coolers for potash processing plants, relying on either rotary or fluid bed methods of heating. Several different design options are available, including counter-current air-swept, internal and external water-cooled, or a combination of air- and water-cooled. The company markets some of the largest fluid bed dryers in the world and offers the some of the most efficient and cost-effective fluid bed drying in the market. Renneburg fluid bed dryers and coolers are available in two types, Trough-Type Fluid Bed and Circular-Type Fluid Bed. A circular dryer has a small footprint.

Each Renneburg unit includes a stand-alone or integral cooler that can be specified with one of the following designs: tough air-swept, in-bed plate, pipe coils and evaporative water spray.

Feeco International has provided potash processing and handling systems and equipment for over 60 years. The company works with Sahut-Conreur of France to provide customers with the highest quality compaction granulation systems. Feeco utilises corrosion and rust resistant techniques to maximise the potash processing equipment's resistance to the corrosive effects of potash, using high-specification stainless steel or nickel alloys. In addition, the equipment may be covered with *UHMW* (Ultra-High Molecular Weight Polyethylene) to prevent further contact between potash and the metal of the equipment.

Whiting Equipment Canada Inc. supplies **Swenson** crystallisation equipment. Swenson was a pioneer in the development of crystallisation technology. For superior control over particle size when excessive fine crystals are present, Swenson has devised the DTB (Double Tube Baffle) crystalliser. This type of crystalliser is built in both the adiabatic cooling and evaporative types and comprises a body on which growing crystals are circulated from the lower portion to the boiling surface by means of a slow-moving propeller circulator. An annular settling zone surrounds the suspended magma, from which a stream of mother liquor bearing fine crystals can be removed. These fines are separated from the growing suspension of crystals by granular settling in the annular baffle zone.

Fines leaving the baffle zone are sent to a following stage or heat exchanger in the case of an evaporative DTB crystalliser. The mother liquid is returned to the suction of the propeller circulator after the fines have been destroyed by heating or mixing with dilute feed or water.

The baffling allows control of the slurry density. Swenson DTB equipment is especially useful in multiple stage crystalliser applications, where cooling of the feed solution limits the natural slurry density to a few per cent. The basic principles of the Swenson DTB crystalliser are:

- Growing crystals are brought to the surface are brought to the boiling surface, where super-saturation is most intense and growth is most rapid.
- The baffle permits separation of unwanted fine crystals from the suspension of growing crystals, thereby affecting control of the product size.
- Sufficient seed surface is maintained in the boiling surface to minimise harmful salt deposits on the equipment surfaces.
- Low head loss in the internal circulation paths make large flows at low power requirements feasibile.

The advantages of the Swenson DTB crystalliser include:

- Capable of producing large singular crystals
- Longer operating cycles
- Lower operating costs
- Minimum space requirements
- Adaptable to most corrosion-resistant materials of construction
- Can be easily instrument-controlled
- Simplicity of operation, start-up and shutdown
- Produces a narrow crystal size for easier drying and less caking
- The product size varies only slightly with large changes in production rate.

One of Whiting Equipment Canada's most recent orders for potash crystallisation equipment came on stream at Qinghai Salt Lake in Western China. The company has also supplied alloy materials to fabricate an evaporation/crystallisation facility for the K+S Potash One Legacy Project potash solution mine in Saskatchewan.

In June 2013, Whiting Equipment Canada entered into an agreement with Karnalyte Resources Inc. for the engineering and design of evaporators, potash crystallisers and auxiliary equipment at Karnalyte's planned potash solution mine in Wynyard, Saskatchewan.

GEA Barr-Rosin has been active in the potash industry for almost 40 years, with references in the Middle East, Africa and Canada, most prominently during the last ten years as the Saskatchewan potash industry expanded its capacity, with a focus on upgrading technology selections, improved process operations, lower energy consumption rates, and lower operational costs.

Historically, the potash industry has relied on traditional technology and processes with little development or improvement for operational efficiency. Over time, working together with key players in the industry, analysing the needs and executing intensive R&D and pilot plant testing, GEA has implemented market-driven, robust, innovative new solutions and upgrades to the potash industry. GEA Barr-Rosin has quickly become a technology leader implementing these new, innovations and concepts in Canada and throughout the world. Table 1 lists some of these innovations.

GEA Barr-Rosin is a leading, innovative supplier of thermal process systems and drying technology for the potash industry, offering proven technology complete with process/project engineering and design services for complete rotary drying and cooling systems, as well as fluid bed dryer/coolers, rotary conditioning/glazing with fluid bed dryer/coolers, as well plate and tubular direct-contact column cooler systems.

Agrium Inc. turned to GEA Barr-Rosin for the provision of a potash conditioning and polishing system at its mine at Vanscoy, Saskatchewan. This is the fourth such installation since 2005 for GEA Barr-Rosin. The system comprises a GEA Barr-Rosin conditioning drum that smooths the sharp edges from particles and adds water to treat and permit surface re-crystallisation. A GEA fluid bed dryer then completes the process with drying, cooling and dedusting to achieve the required cleanness, moisture and temperature.

Table 1: **GEA Barr-Rosin: innovations in potash processing technology**

Innovation	Benefits
Partial gas recycle (PGR) fluid bed dryer for standard grade potash.	Reduces energy consumption about 20% leading to more efficient drying and reduced exhaust gas treatment requirements.
All-metal, high temperature fluid bed design.	Metallic inlet plenum for reduced down time and easy wash-down with water. No refractory damage.
Partial gas recycle (PGR). Ring dryer for fine potash.	Separation and drying of fines, reduces product losses, reduces energy consumption.
GEA Barr-Rosin conditioning system for granular potash.	Improves product quality and reduces product losses during shipping/handling.
Evaporative cooling fluid bed dryer for granular potash.	Eliminates or significantly reduces energy consumption.
Exhaust gas recycle for fluid bed cooler.	Improve downstream coating process by managing final product temperature during summer, winter and capacity turn down. Furthermore, by further introducing an air conditioning concept, this system is also suitable to operate in areas of high ambient humidity.
Direct-contact column cooler.	In addition to the plate-type column cooler design, the tubular-type design with removable coils to further simplify maintenance/cleaning has been enhanced.

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 57 12 58 13 59 14 60 15 61 16 62 17 63 18 64 19 65 20 66 21 67 22 68 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

A GEA Barr-Rosin conditioning drum.

In the GEA Barr-Rosin potash conditioning and polishing system, the product potash feed is introduced to the conditioning drum at a continuous and stable feed rate with consistent moisture content and temperature. As the particles travel through the drum, spray water nozzles glaze and condition the potash with a fine misting of water for uniform product coating, while the drum promotes rapid product tumbling for optimal polishing. The wetted product is then discharged directly into the fluid bed dryer through a discharge chute. The material is distributed across a sloped directional fluidising bed plate to propel the material towards the discharge end of the fluid bed. The plate is dimensioned to provide plug flow, allowing an optimal degree of fluidisation and upward airflow while preventing material from falling through to the lower plenum. An adjustable underflow discharge gate valve controls the bed depth of material to vary the total retention time required and enables rapid and complete emptying of the unit.

Under thermal drying configuration, the hot process air for the fluid bed is supplied by a forced draft fan through and air heater. The exhaust gas is sent to a baghouse for dust collection. Under an evaporative cooling configuration, the hot process air for the fluid bed is also supplied by a draft fan but requires only a small amount of heating during cold conditions to control the fluid bed exhaust temperature and prevent condensation and elated maintenance issues.

Slightly sub-atmospheric conditions are maintained above the bed by a balanced system of forced and induced draught fans to prevent the escape of gases and to eliminate the need for air seals at the feed and discharge points. Exhaust gases are drawn through a centrifugal exhaust fan, which discharge to atmosphere through to vent stack.

In February 2014, GEA Barr-Rosin won the contract to supply drying and conditioning equipment for the Elemental Minerals potash project in the Republic of Congo. Special focus will be on the conditioning systems, which will each include a conditioning drum, a fluidised bed dryer/cooler and a rotary coater.

Veolia Water Technologies has recently supplied Dead Sea Works (DSW), Sdom, Israel with a potash crystallisation system. The new system has successfully operated at a minimum nameplate capacity of 153 t/h of KCl crystals, at greater than 98% purity. Veolia Water Technologies designed a five-train system, using *PIC*™ (draft tube baffle) *HPD*™ crystalliser technology, and is one of the largest KCl crystalliser trains in the world. The design has provided for efficient heat recovery while achieving significant savings in energy consumption. As well as undertaking project management, installation and construction management, process and mechanical engineering, Veolia also provided all major equipment to support the crystalliser plant, including hotwells, feed tank, pumps and a custom agitator for all five stages. The new crystallisation facility has enabled DSW to increase production of KCl by almost 30%.

In April 2014, Veolia Water Technologies delivered *HPD*™ evaporation and crystallisation technology to K+S Potash Canada's Legacy project in Saskatchewan. The process equipment will enable K+S to purify and produce up to 2 million t/a of KCl from solution-mined potash at the Legacy facility from 2017. The individual vessels that make up the crystallisation system range in size up to 30 m in length, a diameter of nearly 10 m and weigh up to 180 tonnes. ■

People & projects

PROJECTS

BHP Billiton advances at Jansen

Countering suggestions that it has gone lukewarm on the project, BHP Billiton has stated that its Jansen potash project in Saskatchewan is now 40% complete. The company plans to invest a total of $2.6 billion in the project's development between 2013 and 2016, finishing the excavation and lining of the production and service shafts and continuing to install associated surface infrastructure. Shaft excavation is continuing at the site, which BHP Billiton states remains within budget. In August 2014, CEO **Andrew MacKenzie** stated that the company was in no hurry to complete the Jansen project and that current potash market conditions may have deterred potential partners from investing there. Production of 10 million t/a KCl is envisaged but is not expected to begin until around 2020.

Solikamsk-2 flooding update

Since flooding at Uralkali's Solimkamsk-2 potash mine began in November 2014, the inflow has levelled off and is currently averaging about 500 m^3/hour. The flooding has forced Uralkali to halt all production at the mine while it attempted to prevent complete flooding in the mine. The situation has been made worse by a sinkhole of around 50 x 80 m in size that has opened 3.5 km from the main site. The Solimkamsk-2 mine accounts for around 18% of Uralkali's total capacity, equivalent to 2.35 million t/a. The mishap has forced the company to write off some $1 billion in asset value. If the flooding rate were to rise to several thousand metres/hour, the pumping system would be overwhelmed and the mine would be lost.

Uralkali believes that the flooding has stemmed from a natural destabilisation that followed an earthquake at the site in 1995, when there was a massive rock collapse in the mine. The company has meanwhile launched a major strategic review of its options, based on the assumption that the mine will not return to production in the short term or at all. The total loss of the Solikamsk-2 capacity would reduce Uralkali's status as the world's largest potash producer, falling behind behind PotashCorp and Belaruskali, and estimated production levels could fall from a record 12.1 million tonnes in 2014 to 10.2 million tonnes this year. Debottlenecking at the Berezniki-2 and -3 sites would partly offset a loss of 2.3 million tonnes from Solikamsk-2. Uralkali may also accelerate the commissioning of new operations, with the potential to raise mining capacity by a further 4.5 million t/a, in addition to improvements already planned.

Vanscoy back on stream

Agrium Inc. has resumed production at its Vanscoy potash mine in Saskatchewan, having completed a major revamp in conjunction with its 1 million t/a expansion project at the site. Agrium suspended production in July 2014, originally for a turnaround that was expected to last for just four weeks. The downtime period was subsequently extended in the wake of a mechanical failure at the processing plant. Capacity at the mine will be expanded to around 2.8 million t/a from 2 million t/a by 2017, giving a projected mine life of around 46 years.

Uralchem signs revamp contract with Stamicarbon

The Russian nitrogen fertilizer producer OJSC Uralchem has signed a contract with Stamicarbon BV for the modernisation of the urea plant at Perm. The revamp envisages a 40% increase in capacity, equivalent to 250,000 t/a in extra output by 2019. The contract is worth an estimated RUB 4.2 billion ($63 million). Stamicarbon will license its *Urea2000plus* production technology and act as general contractor for the project design and survey works. By replacing part of the existing equipment and adding a new cycle of production facilities at Perm, capacity at the site will be increased from 1,930 t/d to 2,700 t/d.

The modernisation of the Perm plant is the second joint project between Uralchem and Stamicarbon. In late 2013, the partners began the development of new technologies for urea synthesis, using Stamicarbon's intellectual property. The revamp will consolidate Uralchem's status as one of Russia's leading producers of nitrogen and phosphate fertilizers, with production capacities of over 2.5 million t/a of ammonium nitrate, 2.8 million t/a ammonia, 1.2 million t/a urea, 800,000 t/a of phosphate fertilizers and 800,000 t/a of complex NPKs.

Uncertainty over Indian urea projects

Against a background of continuing urea shortages and the procurement of additional imports, many Indian projects to develop indigenous capacity remain stalled. Reports suggest that the Government of India may approve less than half of the 12 proposals received. Two proposals involve the development of new plants, while the others seek to expand capacity at existing plants. Eight companies, including Bharat Coal Chemicals, Chambal Fertilisers, Indo-Gulf Fertilisers, Nagarjuna Fertilizers & Chemicals and Zuari Agro Chemicals have submitted proposals. A government panel has been set up to decide upon the issues related to the implementation of the urea investment policy. The government is also considering reopening several idled state-owned fertilizer plants. Approval has already been given to the revival of production at the 1.3 million t/a Hindustan Fertilizer Co. Ltd. (HCFL) urea plant at Baraun, Bihar state, at an estimated cost of INR 60 billion ($953 million). The Government of India has indicated that it will establish the Jagdispur-Haldia pipeline that will enable the HCFL facility and other plants to resume production.

The government has also allocated a 300-acre site near the port of Krishnapatnam, Andhra Pradesh for the construction of a new NP/NPK plant to be developed by KRIBHCO. The plant will be KRIBHCO's first such facility and will source the co-operative's indigenously-produced ammonia. KRIBHCO is also evaluating potential sources of phosphoric acid, including the possibility of entering into joint-venture production.

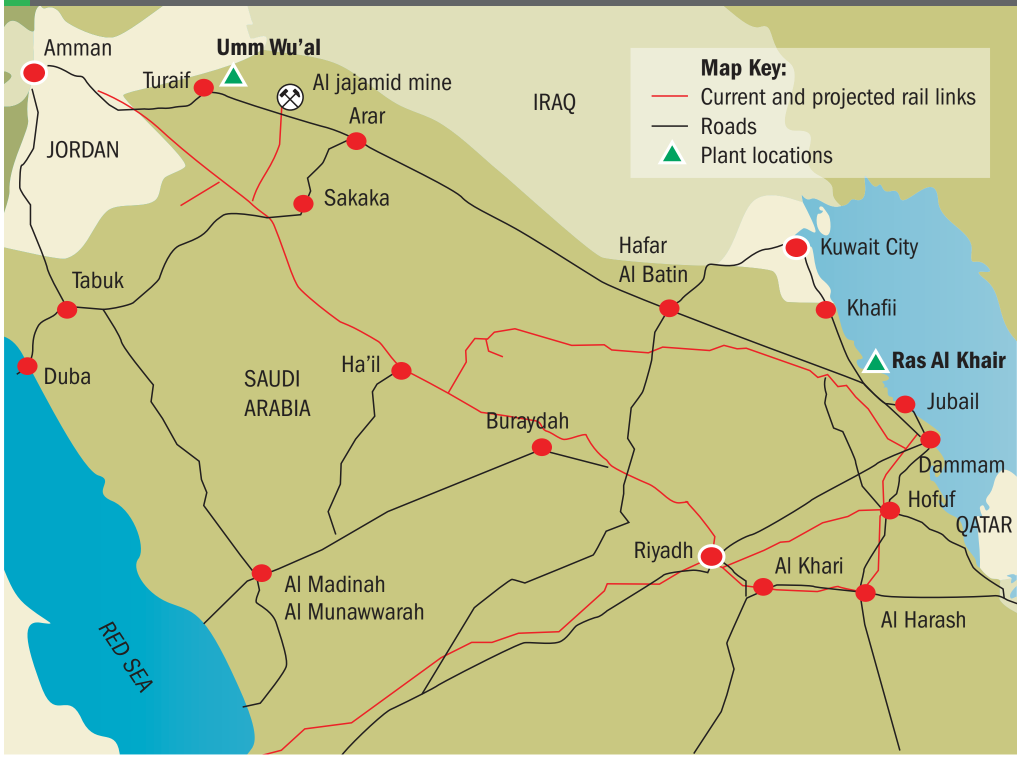
India's demand for urea averages around 30 million t/a, of which 8 million tonnes must be met by imports. Over the longer term, the limited availability of natural gas as well as uncertainty over government policy have been a deterrent to new investment in the Indian nitrogen industry, and self-sufficiency in urea production is unlikely to be achieved in the foreseeable future.

Waad Al Shamal project 40% complete

Ma'aden, the Saudi Arabian mining company, has said that its $7 billion Waad Al Shamal joint-venture phosphate project is now almost 40% complete. The downstream complex will include an ammonia plant, construction of which was 38% complete as at 31 December, and a sulphuric acid plant, which was 36% complete. Work on the DAP facility was 18% complete, while the phosphoric acid unit was 24% complete. An ore beneficiation plant is also under construction. The Waad Al Shamal project is scheduled to be commissioned in 2016. Ma'aden holds a 60% stake in the project partnership, together

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 57 12 58 13 59 14 60 15 61 16 62 17 63 18 64 19 65 20 66 21 67 22 68 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

Fig 1: **Location of the Umm Wu'al Phosphate project sites**



with Mosaic (25%) and SABIC (15%). While some industry analysts questioned whether Ma'aden would achieve this target date, these latest progress reports do suggest that it is feasible.

In a separate development, the SABIC subsidiary Saudi Arabian Fertilizer Co. (SAFCO) has completed mechanical and construction work on its SAFCO-5 3,500 t/d granular urea plant and will shortly commence trial production. With an annual capacity of 1.1 million t/a, this will be one of the largest urea plants in the world.

Topsøe and partners plan Tanzanian project

Haldor Topsøe has joined forces with Ferrostaal Industrial Projects GmbH and Fauji Fertilizer Co. Ltd. of Pakistan to develop a large-scale fertilizer complex in Tanzania, in conjunction with the state-owned Tanzania Petroleum Development Corporation. The project will be the largest investment project in Tanzania, with a mooted investment of more than $1 billion. The fertilizer complex will have a capacity of 1.3 million t/a of nitrogen fertilizers and is scheduled to come on stream in 2019/20. The plant's output will be sold in the Tanzanian and overseas markets.

The consortium was the winner of a tender organised by the Tanzanian government in 2013 and is currently in exclusive negotiations with gas suppliers for the supply of natural gas feedstock. The partners are also providing support through the entire project development, including financing, technology, product off-take, as well as construction, maintenance and operation of the plant. Within the consortium, Topsøe will supply licence, engineering, hardware and catalysts for the fertilizer plant, which will be located in the Mount Wara area of southern Tanzania, close to established port facilities and connections to a future gas grid. The project promises to make a significant contribution to the Tanzanian GDP, enabling the country to monetise its large gas reserves.

Três Lagonas delay

Petrobras has announced that it was shelving the $1.4 billion Três Lagonas nitrogen project in Brazil, as a result of a dispute with contractors. The project envisages the construction of a 760,000 t/a ammonia and 1.2 million t/a urea complex using natural gas imported from Bolivia, which was originally scheduled to begin production in June 2015. In December 2014, Petrobras rescinded the construction and assembly contract for the nitrogen fertilizer plant, UFN III, alleging a breach of contract by Consortium UFN3, consisting of Sinopec and the Brazilian company Galvão Engenharia. Petrobras has emphasised that it has made all payments and upheld all commitments provided for in the contract. In a further development, federal prosecutors have issued charges against four Galvão executives, together with 18 other executives from other Brazilian construction companies, alleging corruption and money laundering in connection with a corruption scandal related to Petrobras.

Galvão has stated that the UFN III facility is 83% complete and that several alterations have been made by Petrobras that put the project over budget. Sinopec has also said that it attempted to raise funds from Chinese banks to continue the project in late 2014, but these proved unsuccessful. The consortium has in turn taken legal action to ensure that construction can continue at Três Lagoas.

State aid approved for Slovakian expansion

The nitrogen producer Duslo a.s., which forms part of the Czech conglomerate Agrofert, plans to expand capacity at its ammonia facility in Šala, Slovakia and has meanwhile applied for a grant aid package worth EUR 58 million from the Slovakian government. The plant is located in an area of high unemployment and a standard of living below the EU average, prompting approval from the European Commission (EC), which indicated that the proposed investment support is in line with EU state aid rules and development objectives. The expanded ammonia plant will cost an estimated EUR 310 million and is due to start production in 2017. It follows on from the inauguration of a revamped urea plant at the Šala site in 2014. This plant uses technology licensed from Stamicarbon.

Ecophos plans new feed phosphate plant in Dunkirk

Ecophos, the Belgium-based producer of animal feed phosphates, has signed a Memorandum of Understanding with the Port Authority of Dunkirk, northern France, to build a 220,000 t/a dicalcium phosphate (DCP) plant at an estimated cost of EUR 60 million. The plant is due to commence production in the first quarter of 2017. **Mohamed Takhim**, CEO and owner of Ecophos, said, "Dunkirk's site answers totally to our logistics and strategic needs to guarantee the future growth of our company. The industrial environment and the local support from the different local authorities and industries provide us all the requested guarantees for the installation of this new production unit in Dunkirk."

Highfield Resources bullish in Spain

The Australian junior mining company Highfield Resources is developing the Muga-Vipasca potash project in northern

Spain and is currently undertaking a drilling programme. Drilling at the site centres on the shallow beds in an area covering around 110 km². The latest findings indicate a 5.1 m space at 16.4% K_2O and a 1.8 m space at 13.9% K_2O. The company is due to complete the final drill holes of the 11-drill programme to complete a block model for the proposed mine at Muga. Highfield Resources also hopes to provide a resource upgrade for the project by the end of December 2014 and prepare a definitive feasibility study in the first quarter of 2015. Production of 1 million t/a potash is envisaged, beginning in the first half of 2017, with most of the output planned for shipment to Brazil, the United States, West Africa and elsewhere in Europe. A pre-feasibility study has suggested total cash costs of $152/t, which would make the Muga site competitive.

The company has meanwhile secured the port capacity it requires to export the potash from the Muga mine, having signed agreements with the ports of Pasajes and Bilbao in northern Spain.

The Muga-Vipasca project is one of four that Highfield Resources is promoting in the Ebro region of northern Spain, covering a total area of almost 400 km². The Muga and Vipasca projects were formerly part of the Javier project and because of the relatively shallow sylvinite mineralisation, form the focus of the initial mine target. The Sierra del Perdón project includes two former operating mines. Highfield Resources has completed a preliminary feasibility study for its Muga project.

New exploration licences for Potash West partner

East Exploration GmbH (EEG), in which Potash West holds a 55% stake, has been granted new potash exploration licences for the Thuringia region of Germany – the historic base for salt and potash mining in Germany.

Potash West's main focus is on the development of the mineral-rich greensand deposits in the Perth Basin of Western Australia. The company has four tenement holdings within the Dandaragan Trough, covering a strike length of approximately 120 km and a width of 20 km, some 100 km north of Perth. The Trough hosts a very large glauconite deposit, mixed with quartz in beds to form greensands, from which potassium can be extracted. Potash West is also evaluating the Dinner Hill project in Western Australia, which covers both phosphates and potash. The company is currently assessing the potential to produce SSP using a stand-alone plant before setting up an integrated operation to produce both P and K fertilizers.

Egyptian phosphate ambitions

The Egyptian state-owned El Nasr Company for Intermediate Chemicals has announced plans to develop a phosphate complex at Ain Sokhna on the Red Sea. The complex will have the capacity to produce 400,000 t/a P_2O_5 merchant phosphoric acid, 100,000 t/a P_2O_5 purified phosphoric acid, 1.25 million t/a sulphuric acid, 400,000 t/a DAP, 100,000 t/a powdered MAP/DAP and 250,000 t/a TSP. The complex could draw ammonia feedstock from the nearby EBIC/OCI 660,000 t/a plant at Suez. Reports indicate that the project would be financed from internal resources and construction could begin later this year, with the goal of achieving first production after 48 months and full production after 52 months.

JPMC concludes acid agreement

Jordan Phosphates Mines Company (JPMC) has signed an MoU (memorandum of understanding) with Gujarat Narmada Valley Fertilisers & Chemicals (GNFC) for the construction of a 300,000 t/a P_2O_5 phosphoric acid plant in India, for which JPMC will exclusively supply 1 million t/a of phosphate rock. This is the first time the company has entered into a partnership venture to build a phosphoric acid plant in India. The new plant will supplement the present JIFCO joint venture with IFFCO, whose 500,000 t/a P_2O_5 phosphoric acid plant at Aqaba is now running at full capacity.

To meet the extra demand, JPMC will ramp up its production of phosphate rock to 15 million t/a by 2020. This compares with a record rock output of around 8 million tonnes in 2014 and planned production of 9 million tonnes this year. JPMC will also supply two JV partners in Indonesia, Kaltim and Pusri, with an additional 1.5 million t/a phosphate rock when their phosphoric acid plants are complete.

JPMC has also indicated its intention to revamp its DAP plant at Aqaba, raising capacity from 800,000 t/a to 1 million t/a.

The Jordan Industrial Ports Company has meanwhile signed an agreement with two Spanish companies to expand the industrial pier at Aqaba. The pier is owned by JPMC and Arab Potash Company. The partners seek to double the pier's handling capacity to enable it to receive vessels of up to 100,000 dwt. The work is expected to take two years to complete.

Casale buys Borealis technology

Casale SA, the Swiss supplier of ammonia, urea, methanol and melamine technology, has acquired the proprietary technologies of Borealis for the production of nitric acid, ammonium nitrate and UAN solutions. The agreement will enable Casale to collaborate with Borealis on further development of the process technologies. The deal will also enable Casale to extend its portfolio into new areas of production technology, covering a full range of nitrogen products. **Federico Zardi**, Casale's chief operating officer commented: "This is much more than a straight technology acquisition. We have entered into a continuing partnership with Borealis, under which the two companies will co-operate closely in the future development of these technologies."

Stonegate Agricom calls a halt

Stonegate Agricom announced on 26 January that it had temporarily suspended permitting activities at its Paris Hills phosphate project in Idaho, blaming financial constraints. The company has also announced that in order to finalise the groundwater model for permitting applications, it has engaged third-party consultants. There is a wide range of estimates of expected groundwater flow rates into the planned underground mining area. As a result, Stonegate Agricom will need to undertake further testing and analysis, which may include additional engineering work. The company's current financial position prevents it from undertaking this additional work at present. As a result, Stonegate Agricom no longer expects to submit the groundwater model and report in the first quarter of this year as planned. The company is reviewing its options with respect to its next steps. As at 31 December 2014, Stonegate Agricom reported cash and cash equivalents totalling $1.4 million and working capital of $1.0 million. It is exploring alternatives to raise additional funds by the beginning of the second quarter of 2015 to cover working capital and fund continuing work on the project.

The Paris Hills deposit is located in Bear Lake County, Idaho and covers an area of around 1,010 ha (2,495 acres), forming part of the western phosphate field. The main phosphate zone comprises and Upper Phosphate and Lower Phosphate Zone, the former being 3-5 m average thickness and the latter between 1.5-3 m thick. The mineralisation extends from the surface to a depth exceeding 300 m. As at 31 December 2012, the Lower Zone mineral reserve was assessed at a total of 16.70 million tonnes at an average grade of 29.2% P_2O_5, with proven reserves of 7.96 million tonnes and probable reserves of 8.75 million tonnes. Stonegate Agricom plans to produce 904,000 t/a of marketable phosphate concentrate over an estimated mine life of 19 years.

Danakil potash DFS expected

The junior miner Circum Minerals Ltd. plans to complete a definitive feasibility study (DFS) of its potash project in the Danakil Basin of Ethiopia by mid-2015 and expects that it will be able to sustain the production of 2.75 million t/a of marketable potash over a minimum of 30 years. The deposit comprises a mineral resource of 1.9 million tonnes, containing 356 million tonnes KCl. Production of both KCl and potassium sulphate is envisaged. The Circum Minerals exploration licence covers an area of 365 km^2.

The German consulting company K-UTEC AG Salt Technologies prepared a maiden NI 43-101-compliant mineral resource estimate in February 2014, covering the sylvinite, upper carnallite, lower carnallite and kainitite potash-bearing beds, and noted an indicated mineral resource of 708.8 million tonnes at an average grade of 19.4% KCl, for a total of 137.7 million tonnes of contained KCl. The inferred mineral resource for all four potash-bearing beds totals 1.116 billion tonnes at average grade of 19.1% KCl, for a total of 213.2 million tonnes of contained KCl.

Changes in Indian ownership are signalled

A two-way tussle is under way over the ownership of Mangalore Chemicals & Fertilizers Limited (MCFL) as Deepak Fertilisers vies with Zuari Agro Chemicals for overall control. Deepak currently holds a 25% stake in MCFL and is seeking to acquire an additional 25%. Deepak's gambit prompted a counter-offer from Zuari, which is seeking to add to its present 16.43% MCFL stake by buying a further 26% of the equity. These rival bids take place against a background of turmoil within MCFL, where shareholders have called for the removal of chairman **Vijay Mallya** after the company was declared a "wilful defaulter" by the United Bank of India. MCFL has also missed the government's deadline of 1 October to switch from naphtha and furnace oil to LNG for urea production. The urea subsidy will be withheld from companies which failed to comply.

The government of India meanwhile plans to sell a small stake in Rashtriya Chemicals & Fertilizers (RCF) during 2015/16. The sale is expected to involve at least a 5% share, possibly rising to 10%. The government currently owns 80% of the RCF equity. In March 2013, the government sold a 12.5% stake in RCF, raising INR 3.1 billion ($50.4 million). RCF is planning to set up a new subsidiary, RCF Videsh, which would focus on overseas joint ventures and asset acquisitions, particularly in areas where natural gas feedstock is cheap and raw materials such as phosphate rock are readily available.

Sirius Minerals planning delay

Sirius Minerals, which is promoting the York Potash polyhalite project in the UK, has withdrawn one of its planning applications for the project. The application in question is for a development consent order over proposed harbour facilities in Teesside, certain options of which Sirius Minerals now wishes to amend. The company said that the purpose of the resubmission is to help make the approvals review more efficient. A revised application will be submitted shortly. The decision reached is not expected to affect the overall project timescale or other key planning decisions. A decision on the planning application is now expected by May 2015, slightly later than previously expected.

Sirius Minerals meanwhile continues to report new offtake agreements for its eventual production of *POLY4*, this time concerning a customer in the sector for animal feed supplements. The seven-year take-or-pay agreement is for an offtake of 50,000 t/a with a major US animal feed distributor, with the option for an additional 25,000 t/a. The deal is on a fixed-price basis and is competitive with established products on the market, Sirius Minerals stated. To date, the company has secured customers for at least 6 million t/a of product, raising hopes that it is close to completing agreements for its planned initial production of 6.5 million t/a from 2018.

Haldor Topsøe and FLSmidth team up

The leading catalyst technology supplier, Haldor Topsøe A/S, has signed a co-operation agreement with FLSmidth A/S, a leading supplier of processing equipment, to commercialise a newly-developed catalytic filter bag technology. The new product will have the *EnviroTex*™ brand-name and has been designed to remove dust, volatile organic compounds and nitrogen oxides in one integrated and economical process. There are numerous applications for the product in the cement, power, biomass, waste incineration, and glass and metal production industries around the world.

Fabric filters are used in many processing industries, providing a final purification step in the removal of particulate matter from flue gas. FLSmidth has enjoyed global market leadership in the design and manufacture of fabric filters for a broad range of processing industries. The new *EnviroTex* range incorporates three layers of filter fabric. Each layer contains a tailored catalyst, optimised for the removal of specific kinds of compounds from the off-gases passing through it. **Bjeren S. Clausen**, CEO of Haldor Topsøe said. "The three-layer structure is unique. Not only because it provides us with the flexibility to tailor different catalytic combinations for different industries, it also makes it possible to handle the removal of several critical compounds in one integrated process. This can significantly reduce the cost of off-gas cleaning, because today's standard is to use separate stand-alone systems to address removal of specific compounds. This translates to complexity and higher customer operating cost."

As part of the agreement between Haldor Topsøe and FLSmidth, the *EnviroTex* range will be manufactured in the latter company's bag production facilities in Georgia, USA. The filter bags will then be catalysed and assembled at Topsøe's catalyst production site in Houston, Texas, which will be expanded to cater for the additional production by the end of 2015.

OCP buys 10% stake in Brazilian distributor

OCP, Morocco has completed the purchase of a 10% stake in the Brazilian company Fertilizantes Heringer, providing it with a long-term supply agreement for phosphate products. The deal was concluded at a reported price of approximately $55 million, after the Moroccan and Brazilian regulatory authorities gave their approval. The agreement follows an earlier deal concluded between supplier Mosaic and the Brazilian distributor ADM and marks further consolidation in the market where

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68

OCP, Mosaic and Yara compete for sales. Heringer is one of the largest distributors in Brazil. In 2014, OCP supplied Brazil with an estimated 1.7 million tonnes of DAP, MAP, TSP and NP fertilizers, down from 2.2 million tonnes in 2013. OCP is understood to have lost market share because of an influx of Chinese MAP imports.

APPOINTMENTS

K+S Kali announces new organisation

With effect from 1 January, K+S Kali GmbH has recast its management structure, with the goal of achieving a greater market orientation and higher overall efficiency. As a result, market activities have been combined into three segments: Commercial Units Fertilizer, Industry and Health Care & Nutrition. The Fertilizer commercial unit is headed by **Dr. Josef Wiebel**, with support from **Matthias Schulze**, Sales & Marketing Europe; **Gerald Sternberg**, Sales & Marketing Africa; **Dr. Marcus Ross**, Sales & Marketing Asia & Oceania; and **Marc Gronemeier**, Sales & Marketing Americas. **Matthias Pfaff** heads the Industry commercial unit, while **Alexander Baart** heads the Health Care & Nutrition commercial unit.

As a result of the re-organisation, the previous distribution company K+S Benelux has been wound up. Its former managing director **Niels Fanselow** has transferred to the Industry commercial unit as head of Chemicals.

At the same time, **Dr. Martin Brown** has been promoted to head of K+S North America Corporation. He was previously head of supply chain management at the North American distribution operation and succeeds **Gerhard Horn**, who has returned to Germany after nearly four years as president. With effect from 1 May, the headquarters of the subsidiary will move from New York to Chicago.

Wolfgang Wild, latterly head of overseas distribution at K+S Kali GmbH, will retire on 1 April after a 46-year career in the German potash industry.

Yargus sales team boost

Mark Taylor has joined Yargus Manufacturing Inc. as Vice President of Industrial Sales and will oversee production of the

Mark Taylor.

Layco line of material handling equipment. He joins Yargus after an initial 12-year career in the pulp and paper industry, followed by 15 years in charge of DMS Environmental, developing and engineering fuel for the cement and lime industry. Company President **Larry Yargus** said, "Yargus is pleased to have Mark Taylor join our team. His extensive experience in the recycling and plastic industry will enable the Layco line to expand into the domestic and international industrial market-place." ■

Calendar 2015

MARCH

23-25

Phosphates 2015, CRU Events, TAMPA, Florida, USA. Contact: CRU Events
Tel: +44 20 7903 2444
Email: conferences@crugroup.com
Web: www.crugroup.com

23-26

IFA Global Safety Summit, VANCOUVER, Canada. Contact: IFA Conference Service
Tel: +33 1 53 93 05 25
Email: conference@fertilizer.org
Web: www.fertilizer.org

29-3 April

Beneficiation of Phosphates VII, Engineering Conferences International, MELBOURNE, Australia. Contact: ECI. Tel: +1 212 514 6760
Email: info@engconfintl.org
Web: www.engconf.org

APRIL

20-22

TSI Sulphur World Symposium 2015, The Sulphur Institute, BARCELONA, Spain. Contact: Joshua Maak Tel: +1 202 296 2318
Email: JMaak@sulphurinstitute.org
Web: www.sulphurinstitute.org

MAY

18-20

SYMPHOS 2015, 3rd International Symposium on Innovation and Technology in the Phosphate Industry, MARRAKESH, Morocco.
Contact: SYMPHOS Technical Committee
Tel: +212 5 23 34 51 22
Email: symposiumocp@ocpgroup.ma
Web: www.symphos.com

25-27

83rd IFA Annual Conference, ISTANBUL, Turkey. Contact: IFA Conference Service
Tel: +33 1 53 93 05 25
Email: conference@fertilizer.org
Web: www.fertilizer.org

JUNE

5-6

***Clearwater 2015*, 39th Annual International Phosphate Fertilizer and Sulphuric Acid Technical Conference**, AIChE Central Florida, CLEARWATER, Florida, USA.
Email: chair@aiche-cf.org
Web: www.aiche-cf.org

23-24

IFS Technical Conference, International Fertiliser Society, Geological Society, London, UK.
Tel/Fax: +44 1206 851 819
Email: secretary@fertiliser-society.org
Web: www.fertiliser-society.org

SEPTEMBER

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

NOVEMBER

9-12

Sulphur 2015, CRU Events, TORONTO, Canada. Contact: CRU Events.
Tel: +44 20 7903 2444
Email: conferences@crugroup.com

For further information on these and other events see www.bcinsight.com

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Next issue: May/June 2015

Distribution at:
IFA Annual Conference, Istanbul, Turkey
AIChE Clearwater Convention, Clearwater, Florida, USA

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Closing date for advertisement space booking is 7 May 2015
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Subscription rates:
GBP 300; USD 550; EUR 450
Subscription claims:
Claims for non receipt of issue must be made within 3 months of the issue publication date.
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Previous articles from *Fertilizer International* and *PK Insight* from 1997 to the present are available digitally in PDF format. To make a purchase, or for a list of available articles, please see: www.bcinsight.com

ISSN: 0015-0304
Design and production:
JOHN CREEK, DANI HART
Printed in England by:
Buxton Press Ltd
Palace Road, Buxton, Derbyshire, SK17 6AE

BCInsight
Published by: BCInsight Ltd
Southbank House, Black Prince Road
London SE1 7SJ, England
Tel: +44 (0)20 7793 2567
Fax: +44 (0)20 7793 2577
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