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Don’t blame us

> **“Blaming fertilizers as one of the main causes of a major air pollution alert... is therefore a questionable claim.**

The British are famously obsessed with our ever-changing weather. To me, it is a surprising fact that, very occasionally, when warm air moves up from the south, Saharan dust will fall from the sky in the UK – having been transported over 1,000 miles from North Africa. When it happens, this rare event is usually barely noticed, except for the tell-tale thin coating of red dust on people’s cars.

The arrival of Saharan dust one warm, sunny weekend in April this year was a little different, however, as it caused a major media upset over air pollution that ended with fertilizers being blamed for “deadly agricultural smog”.

The controversy began when the UK government’s environment department (Defra) issued an air quality warning for England’s south coast on Sunday 3 April. Defra warned of high and very high levels of air pollution, blaming this on a Saharan dust episode. The government’s advice was quite strict. Older people and people with lung and heart problems were told to avoid strenuous physical activity. Anyone experiencing sore eyes, a cough or sore throat was also advised to stop exercising.

The Sunday Times newspaper covered this in a front page splash under the banner ‘Pollution alert as heatwave hits UK’. Alarmingly, this warned that parts of England faced a “major pollution alert” due to the arrival of “an agricultural smog of toxic farm chemicals from Europe” coinciding with a spring heatwave. The newspaper added: “Such pollution surges, which can also coat cars and laundry in grime, have been blamed on Saharan dust storms. But scientists now say the dust comes from farms in France, Germany, the Benelux countries and Poland. Research published last week shows that its main components are toxic ammonium nitrate from fertilisers and manure.”

Being curious about whether fertilizers really were partly to blame, I contacted Dr Stefan Reis of the UK’s Centre for Ecology & Hydrology, one of the scientists responsible for the research mentioned. Stefan and colleagues had recently published a paper in *Environmental Research Letters* about the UK air pollution caused by a previous Saharan dust storm in the UK two years previously.

Dr Reis was able to confirm two things. Firstly, that the “agricultural smog” was only partly agricultural in origin. In fact, it was actually made up of tiny ammonium nitrate particles which formed in the atmosphere when urban pollution (mainly NOx from vehicles) mixed with ammonia emitted by agriculture. He also told me that fertilizers were only responsible for a very minor part of agricultural ammonia emissions. These emissions mostly came from manure management (40%) and the land application of manure (29%), with mineral fertilizers typically generating just 13% of total agricultural ammonia emissions.

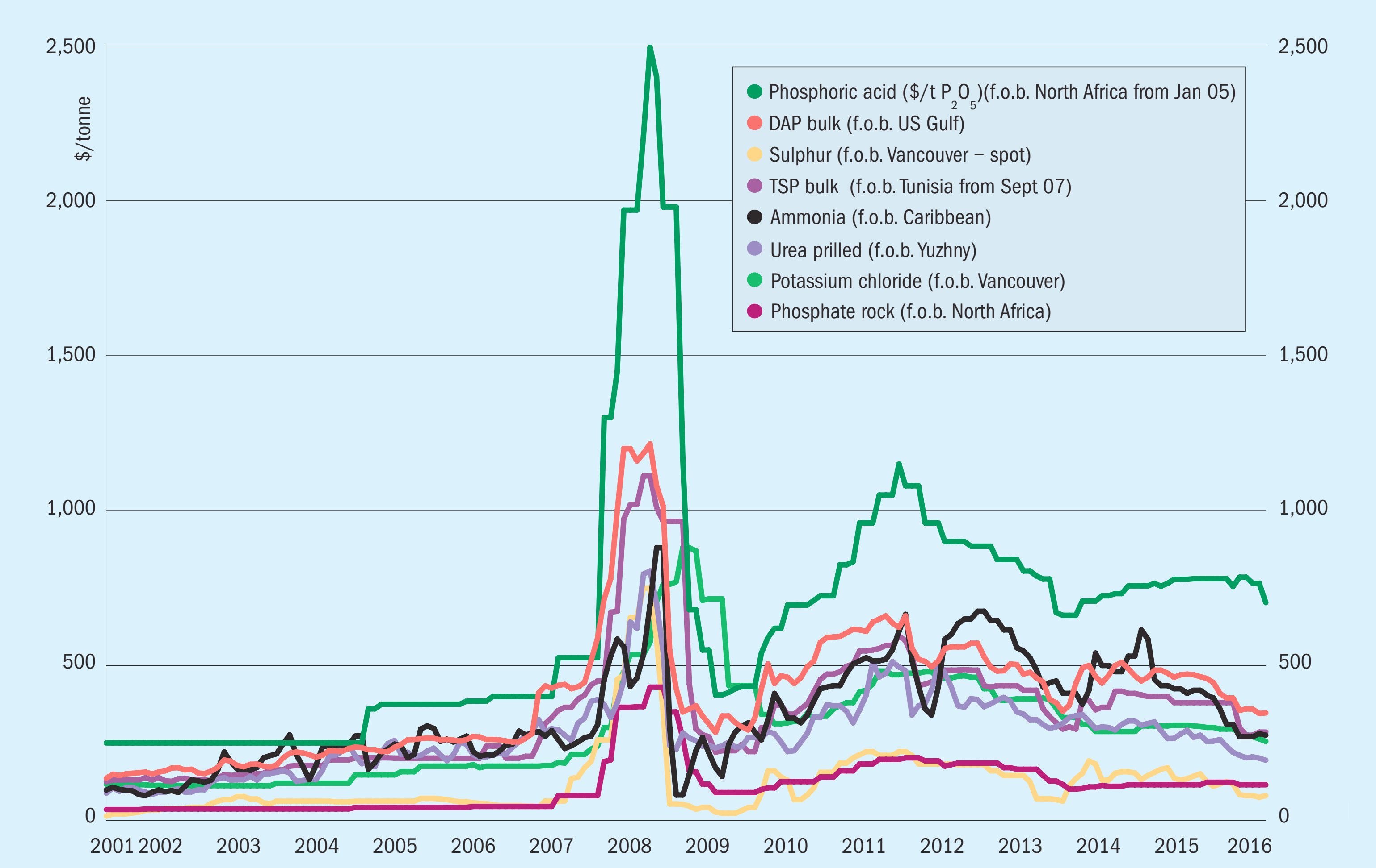
The *Environmental Research Letters* paper makes it very clear that two types of air pollution were present in the Saharan dust storm which hit the UK in 2014: (a) fine desert dust and (b) secondary ammonium nitrate particles formed by urban pollution mixing with farm emissions.

Agricultural ammonia emissions are clearly an environmental issue that warrants serious attention. But it is a problem overwhelmingly, though not exclusively, caused by how manure is handled and used on farms. Naming and blaming fertilizers as one of the main causes of a major air pollution alert – and explicitly linking fertilizers with airborne “toxic farm chemicals” – is therefore a questionable claim.

Thankfully, the science tells us that mineral fertilizers probably contributed very little to the invisible dust blanketing the English Channel coast on that warm, sunny weekend in April – an interpretation that should allow us all to breathe more easily. ■

Market outlook

Historical price trends $/tonne



Source: BCInsight

Market insight courtesy of Integer Research

AMMONIA

The Yuzhny f.o.b. price for ammonia reached $285/t in May – an upward increase of $33/t since February – supported by brisk spot business in Europe, India, Africa, China and the Arab Gulf. A strong US spring planting season saw the US Gulf price stabilise at $323/t cfr in May. Demand later softened In June as the market struggled to absorb new capacity from Russia and the US. Baltic supply availability increased in June as Acron shipped volumes from its new Russian plant in Veliky Novgorod to two new long-term partners, Yara and OCI. Ammonia prices began to stall, as buyers waited for further price direction, before oversupply saw the Yuzhny price fall to $255/t f.o.b. in late June, its lowest since February.

UREA

The urea market showed signs of stability in April and early May. The Yuzhny f.o.b. price traded at around $215/t, supported both by healthy US spring demand and STC India's 19 May tender for 1.36 million tonnes of urea. Supply remained tight in the Baltics due to domestic commitments and several maintenance turnarounds at plants in Russia. After a temporary respite, prices began to fall through late May and June, partly due to the seasonal lull in northern hemisphere demand. Increased availability in the Middle East was another factor, with Egyptian producers increasing their operating rates after several gas curtailments. With the market already oversupplied, urea prices came under additional pressure when Indorama started urea production at its new 1.4 million tonne per year plant in Port Harcourt, Nigeria in mid-May.

PHOSPHATES

Processed phosphate markets remained under pressure at the end of June. Buying activity remained thin and phosphoric acid contracts negotiations between Indian buyers and acid suppliers continued to stall. By the end of June, India's IFFCO was finally reported to have settled phosphoric acid contracts with two suppliers at $600/t cfr, a significant reduction of $115/t on first quarter contracts. Meanwhile, Chinese DAP made its way into India in the low $340/t cfr in the last week of June. Indian DAP demand also picked up in June, with material booked from Russia, the Middle East and China. Meanwhile, West of Suez, Tampa DAP prices continued to slide as Mosaic sold 7,000 tonnes at $345/t f.o.b. to Latin America for July shipment. The Brazilian market also softened in June with only small shipments reported from North America and China.

POTASH

Low demand in the international potash market prevailed throughout almost all of the second quarter, reflecting the absence of a Chinese or Indian contract price. However, a potash contract for 2016-2017 was finally concluded between Belarus and India at $227/t cfr for 700,000 tonnes, following months of delay. Although anticipated, the price level is a significant $105 per tonne reduction on last year's agreement of

$332/t cfr for 800,000 tonnes. The China contract price has historically settled at $15-20/t lower than the Indian price, suggesting this year's contract price in China may be agreed at around $210/t cfr.

Potash prices in many other markets have continued to come under pressure. Despite suppliers targeting higher prices in Brazil, prices remained at $225-235/t cfr in May and June. Standard MOP prices in Southeast Asia also fell to $220-265/t cfr in June.

SULPHUR

Sulphur prices showed signs of stability and recovery through May, supported by limited spot market availability. Wildfires in Alberta, Western Canada also disrupted production. Middle East production was also tight as contract commitments took priority during a period of maintenance. Prices then began to ease again through June as the lacklustre processed phosphates market failed to boost sulphur demand. At the same time, sulphur stocks at the nine major ports in China have now risen from an average 1 million tonnes in 2015 to 1.7 million tonnes. This has put downward pressure on spot prices in China, with many end-users adopting a hand-to-mouth buying strategy. Chinese stocks have built on the back of a surge in sulphur imports in the first five months of the year, up by around a fifth on 2015 at 5.2 million tonnes. Middle East producer prices have dropped, down to $73-80/t for July shipments, with expectations of further decreases. ■

Market price summary $/tonne – Late-June 2016

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phosphoric Acid
f.o.b. Caribbean	255	n.m.	f.o.b. E. Europe 95-100	f.o.b. US Gulf	345	n.m.	n.m.
f.o.b. Yuzhny	255-265	184-187	-	f.o.b. N. Africa	335-360	275-295	565-840
f.o.b. Middle East	300-310	166-195**	-	cfr India	342-350	-	640*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	195-305	-	cfr US Gulf	30-40	f.o.b. Vancouver	75-85	
f.o.b. Middle East	185-305	-			f.o.b. Arab Gulf	75-85	
f.o.b. Western Europe	-	€460-470			cfr North Africa	70-80	
f.o.b. FSU	190-295				cfr India	90-95+	

Prices are on a bulk, spot basis, unless otherwise stated. (= contract ** = granular). Phosphoric acid is in terms of $/t P_2O_5 for merchant-grade (54% P_2O_5) product. Sulphur prices are for dry material. (+ Quotes for product ex-Arab Gulf)*

MARKET DRIVERS

- **Ammonia outlook:** The global ammonia market will struggle to absorb new capacity from the US and Russia in July and August, suggesting that ammonia prices are unlikely to recover in the next couple of months. Indian buyers are expected to look for cheaper Black Sea spot volumes which are expected to fall to the low $240s/t f.o.b. This, in turn, will put pressure on prices in the Middle East. Several planned turnarounds are expected in July, including maintenance at Uralchem and Acron's ammonia plants in Russia. In addition, completion of expansions in the US, such as Dyno Nobel's site in Waggaman, Louisiana, will add to capacity.
- **Urea outlook:** Global urea prices will come under further pressure in July and August as Chinese sellers shift their focus to exports. The Yuzhny f.o.b. prilled urea price is expected to fall further to the low $180s/t in July, as seasonal demand slows in Europe and the US, while the Chinese urea price is likely to fall below $200/t f.o.b. Further price declines below this level could result in Chinese producers making significant gross losses on exports. Current market oversupply will be exacerbated during the third quarter as several US capacity expansions come online. Suppliers are also awaiting the next Indian import tender. Good monsoon rains usually result in robust demand, although India will most likely only tender for 500,000 tonnes.
- **Phosphates outlook:** There is reason to believe that the settlement of phosphoric acid contracts in India, and a good start to the monsoon season, may lead to DAP demand improving in July, even though Indian stocks are still reported to be high. While prices may find support in renewed activity from India, any upside will be capped by the intense competition for Indian tonnages during July. Additional MAP demand is expected to surface in Brazil as attention turns to the forthcoming *safrinha* planting season.
- **Potash outlook:** Some demand upside in the global potash market is anticipated looking forward. The conclusion of the Indian contract price at $227/t cfr, for example, is a boost for Indian import demand and should set a floor price for the market. Also, according to Integer's cost analysis, there is not much room for further prices falls without financial losses for some potash makers. Overall, market developments should lead to growing confidence and rising buying activity in the second half of 2016. Potash buying in the remainder of the year should be supported by a number of factors. These include a favourable monsoon in India, and firm crop acreages and production estimates for soybeans and corn in Brazil and the US.
- **Sulphur outlook:** Sulphur prices are expected to remain weak in coming weeks, as high stocks in China puts pressure on traders to liquidate stocks at low prices. The Middle East supply outlook is, however, more balanced than expected. Export availability in 2016 has been revised downwards by around 800,000 tonnes as delays to the Qatar's Barzan project have put back its start-up to next year. On the demand side, Brazilian sulphur imports have declined by around a tenth so far this year, and expectations of a revival in India have yet to materialise. New demand from Sheritt's sulphuric acid plant in Moa, Cuba is likely to provide an outlet for extra Vancouver trade, lending support to Western Canadian sulphur pricing. ■

Fertilizer Industry News

TURKEY

Turkey bans nitrate fertilizers

Turkey has suspended the production and sale of ammonium nitrate fertilizers. The Turkish government decision was taken in response to a series of terrorist attacks in the country, culminating in the recent Istanbul car bombing on 7 June. In this latest terror attack, ammonium nitrate explosives were remotely-detonated during the city's morning rush hour, killing 11 people.

The suspension came into force on 8 June and applies to other nitrate fertilizers, including calcium ammonium nitrate (CAN), potassium nitrate and sodium nitrate.

Nitrate fertilizer stocks currently in the distribution chain have apparently been placed under government control. The suspension also encompasses pending nitrate fertilizers sales totalling some 64,000 tonnes.

Turkish agriculture minister, Faruk Celik, said: "Turkey has banned the sale of fertilizers which could be used as explosives, so all sales of the fertilizer nitrate can no longer be carried out in Turkey."

Turkey is a major market for ammonium nitrate, consuming around 1.5 million t/a out of total domestic fertilizer consumption of 5.5 million t/a. Fertilizer-grade ammonium nitrate imports were 625,000 tonnes in 2014, supplemented by domestic production of 306,000 tonnes. Turkey is also a significant CAN producer with an output of 722,000 tonnes in 2014.

Turkish producer Bagfas remained upbeat, saying the ban on sales was likely to have a minimal impact on its business, as 60% of its nitrates sales are export-oriented. The ban's imposition may even have an upside for some fertilizer producers and distributors, if imports and sales of other nitrogen fertilizers rise to meet the gap in domestic Turkish demand.

Exactly how long the Turkish nitrates suspension will last is unclear. ■

UNITED STATES

CF and OCI mega merger called off

The proposed merger between CF Industries and OCI's global distribution arm and European and North American businesses has collapsed in the wake of a new tax ruling by the US Treasury. Both companies confirmed the merger's termination in a joint statement on 23 May.

The failure of the merger followed US Treasury rule changes, announced in April, limiting so-called 'corporate tax inversions'. These had allowed US companies to adopt a foreign address for tax purposes by purchasing an overseas business. The removal of this tax option appears to have damaged the financial rationale for the merger, as it "materially reduced the structural synergies of the combination" according to the joint statement. CF Industries had wanted to move its corporate address to the United Kingdom as part of the proposed deal.

"Although the original deal created significant value for both parties, changes in the regulatory and commercial environments forced us to re-evaluate the combination and led us to the conclusion that terminating the agreement is in the best interests of CF Industries and its shareholders," said Tony Will, president and CEO of CF Industries. "I want to thank the management team of OCI for their professionalism and collaboration throughout our discussions."

Nassef Sawiris, the CEO of OCI, also thanked CF Industries management, and raised the possibility of future collaboration: "The level of goodwill and collaboration between the two companies has been positive at all levels of management since our discussions started last year, which leads me to believe that in the future we can explore alternative ways of collaboration or structures to create value for our respective shareholders."

A clause in the merger agreement means OCI will now receive $150 million from CF Industries as a result of its termination.

Honeywell spins-off ammonium sulphate business

Honeywell is divesting its ammonium sulphate fertilizer business as part of a spin-off of its resins and chemicals operations. The spin-off will become a separate, standalone company named AdvanSix Inc.

"Our $1.3 billion Resins and Chemicals business enjoys a leading position in the industries it serves and a global cost advantage. It is favourably positioned to continue to achieve global growth as a standalone enterprise, with added flexibility to make capital investments that enhance its offerings and service to customers," Dave Cote, Honeywell's chairman and CEO said in a 12 May statement.

AdvanSix is set to become a leading manufacturer of nylon, *Sulf-N* ammonium sulphate fertilizers and a range of chemical intermediates on completion of the spin-off. AdvanSix will also be the world's largest single-site producer of caprolactam due to its ownership of the Hopewell, Virginia plant.

Erin Kane will become president and CEO of AdvanSix when it is up and running. She is currently vice president and general manager of Honeywell Resins and Chemicals, a position she has held since October 2014.

Honeywell hopes to complete the spin-off by early next year.

BRAZIL

Speculation continues over Vale sell-off

The Mosaic Company is reported to be in talks to buy Vale's fertilizer assets in a deal that could total $3 billion.

News agency *Reuters* reported on 17 June that talks between the two companies were taking place, citing three anonymous sources, with a cash-and-stocks deal being the preferred option. If finalised, such a deal would place 12-15% of Mosaic's shares in Vale's hands, making the mining giant Mosaic's largest shareholder.

Yara International has also expressed an interest in Vale's fertilizer business in recent months. Its chief financial officer described Vale's fertilizer assets as an attractive investment opportunity at a New York investor conference in May. Yara's comments followed reports in April that Vale was considering offering a 40% stake in its fertilizer business for $1.2 billion. Yara has made successful deals with Vale in the past, having bought Bunge Fertilizers off the company in 2012.

Vale is Brazil's largest phosphate and nitrogen fertilizer producer and its assets also include the 625,000 t/a Sergipe potash plant, the country's only operational potash mine. Many of these assets and much of Vale's distribution network were acquired through its purchase of Fosfertil in 2010. Vale already has an existing business connection with Mosaic through the 3.9 million t/a Bayovar phosphate joint venture in Peru.

Neither Vale or Mosaic have commented on or confirmed the *Reuters* story.

EuroChem takes control of Fertilizantes Tocantins

EuroChem has purchased a controlling stake in the Brazilian fertilizer distributor Fertilizantes Tocantins for an undisclosed sum.

EuroChem announced it had bought a 50% plus one share of the company on 6 July. It expects to conclude the deal by the end of August, subject to regulatory approval.

The part-purchase will strengthen EuroChem's access to one of the world's largest and fastest growing fertilizer markets.

Fertilizantes Tocantins distributed 740,000 tonnes of fertilizers in 2015, having achieved double-digit annual sales growth over the last seven years. Its location in what EuroChem calls the "emerging fertile farming regions in the North, Northeast and Mid-West" of Brazil also makes it an attractive proposition.

Fertilizantes Tocantins' owner, Eduardo Motta, will stay on as CEO to direct the business and will retain a "significant interest" in the company under the terms of the deal.

"The acquisition of Fertilizantes Tocantins creates compelling growth opportunities for EuroChem in Brazil, allowing us to significantly expand our offering of high-quality fertilizers to local farmers," said Dmitry Strezhnev, EuroChem's CEO.

CANADA

Canpotex scraps export terminal plan

Canpotex has abandoned plans to build a new Pacific potash export terminal at the Port of Prince Rupert in British Columbia.

The North American export consortium announced the decision to abandon construction in a brief press statement on 17 June, citing economic and commercial factors. Canpotex also concluded that it already has enough port access and export capacity at its existing Vancouver, Saint John and Portland export terminals. "The decision was made after careful deliberation of Canpotex's current and anticipated terminal capacity needs, and the options we have to meet those needs," said Ken Seitz, Canpotex president and CEO.

Canpotex, the export partnership between PotashCorp, Mosaic and Agrium, put the CAD 775 million ($607 million) terminal project on hold, following PotashCorp's production closure at Picadilly, New Brunswick in January. The company has already invested millions in Port Rupert's infrastructure, having provided a quarter of the funding for the CAD 90 million road, rail and utility corridor completed by the Prince Rupert Authority in May.

Canpotex could reverse its decision over the terminal's construction, but has said this is unlikely in the foreseeable future.

Saskatchewan may scrap potash royalties review

The Saskatchewan government may scrap its potash mining royalty and tax review, due to soft market conditions and the pressures facing the province's producers.

The review was announced in the 2015 Saskatchewan budget by the province's former finance minister, Ken Krawetz. Under current arrangements, Saskatchewan receives a royalty on potash mined on crown lands and a potash production tax. The review was considering whether to change the current weighting so that government potash revenues would be based more on production and less on prices in future.

"Part of the discussion is whether or not we do anything at the moment or whether we hold off on any kind of further discussion," Saskatchewan's economy minister, Bill Boyd, told *Reuters* on 16 June. This was confirmed by Cory Hughes, the province's executive director of mineral policy. "The review was originally scheduled for completion by the end of 2016. But based on poor current market conditions, the government of Saskatchewan has indicated that the review may not move forward at this time," Hughes told *Industrial Minerals* magazine.

Boyd insisted that Saskatchewan potash producers – who reportedly pay the highest royalties in the world – had not urged the government to drop the review. But he stressed that the province did not want to add to current pressures on Canada's potash industry. "It's important to note that certainly markets are soft and that there's increased production from competitors around the world, so we have to be careful," Boyd said.

Saskatchewan collected a record CAD 1.36 billion ($1.05 billion) in potash revenues in 2008/09 at the height of the commodity prices spike. The government is forecasting CAD 420.4 million in revenues for the current year, a drop of more than a third on 2015 revenues.

A final decision on the future of the review is expected imminently.

Wildfires hit Fort McMurray production

Wildfires raging around Fort McMurray in northern Alberta have shutdown production at most of the region's oil sand facilities. Major oil sands plants at Suncor and Syncrude were evacuated because of the wildfires, causing production at Syncrude to completely shutdown for the first time since 1978.

The US Energy Information Administration (EIA) reported disruption to oil production averaging 800,000 bbl/d in May, and predicted June's production could also be down by 400,000 bbl/d on average.

Developments at Fort McMurray are being keenly watched as the area usually produces around 1.8 million t/a of sulphur, a major fertilizer industry raw material and a particularly important supply source for US phosphates production.

RUSSIA

Onexim Group sells 20% Uralkaki stake

Onexim Group, owned by Russian billionaire Mikhail Prokhorov, has sold its 20% stake in Russian potash producer Uralkali, *Bloomberg* reported on 8 July. It named Belarusian businessman Dmitry Lobyak as the buyer.

The new owner is a business associate of Uralchem's Dmitry Mazepin, according to *Bloomberg*. Uralchem, a major Russian nitrogen fertilizer producer, itself owns a one fifth stake in Uralkali. Although Onexim sold its share for an undisclosed sum, a market value of around $1.7 billion was thought likely.

Uralkali delisted from the London Stock Exchange in December 2015 and is currently pursuing an exit from Moscow's Exchange. The sell off of Onexim's stake is likely to fuel speculation about a possible Uralchem–Uralkali merger.

Analysts also linked the development to a possible return to potash trade cooperation between Uralkali and Belaruskali. "The sale of a stake in Uralkali to entities close to Mazepin increase the likelihood of a trade agreement," commented Denis Vorchik, an analyst at UralSib Financial Corp.

Belarusian president Alexander Lukashenko has also spoken positively about a possible return to potash cooperation between his country and Russia. "Virtually every month new shareholders of Uralkali contact me to say that they want to cooperate. I tell them that I am ready to meet with them if they have proposals," Lukashenko told the 5th Belarusian People's Congress on 23 June, according to state news agency *BelTA*.

Lukashenko added. "Today they are ready to cooperate with us. We are not against it. But we will work on our terms. Let's resume work, let's agree on the volumes of production. To put it plainly, we will divide markets and will not compete with each other. It will bring good dividends."

FLSmidth secures €160m port supply deal

FLSmidth has secured a €160 million contract with the Russian marine export terminal owner Oteko-Portservice. The engineering, supply and supervision (EPS) contract covers the installation of material handling equipment at the port of Taman on the Russian Black Sea Coast.

FLSmidth will supply the port with railcar unloading, screening and crushing equipment, stockyard machines, ship loaders and associated conveyor systems. The new cargo terminal under construction at Taman will handle Russian fertilizer, coal, iron ore and sulphur exports.

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

UNITED KINGDOM

Sirius Minerals aims for September construction start

Sirius Minerals hopes to begin building its UK-based York Potash project in September, the company has told the *Financial Times*.

"We are targeting to be in a position to start construction in September… that is what we are working to achieve," said the company's CEO Chris Fraser.

Sirius Minerals unveiled its latest plan for a 10 million t/a capacity polyhalite mine in a definitive feasibility study this spring. Estimated construction costs for the project recently fell to $2.9 billion, after talks with contractors identified significant savings.

Sirius now believes the mine's initial construction phase will cost $1.1 billion, one-third less than previously expected. Cuts to construction costs also mean the amount of new equity the company needs to raise has fallen from $800 million to around $550 million.

Sirius hopes to raise money for the construction of the mine in coming weeks, despite market volatility following the UK's decision to leave the EU. The project's construction costs may even fall further due to recent declines in sterling's value. Costs "have moved in our favour", said Fraser. "We are a dollar asset but a big part of the costs will be [paid in] sterling [for] labour… With lower sterling, we will be in a stronger position."

Initial polyhalite production from the project is scheduled for 2021, with a ramp-up in production to 10 million t/a by 2023, under the current timetable.

Fatality at Boulby potash mine

An employee at ICL UK's Boulby potash mine died on 17 June following an underground gas blowout. All other workers in the mine were safely evacuated.

"Following the fatal incident at the ICL UK Boulby mine earlier today investigations have begun with senior mine management, together with the police and Her Majesty's Mines Inspectorate going underground to examine the scene," ICL UK said in a statement.

A company spokesman told the BBC: "The incident is believed to have involved a gas blowout – a sudden and powerful release of gas. Company staff will be offering all possible support to the man's family." During a press conference, Boulby mine safety manager, Simon Hunter, said there was no suggestion that safety procedures were not being followed.

The fatality comes after a fire at Boulby mine in April left seven employees temporarily hospitalised.

TANZANIA

$3bn urea plant joint venture

Tanzania has unveiled plans to build a $3 billion nitrogen fertilizer plant in partnership with an international consortium of German, Danish and Pakistani partners.

State-owned Tanzania Petroleum Development Corporation (TPDC) has signed a joint venture agreement for the 3,800 t/d urea plant with EPC contractor Ferrostaal, technology-provider Haldor Topsoe and plant operator Fauji Fertilizer Co. The plant's output will be aimed at both the domestic and export markets.

Construction is due to start in December in the south of the country and will access large offshore gas finds located nearby. Tanzania announced the discovery of another 2.2 trillion cubic feet of offshore gas in February, raising its reserves to more than 57 trillion cubic feet.

The plant's completion would be a significant development for Tanzanian agriculture. The sector, which makes up more than a quarter of GDP and employs 75% of the labour force, remains heavily reliant on fertilizer imports currently. Tanzania's agricultural productivity is also hampered by a combination of lower fertilizer application rates and low yields.

However, analysts CRU reacted to the project's announcement with caution. This was due to funding uncertainties and risks around the current state of the nitrogen market.

"On paper this project has favourable fundamentals, benefiting from natural gas supply, its ability to serve the domestic market, as well as India and Europe, and political stability," commented CRU. "Despite this, no clear information is provided regarding how the $3 billion plant will be financed – or what is included in the $3 billion cost estimate." ■

Erratum

Updates and corrections to the **OCP Group profile** published in the May/June 2016 issue of Fertilizer International:

- Office Chérifien des Phosphates became OCP S.A. in 2008 and, together with its subsidiaries, forms part of OCP Group
- OCP Group's investment programme runs between 2008 and 2025 and is valued at $21 billion
- Overall OCP Group investment during 2008-2015 was $5.5 billion
- The Africa Fertilizer Complex is able to produce a range of phosphate fertilizers and required an investment of $545 million
- OCP Group's total debt at the end of 2015 was MAD 51 590 million
- OCP Group did not provide the map shown in Figure 1 of the article
- The industrial development programme in Figure 2 dates from March 2015 and has since been updated
- The finance agreements mentioned in the article only cover a part of the 2014-2015 funding of the development programme

The online version of the article has been updated to reflect these changes.

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People

Tekalign Mamo receives Norman Borlaug Award

Professor Tekalign Mamo was awarded the 2016 Norman Borlaug Award in a presentation ceremony at the International Fertilizer Industry Association's (IFA) Annual Conference at the end of May. Professor Mamo, a distinguished soil scientist and Ethiopia's former agricultural minister, received the award for his outstanding contribution to soil health and natural resources in Ethiopia. Professor Mamo's work has directly benefitted more than 11 million of the country's smallholder farmers. In 2005, a community-based watershed strategy spearheaded by Professor Mamo rehabilitated more than 15 million hectares of degraded land across Ethiopia. Professor Mamo was also responsible for the Ethiopian Soil Information System (EthioSIS), the most advanced soil fertility mapping exercise on the African continent.

"I am honoured to receive this award, and am proud Ethiopia's leadership in addressing soil health issues is being recognised internationally," commented Professor Mamo. "Much remains to be done to continue Ethiopia's transformation and lift even more people out of poverty, but an accolade such as this serves as encouragement to continue this important journey by fellow citizens and African colleagues."

Andrey Guryev is RAAP's new president

PhosAgro's CEO **Andrey Guryev** is the new President of the Russian Association of Fertilizer Producers (RAAP). He was also re-elected as Vice President Eastern Europe & Central Asia of IFA at the end of the trade association's Moscow conference in June.

"I see my chief task as President of the RAAP as creating new opportunities to modernise and streamline the sector amid today's prevailing economic conditions," said Guryev. "I firmly believe that the chemicals industry is able to become one of the Russian economy's most technologically advanced sectors and a key guarantor of food security for Russia and the whole world."

Stefan Borgas is IFA's new public affairs chair

Stefan Borgas has been appointed as chairperson of IFA's Communications & Public Affairs Committee. Borgas, who is also the chairman of ICL Fertilizers, was delighted to be taking up the position: "I am excited to be able to serve as a champion of our industry and look forward to working with IFA in the communications & public affairs domain."

In terms of priorities, Borgas said: "IFA's advocacy must be squarely focused on those UN initiatives with a strong agricultural and environmental angle, such as the 2030 Sustainable Development Agenda and UN climate change negotiations. At the UN agency level, I am pleased to say that IFA is working to put a broader memorandum of understanding with the UN Food & Agricultural Organization into place, and will be stepping up our outreach to the ever more important UN Environmental Programme."

He also believed there was scope for improved communication: "I believe that our industry has a great story to tell but that we do not always tell it as well as we could and not as well as it is necessary… We do great things, but we should talk about them more!"

Vatren Jurin Joins Compass Minerals

Compass Minerals has hired **Vatren Jurin** as its senior product manager for liquid micronutrients. Jurin, a veteran of the plant nutrition industry, will steer the company's expansion into speciality liquid fertilizers.

Jurin brings with him more than 25 years of experience in the agricultural industry, most recently with Brandt Consolidated. He will have particular responsibility for developing and growing the company's liquid micronutrient business globally.

"Jurin has an extensive background in foliar plant nutrition, micronutrients, biostimulants and soil chemistry/biology," said Will Hill, vice president of micronutrients for Compass Minerals. "This background, in addition to his experience in product development, sales and marketing, makes him uniquely positioned to lead our company's future in the liquid market."

Compass Minerals is focussed on building a line of specialised liquid products that farmers can apply in different ways throughout the season to enhance plant health. "Water or some other liquid will be the delivery system, not necessarily the product," explains Jurin. "What we develop for liquids will complement the innovative Wolf Trax DDP Nutrients designed for dry fertilizer delivery systems."

He added: "Compass Minerals is equipped with analytical labs, chemists, and a multinational agronomic research and development team. With the recent acquisition of a 35% stake in Produquimica, we are adding a partner with deep experience in manufacturing and development of water soluble and liquid technologies." ■

Calendar 2016

SEPTEMBER

6-8
7th GPCA Fertilizer Convention,
DUBAI, UAE
Contact: Ammara Shahiryar
Tel: + 9714 4510666
Email: ammara@gpca.org.ae

25-27
TFI World Fertilizer Conference,
SAN DIEGO, California, USA
Contact: Linda McAbee
Tel: +1 202 515 2707
Email: lmcabee@tfi.org

OCTOBER

10-12
CRU Africa Fertilizer Agribusiness 2016,
DAR ES SALAAM, Tanzania
Contact CRU Events
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11-13
29th AFA International Fertilizer Technology Conference & Exhibition, TUNIS, Tunisia
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Fax: +20 2 2305 4454
Email: info@afa.com.eg

25-27
IFA Production and International Trade & IFA Crossroads Conferences, SINGAPORE
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Email: ifa@fertilizer.org

NOVEMBER

7-11
IFDC Granular Fertilizer Production Workshop, BANGKOK, Thailand
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Tel: +1 256 381 6600
Email: training@ifdc.org

Fertilizer investment still has steam

Investors have historically viewed the fertilizer industry as a safe prospect due to its highly attractive long-term fundamentals. Although confidence has weakened during the commodities downturn, current investor sentiment towards the fertilizer majors has held up well, when compared to large, diversified mining companies.

It was not only global crop prices which governed the fertilizer market last year. A host of other macroeconomic factors also held sway in 2015, according to merchant bank Hannam & Partners, most notably lower energy prices and the strength of the US dollar[1]. Although the outlook for 2016 remains mixed, the bank expects the global economy to edge up this year, with some market developments likely to stimulate fertilizer demand. Lower fertilizer and energy prices, in particular, when combined with currency depreciation, should maintain agricultural margins and boost fertilizer affordability.

Although mining industry capital expenditure has contracted sharply since 2012, the fertilizer sector is continuing to make substantial investments in new capacity. Capital spending by the ten major fertilizer producers is expected to remain above $6 billion per annum over the next three years, according to Hannam & Partners. Comparatively sound sector finances, together with low capital costs, are helping prolong the fertilizer industry's capital expenditure cycle. The capital structures of the major fertilizer producers – the balance of debt and equity needed to finance their operations and growth – are also generally healthy. Equity capital markets also seem to have bottomed-out, potentially making it easier for fertilizer producers to raise finance going forward.

Outperforming London-listed miners

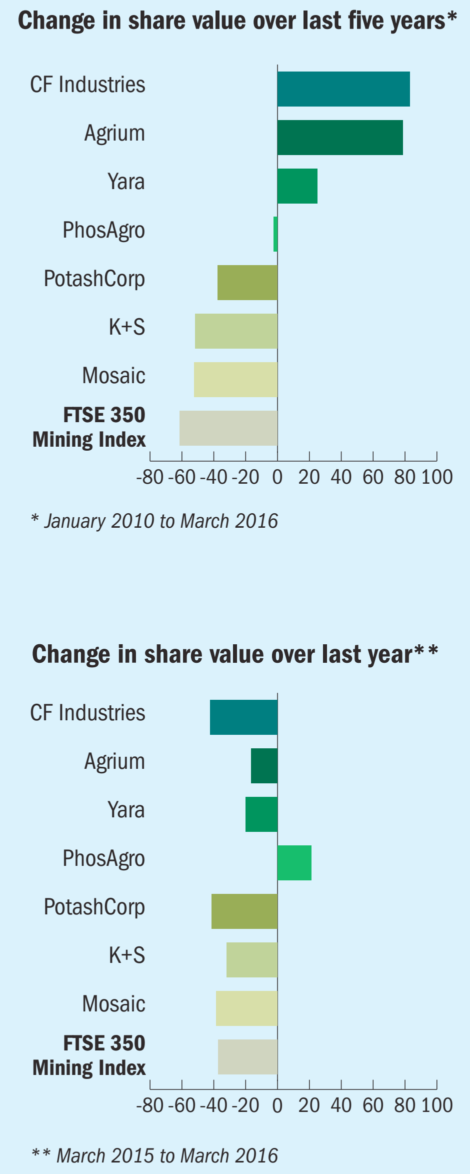
The last six months has been a particularly tumultuous period for large, diversified mining companies. £4.7 billion was wiped from their value in a single day last December when the FTSE 350 mining index fell by more than 7% to its lowest level in 11 years. The index has fallen dramatically since the start of the decade, from over 28,000 at the end of 2010 to below 6,000 by mid-January 2016, although the index has since rallied.

Encouragingly for the fertilizer sector, an analysis by Hannam & Partners confirms that the major fertilizer companies have outperformed London-listed mining companies over the last five years[1]. The FTSE 350 mining index lost almost two-thirds of its value between January 2010 and early March this year. The share value of listed fertilizer companies, in contrast, generally held up better over this period, although stock market performance was mixed with both sharp gains and falls in value reported (Figure 1). However, the general weakening in fertilizer prices has taken its toll on the share value of fertilizer companies over the last 12 months, according to Hannam & Partners.

"If you look at what's happened in the capital markets over a long period of time," comments Ingo Hofmaier, a director at Hannam & Partners. "Overall the fertilizer industry has beaten the FTSE 350 mining index over the longer term and in the last year."

The contrasting fortunes of the mining majors, including BHP, Rio Tinto, Vale, Anglo American and Glencore, in comparison to their peers in the fertilizer sector, such as PotashCorp, Yara, Agrium, Mosaic, CF Industries and ICL, is also illustrated by changes to capital structures over the last five years (Figure 2). Large diversified mining companies have collectively seen their market capitalisation – the market value of their shares – fall by almost 60% since 2011 and net debt levels balloon to $120 billion. For min-

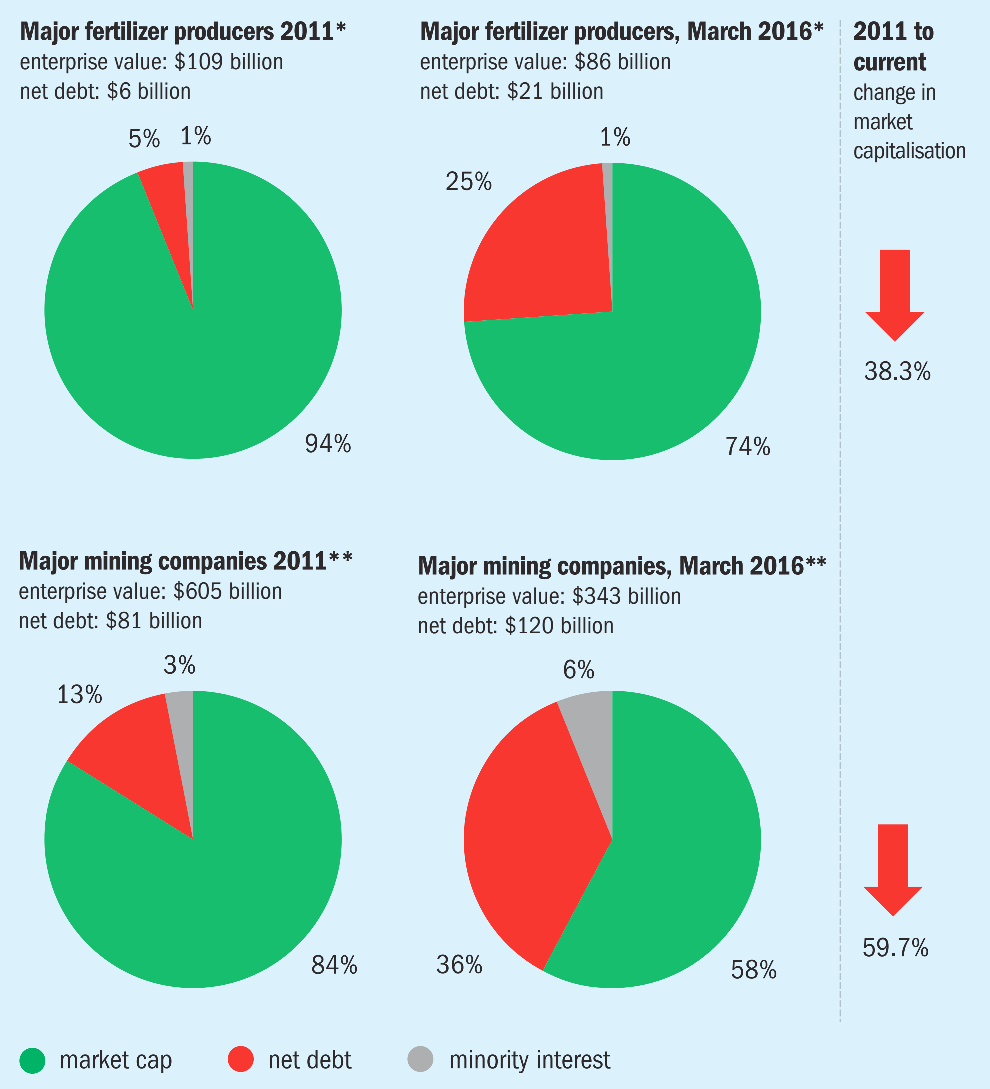
Fig 1: Change in the share value of major fertilizer producers compared to the FTSE 350 mining index



Source: Hannam & Partners / S&Q Capital IQ, March 2016

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

Fig 2: **Capital structure of large, listed fertilizer producers versus diversified mining companies**



Source: Hannam & Partners / S&P Capital IQ
** Major fertilizer producers include PotashCorp, Yara, Agrium, Mosaic, CF Industries and ICL.*
*** Major mining companies include BHP, Rio Tinto, Vale, Anglo American and Glencore.*

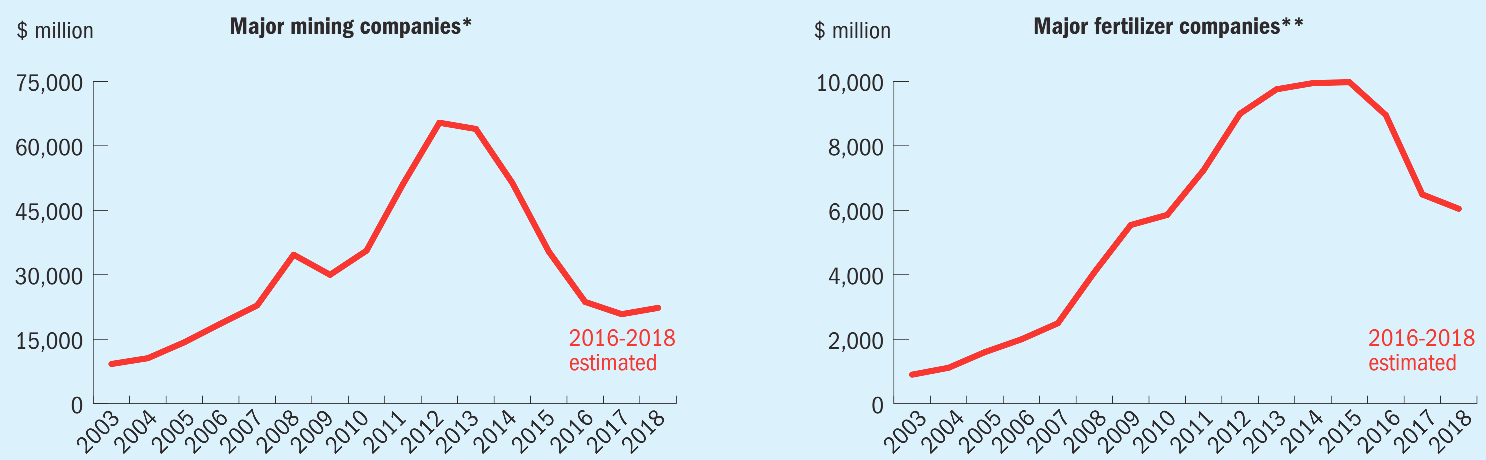
ing majors, this level of debt is equivalent to more than a third of their total 'enterprise value', the sum of market capitalisation, net debt and minority interest.

"Today, almost 40% of the capital structure of the major mining companies is debt – we estimate that an injection of around $60 billion is needed to put things right," comments Hofmaier. "There is currently hardly any mining sector investment going into greenfield capacity because the majority of capital generated in these businesses is instead being used to service or reduce debt."

Although they have been unable to buck the general trend, the financial health of the fertilizer majors has been less affected by the commodities downturn. Their overall market capitalisation has fallen by almost two-fifths since 2011, and total net debt in the fertilizer sector currently stands at around $21 billion, equivalent to a quarter of their combined enterprise value (Figure 2).

Fertilizer majors, although generally in better shape then their large mining company peers, have not been immune to the general downward slide in equity, the balance of assets relative to liabilities, affecting commodity companies. There is a growing realisation that "equity is the flexible number" according to Hannam & Partners. "If you look at the fertilizer sector, excluding EuroChem and OCP, leverage of the largest listed companies has gone from $6 billion in 2011 to $21 billion at the start of this year," explains Hofmaier. "The market has punished companies with high leverage significantly as, unfortunately, it is equity that leads the squeeze in valuations."

Fig 3: **Capital expenditure by major mining and fertilizer companies**



Source: Hannam & Partners / S&P Capital IQ, March 2016
**Major mining companies include: BHP Billiton, Rio Tinto, Vale, Glencore, Anglo American.*
***Major fertilizer companies include: Photash Corp, Mosaic, CF Industries, Agrium, Yara, ICL, K+S, Incitec, PhosAgro, SQM.*

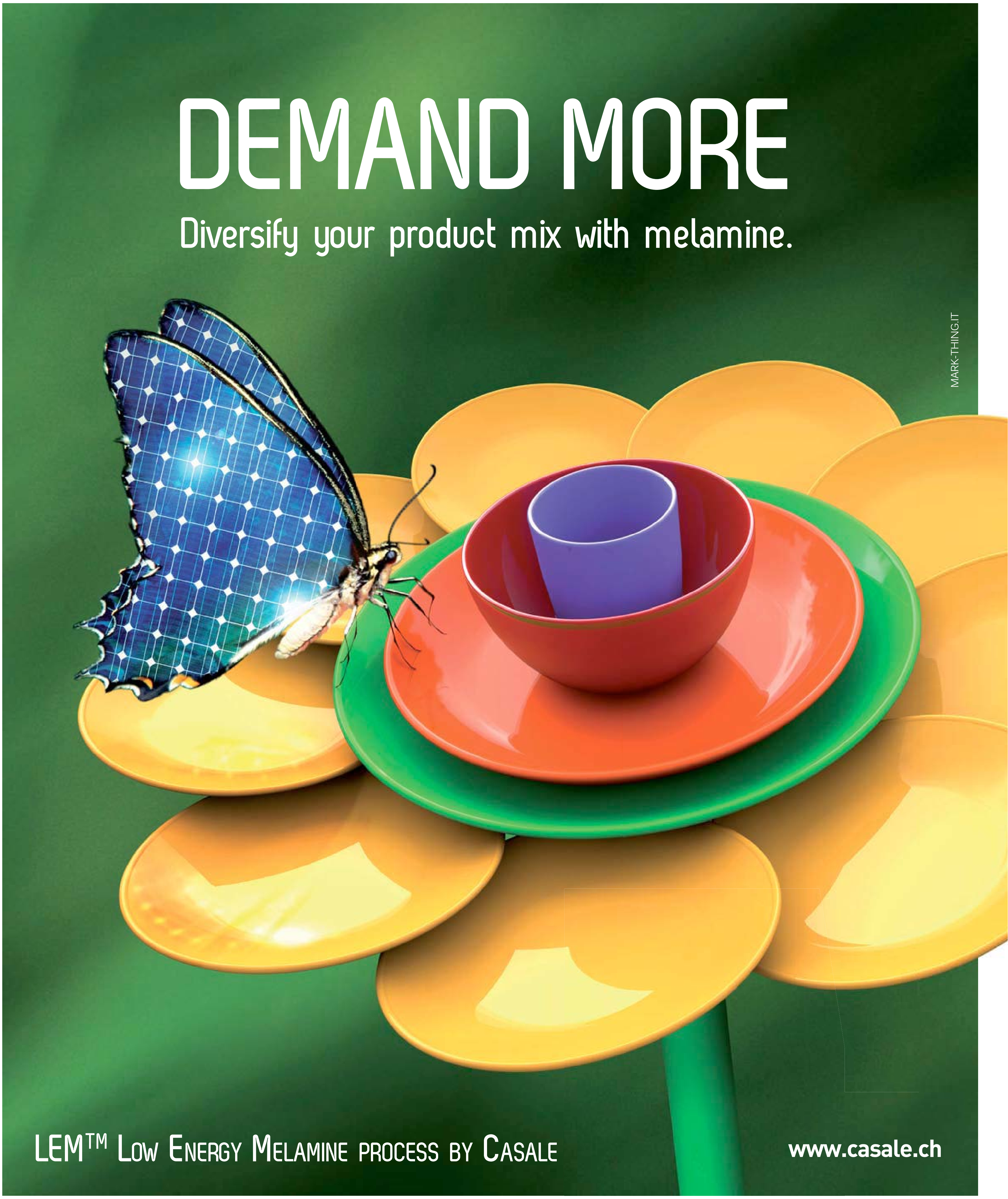

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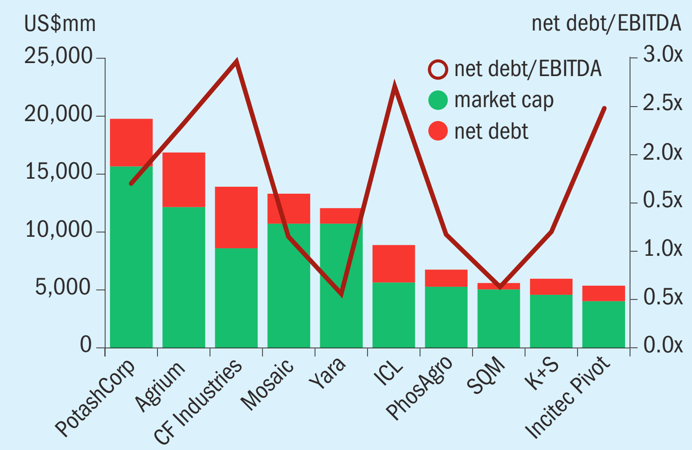
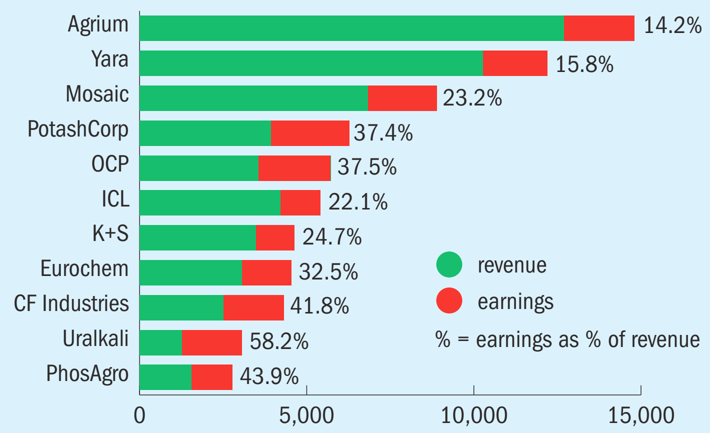
Fig 4: **Net debt of major fertilizer producers relative to market value and earnings**



Source: Hannam & Partners / S&P Capital IQ, March 2016.

Fig 5: **Revenue and earnings of major fertilizer producers, 2015**



Source: Hannam & Partners / S&P Capital IQ / Company filings.

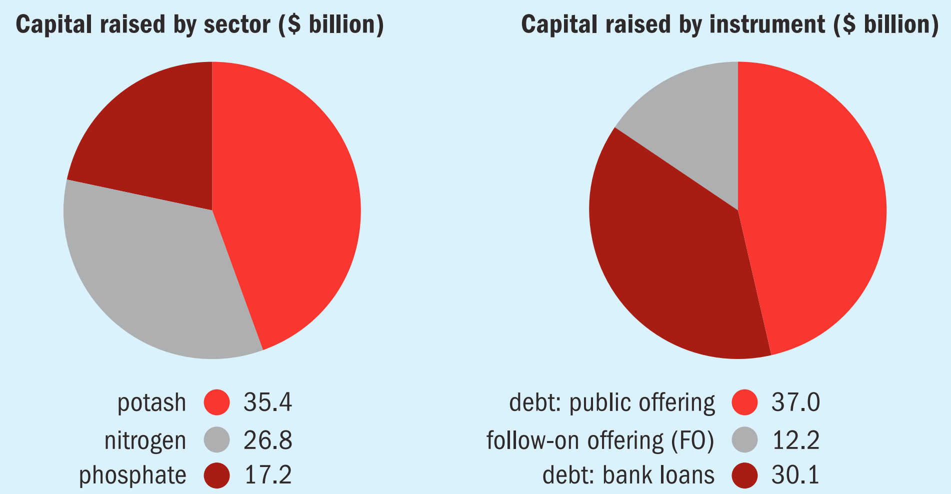
Fertilizer sector investment powers on

Mining majors have dramatically scaled-back investment since the height of commodity 'Super Cycle'. Collective investment by BHP Billiton, Rio Tinto, Vale, Glencore and Anglo American peaked at $65 billion in 2012 but is expected to drop by more than two-thirds to $21 billion by next year (Figure 3). "For diversified mining companies, their commodity prices peaked in around 2011. Capital expenditure this year is expected to come down by 60-70% from its 2012 peak level, depending on the company," comments Hofmaier.

The capital investment cycle for fertilizers, in contrast, "still has steam" in Hofmaier's view. Combined annual investment by PotashCorp, Mosaic, CF Industries, Agrium, Yara, ICL, K+S, Incitec Pivot, PhosAgro and SQM peaked at just under $10 billion in 2015 – three years later then the corresponding peak for mining majors. Fertilizer companies are still expected to invest almost $9 billion this year, falling to $6.5 billion next year and then to $6 billion by 2018, a decline of around two-fifths from the 2015 peak (Figure 3).

The fact that the fertilizer sector is more conservatively funded than the mining sector, with generally lower levels of debt relative to earnings, helps explain why fertilizer majors have been able to sustain their investment levels. Although the ratio of net debt to EBITDA (earnings before interest, tax, depreciation and amortisation) within the fertilizer industry has generally risen during the past four years, it remains below three, a level that is seen as just acceptable and a level below what is regularly demanded by fixed income investors (Figure 4).

Fig 6: **Capital raised by major fertilizer producers,* 2010-2015**



Source: Hannam & Partners
** Including Agrium, CF, ICL, Eurochem, K+S, Mosaic, OCP, PhosAgro, Uralkali, Yara and others.*

"No major fertilizer company is breaking the three times net debt to earnings covenant at this moment , which is a sign of health," comments Hofmaier. "So overall the industry is in better shape, although there are lessons to be learned from companies in the mining arena, particularly from those who don't only operate tier 1 assets."

He continues: "Ma'aden is a slightly different case because they're going through a massive expansion programme. For OCP, who are not listed yet, we estimate the net debt/EBITDA level is somewhere between 2 and 2.4. They've successfully raised two bonds in the last two years and have a lot of operational flexibility to adjust to falling prices."

Dividends are also continuing to provide investors in fertilizer majors with attractive returns. Whilst total shareholder returns (dividends and capital gains from share price appreciation) have varied over the last couple of years, average 'dividend yield' – the annual dividend expressed as a percentage of share price – for the sector has remained fairly constant.

"In terms of what investors are actually seeking – total shareholder return – it's quite unpredictable. What's much more predictable is a relatively consistent and high dividend yield. Last year the dividend yield was 5.0% and today for fertilizer companies it's 4.6%. From an investors perspective, that makes the fertilizer industry quite

Table 1: **Fertilizer industry capital expenditure, 2016-2020**

	Potash	Nitrogen*	Phosphate
Capacity expansion (million t/a)	12.4 (KCl)	27.0	4.2 (P_2O_5)
Capital expenditure ($ billion)	19.1	17.8	12.0
Notable projects	**EuroChem** VolgaKaliy: $4.0 billion Usolskiy: $2.9 billion	**CF Industries** Donaldsonville: $2.1 billion Port Neal: $1.7 billion	**OCP** Investment programme: >$6.0 billion
	Belaruskali Petrikov: $3.0 billion	**Dangote** Fertilizer complex: $1.9 billion	**Ma'aden/Mosaic/SABIC** Wa'ad Al-Shamal: $3.0 billion
	Uralkali Ust-Yayvinsky: $2.6 billion	**North Dakota Corn Growers Association** Northern Plains Nitrogen: $2.1 billion	
	BHP Billiton Jansen: $2.1 billion		

*Excluding Asia

Source: Hannam & Partners/CRU

attractive when almost every major mining company, from BHP Billiton to Glencore, is negatively rated on dividend policy, and this is expected to continue in the coming years, even so the stocks rerated."

What is also encouraging for the fertilizer sector is that margins (earnings as a percentage of revenue) of many major producers outside North America have been maintained or increased during a period of falling prices, particularly for companies such as OCP, PhosAgro and Uralkali (Figure 5), benefiting from a mix of lower energy prices and falling host country currencies, plus operational improvements and increasing volumes.

Past and future investments

Major fertilizer producers raised in excess of $79 billion in capital over the six years from 2010 and 2015, with around $35 billion allocated to potash, $27 billion to nitrogen, $17 billion to phosphate sector projects (Figure 6). Capital was mainly raised using debt-based financial instruments and to a lesser degree public offerings and bank loans. In general, fertilizer producers have not gone to the equity markets to raise capital through follow-on offerings (FO) over the last four years. "There has been no real equity market activity in the sector since 2011," comments Hofmaier. "I think this an enormously important lesson: in the commodity sector you can't rely on the equity market for fresh capital."

Looking ahead, fertilizer majors are expected to commit almost $50 billion of capital investment over the next four years, with $19.1 billion earmarked for new potash fertilizer capacity, $17.8 billion for nitrogen fertilizers and $12.0 billion for phosphates production. Globally, this should add an additional 12.4 million t/a of potash capacity (KCl), 27.0 million t/a of nitrogen capacity and 4.2 million t/a of phosphate (P_2O_5) capacity by 2020.

Ingo Hofmaier expects fertilizer sector merger and acquisition (M&A) activity to increase in future, driven by four distinct drivers: "The first one is horizontal mega mergers, even so there is a high risk of not successfully completing these transactions. Secondly, international joint ventures are becoming more and more important for access to markets and/or resources – as shown by ICL moving into China and Mosaic joining up with Ma'aden."

He continues: "The two final drivers are the need to secure access to markets and access to raw materials, may it be gas, potash or phosphates. We expect to see a lot of these types of M&A activity in Africa. Potentially, that continent is going to become the battleground for the industry in terms for logistics and raw material access. The valuations are low and the opportunities have matured in a positive way in the last years."

Author's note

Please note that all financial information quoted in this article was accurate as of early March 2016.

References

1. Hofmaier, I., 2016. Phosphates – the capital market perspective. *Phosphates 2016*, 13-15 March 2016, Paris, France.

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

Bigger, cleaner, more reliable

Worldwide trends in urea process technology, plant construction materials and product innovation are investigated.

The last decade has been a highly active period for the design, engineering, procurement and construction of urea plants internationally. The award of new urea plant licenses annually, for example, has almost doubled since the global financial crisis of 2008, according to some estimates[1].

Urea production on an industrial scale has its origins in the first half of the 20th Century. Because it is a mature technology, plant operators typically have high expectations when it comes to modern urea process design. To meet those expectations, technology licensors generally need to devise a urea process concept able to combine: high feed material conversion, low energy consumption, low environmental footprint, low initial investment, high operating reliability and high product quality.

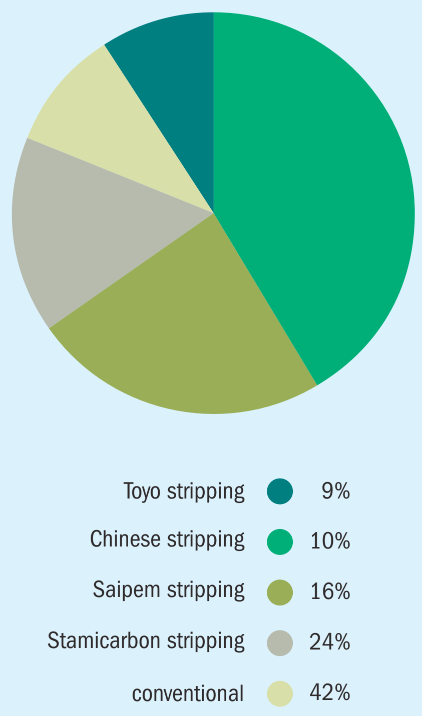
Comparing different commercial urea production processes reveals that, while the underlying process chemistry is essentially the same, they mainly differ in the choice of synthesis conditions and the way in which unconverted material is recycled[2].

Corrosion and operational reliability are two particularly challenging aspects of urea process design. As a recent review noted[2]: "A special challenge in urea technology arises from the fact that the intermediate product, ammonium carbamate, is highly corrosive towards steel, especially in the parts of the plant operating at the highest temperatures and carbamate concentrations. To achieve high operating reliability, it is necessary to select a combination of process conditions and materials of construction that will prolong the service life of equipment items handling such ammonium carbamate-rich solutions and thus allow long, uninterrupted production runs."

A number of clear urea technology trends have emerged over the last decade[1]. There is an expectation in future that:

- Urea plant capacity will increase to 4,000 t/d and beyond
- Two process design concepts – low elevation and submerged condensation – will both become more widely used in the synthesis sections of urea plants
- Emissions will need to comply with more stringent standards
- The use of high alloy super-duplex stainless steel in high pressure-synthesis sections will become more popular
- The market for multi-nutrient and higher nitrogen use efficiency (NUE) fertilizer products will grow

Fig 1: Urea process technologies of existing urea plants



Source: Eijkenboom & Brouwer (2015)

Current global players

Of the more than 500 urea plants that are currently active globally, a sizeable proportion, around two-fifths, are classed as **conventional plants** (Figure 1). These are generally older plants operating without stripping technology (see box) and are typified by relatively high energy consumption and lower production capacity. Common licensors for conventional plants include Stamicarbon, GIAP, Toyo Engineering Corporation, Tecnimont and Chemico[1].

Almost three-fifths of global urea plants now employ some form of **stripping technology** (see box). Stamicarbon CO_2 stripping technology is most widely employed, making up almost a quarter of global plant numbers, and a further one in six urea plants use Saipem stripping technology. Toyo stripping technology and Chinese stripping technology each hold about a tenth market share. However, different market shares apply to the main licensors, Stamicarbon (47%), Saipem (43%) and Toyo (10%), for plants built in the last 10 years, according to Saipem's database.

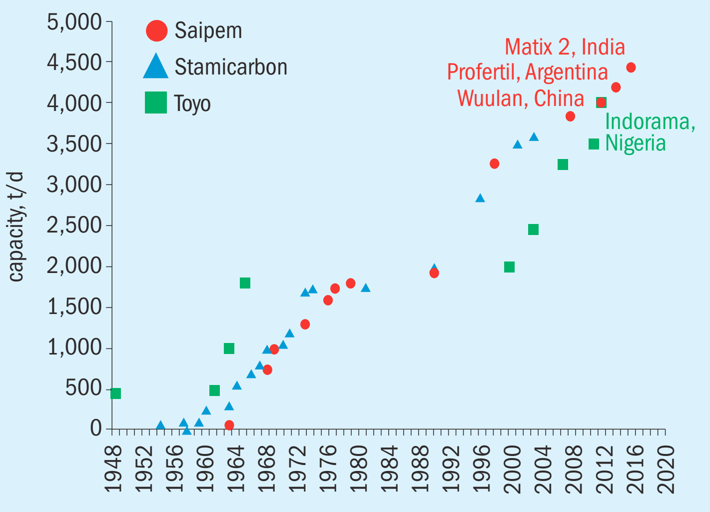
Looking ahead, whilst Stamicarbon and Saipem are likely to retain their market-leading positions internationally over the next five years, the popularity of the Toyo- and Chinese-designed plants looks set to increase. Toyo is increasingly licensing its urea technology for new plants, as well as for revamp and de-bottlenecking projects. The technological sophistication of Chinese urea plants is improving and Chinese-engineered plants also offer distinct cost advantage over their international rivals[1].

Chinese innovation

Chinese CO_2 stripping plants are typically based on a falling film, high-pressure carbamate condenser design. Domestic Chinese companies can engineer, procure and construct these 'Stamicarbon-type' plants at a very competitive cost. Indeed, Chinese CO_2 stripping plants can

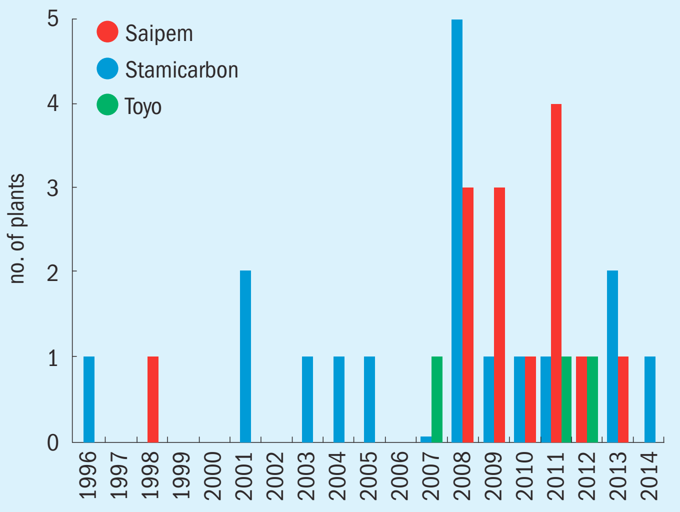
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

Fig 2: **Largest design capacity awarded in time**



Source: Eijkenboom & Brouwer (2015)

Fig 3: **3,000 t/d urea plants awarded during last two decades**



Source: Eijkenboom & Brouwer (2015)

be built for 25% of the investment cost of similar plants in other parts of the world, according to some estimates[1]. Chinese-designed urea plants have also been growing in capacity since the country's early 1,000 t/d plants, a trend that is likely to continue. The capacity of the latest generation of Chinese urea plants has now reached 2,700 t/d.

One example of Chinese process innovation is the *JX Urea Technology* developed by Chengdu-based company JX. The firm has applied new technology to reduce the steam, cooling water and power consumption of conventional total recycle urea plants. *JX Urea Technology* achieves an energy consumption comparable to stripping technologies at a significantly lower investment cost. This technology has been proven at 1,000 t/d since January 2009, and there are also several references at 1,500 and 2,000 t/d.

Trend 1: mega plants

Urea plant capacity has been on the increase since the mid-1950s, a long-term trend driven by economies of scale, cost reductions and innovations in process technology, materials and plant design (Figure 2). Mega urea plants – defined here as those of 3,000+ t/d capacity – have become increasingly popular since their emergence in the late 1990s (Figure 3).

The three major global urea licensors, Stamicarbon, Saipem and Toyo, are all active and successful players in the mega plant market. As of the end of 2014, Stamicarbon had been awarded 17 mega urea plants, compared to the 15 awarded to Saipem and the three awarded to Toyo. Nearly all of these mega plants produce granular urea using fluidised beds. The exceptions are three mega urea plants operated by Engro in Pakistan, Erdos in China, and Matix in India which are all dedicated to prill production.

The trend for increasing design capacity looks set to continue. The latest figures from Saipem confirm it has now designed and licensed 20 mega plants worldwide, eight of which are in operation. These include a 4,000+ t/d plant under construction in China (Wuulan). Saipem is also the licensor for the planned 4,430 t/d Matix 2 project in India, currently the largest global urea plant on the drawing board.

Toyo recently built a 4,000 t/d plant in Nigeria (Indorma). Earlier this year, Toyo also won a licensing and EPC contract from CFCL for a major urea project in India, comprising a twin train 2,000 t/d *ACES21* synthesis section and a 4,000 t/d finishing/prilling section.

The rationale for pursuing economies of scale still appears to hold true with some

The emergence of the stripping process

The commercial synthesis of urea has undergone various stages of technological development and innovation. The **total recycle** process, nowadays called the **conventional** urea process, eventually emerged during the 1940s-1960s as the preferred route for the industrial manufacture of urea. It was this technological breakthrough which paved the way for economically viable, large-scale urea production in integrated, self-contained plants which, importantly, did not depend on additional downstream processes to utilise unreacted ammonia[2].

Stamicarbon, Mitsui Toatsu, Montedison, Snamprogetti (now Saipem) all developed their own proprietary technologies for **the carbamate-solution-recycle system**, the most popular type of conventional urea process. All solution-recycle processes involve absorbing CO_2 and NH_3 in water and recycling to the synthesis step as carbamate solution[3]. Design differences between the various solution-recycle technologies largely disappeared over time. Eventually, most conventional urea production involved similar reactor conditions (185 centigrade and 200 atmospheres), maintained the NH_3:CO_2 ratio at about 4:1 in the synthesis loop, and achieved a similar degree of CO_2 to urea conversion (65-75%) for each pass through the synthesis reactor[3].

The **CO_2 stripping** process was first introduced by Stamicarbon in 1966 with

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BCInsight

Yara's Sluiskil urea plant.

experts predicting that the first 5,000+ t/d urea plants will be built within the next five years. Urea plant capacity could also break through the 5,000 t/d barrier if Stamicarbon were to introduce de-bottlenecking technology, such as the *Medium Pressure Add-on*, at one of its existing mega urea plants, for example. Saipem has also developed a design for a 5,000+ t/a scale plant.

Revamp projects deploying de-bottlenecking technologies at existing urea plants have also enabled licensors to significantly exceed original plant design capacities. Examples include:

- Yara Canada, a 2,000 t/d Stamicarbon-licensed plant now running at 3,300 t/d
- Profertil, a 3,250 t/d Saipem-licensed plant de-bottlenecked to 4,200 t/d but operating at around 3,950 t/d
- Erdos, a twin 1,000 t/d Stamicarbon-licensed plant de-bottlenecked to 3,520 t/d single train capacity
- Sichuan Chemical Works, a Toyo-licensed plant de-bottlenecked to 2,460 t/d using *ACES21* technology

Trend 2: process innovation

One major urea process innovation that has allowed technology licensors to reduce plant investment costs has been **lower elevation synthesis** sections. Saipem and Toyo have achieved this by incorporating a high pressure ejector to drive circulation, while Stamicarbon, in their *Avancore* process, rely on gravity circulation (Figures 4, 5 & 6). **Submerged condensation** in the synthesis section has been another important process development. This technological innovation was first introduced by Stamicarbon's *PoolCondenser* in 1996. Toyo then followed suit with the *Vertical Submerged Carbamate Condenser (VSCC)*. Casale also introduced *Full Condenser* as a 'submerged' revamp option for falling film high pressure carbamate condensers. Using a submerged condenser in the synthesis section has a number of benefits[1,2]:

- More efficient condensation as the heat transfer coefficient is around 40% higher than that of falling film condensation
- This makes it possible to either reduce the heat-exchanging surface, cutting initial investment costs, and/or reduce energy consumption by raising LP (low pressure) steam pressure
- Ammonium carbamate is also retained in the condenser long enough for a significant proportion to convert to urea and water
- This allows the condenser to be operated at a higher process temperature, enabling further reductions in the heat-exchanging surface and/or increases in LP steam pressure
- Easier and more stable operation as the submerged condenser moderates fluctuations in NH_3/CO_2 ratio

The potential for efficiency improvements at urea plants appears to be somewhat limited. Energy consumption did improve markedly following the introduction of CO_2 stripping in the late 1960s. But the efficiency of urea plants has been more or less constant for several decades, with no significant differences between the various process technologies[1]. The successful drive to improve ammonia and carbon dioxide consumption also means that this is now approaching theoretical limits. However, there remains scope for improving the efficiency of some aspects of the urea production process – by introducing integrally-geared CO_2 compressors, for example, or *Green Granulation* fluidised bed technology.

the construction of a 220 t/d urea plant for its parent company, Dutch State Mines (DSM). Stamicarbon subsequently completed a 1,000 t/d CO_2 stripping plant for DSM in 1968. Snamprogetti (now Saipem) went on to design and build its first **NH_3 stripping** plant shortly after this, and later championed the **thermal stripping** process. Toyo Engineering Corporation later entered the market with its own proprietary CO_2 stripping technology.

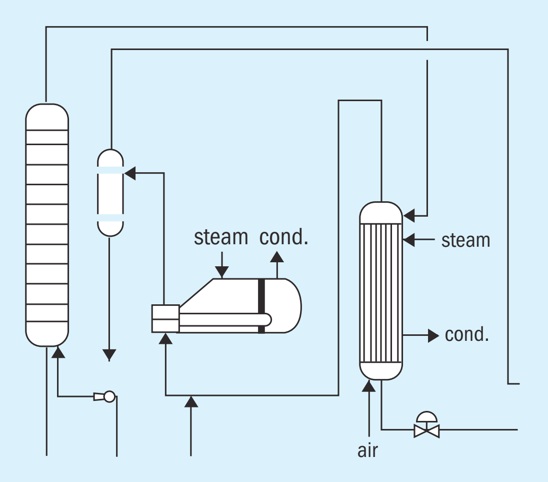
Stamicarbon went on to develop the *Urea 2000plus*, a second generation CO_2 stripping process, at the turn of the millennium. This is offered in two variants, a pool condenser concept and pool reactor concept, respectively. Toyo first introduced its CO_2 stripping process, *ACES* (Advanced process for Cost and Energy Saving), in the 1980s. In the latest version of Toyo's stripping process, *ACES21*, synthesis is by pool condensation in a *Vertical Submerged Carbamate Condenser* (VSCC). Saipem currently offers a thermal stripping process for urea production based on a horizontal layout which uses a high-pressure ejector to drive circulation in the reactor-stripper-condenser-reactor loop[2]. The several types of commercially-licensed stripping processes largely differ according to:

- The type of stripping agent used
- How feed and recycle streams are introduced into the synthesis loop
- Equipment design
- The layout of the synthesis section
- The integration of basic process steps

The stripping process was a major innovation in 'total recycle' urea production and by the late 1990s the technology was being adopted by over 95% of completed plants[3]. ■

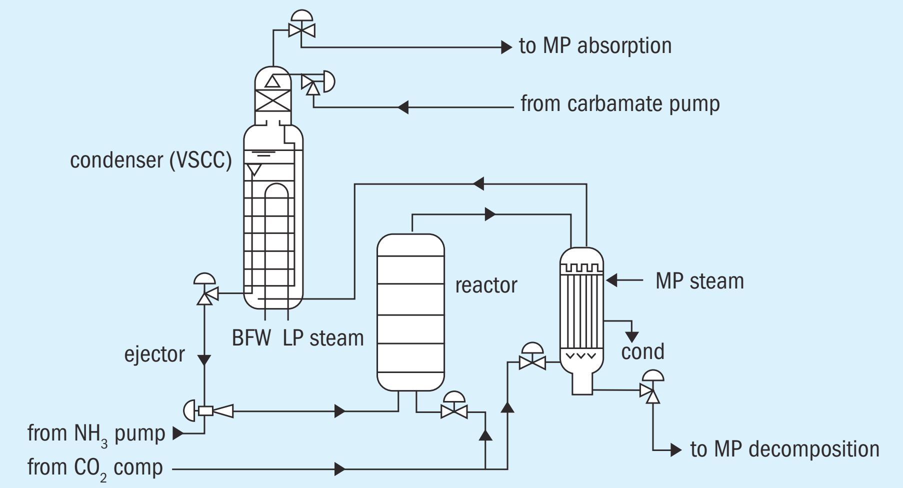
1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

Fig 4: **Layout of Saipem synthesis section**



Source: Eijkenboom & Brouwer (2015)

Fig 5: **Layout of Toyo ACES21 synthesis section**



Source: Eijkenboom & Brouwer (2015)

Urea plants operating globally are having to comply with increasingly strict emission requirements. Environmental permits for new plants in the US are particularly stringent (*Fertilizer International,* 469 p25). Urea plants operating in Saudi Arabia also need to implement acid washing to minimise prilling towers and granulation plants NH_3 emissions. These regulatory developments, and the growing capacity of urea plants, have encouraged efforts to cut finishing plant emissions. Uhde Fertilizer Technology, Stamicarbon, PROZAP and MECS have all invested in new and improved dust and NH_3 scrubbing technologies in recent years (*Fertilizer International,* 469 p25). The *Rotoform* granulation technology developed by Sandvik Process Systems has also helped eliminate emissions from plants manufacturing speciality products such as technical urea, *AdBlue* and urea + ammonium sulphate.

Trend 3: super-duplex stainless steel

Another marked trend in urea process technologies is the development of high alloy **super-duplex stainless steels** with improved resistance to corrosion. These materials are less sensitive to chloride stress corrosion cracking and have other benefits as an engineering material, such as higher strength and thinner wall thickness. Importantly, construction using high alloy materials also improves plant operational reliability and safety. This means urea plants can remain on-stream for longer periods, raising output and increasing their profitability.

Stamicarbon and Toyo have both pioneered the use of super duplex stainless steel in high-pressure synthesis sections. Stamicarbon, for example, offers *Safurex*, a duplex (austenitic/ferritic) stainless steel, as the standard construction material for its urea plant synthesis sections. More than 25 Stamicarbon urea plants with a *Safurex* synthesis section are currently in operation. *Safurex,* developed in collaboration with Sandvik Materials Technology, possesses superior mechanical properties and is highly corrosion resistant at low oxygen concentrations, allowing for much lower air dosing in urea plants. Toyo developed it latest duplex stainless steel, *DP28W*™, in collaboration with Sumitomo Metal Industries Ltd. *DP28W*™ provides improved corrosion resistance in comparison to conventional duplex steel and also shows excellent passivation behaviour in urea carbamate solutions[2]. Two Toyo urea plants are currently operating with high-pressure sections made from *DP28W*™.

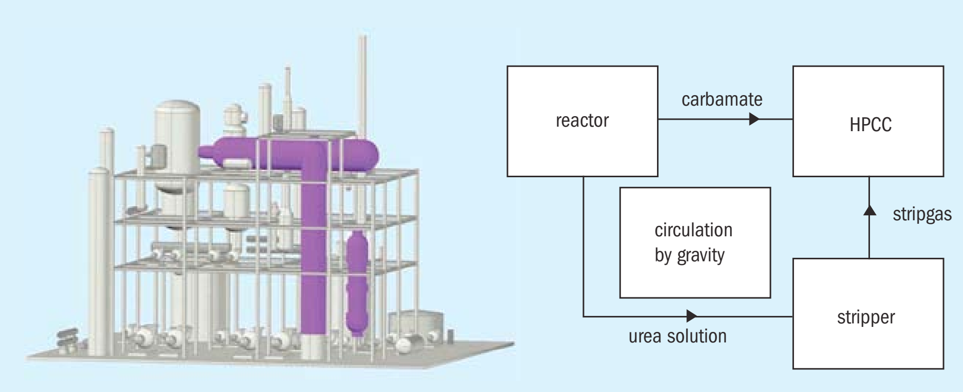
The relatively high temperature of the thermal stripping process precludes the use of stainless steel. Saipem (Snamprogetti) therefore used high pressure stripper tubes made from titanium in its early plants. In the late 1980s, these were replaced by bimetallic coaxial tubes consisting of an inner zirconium tube surrounded by a 25-22-2 Cr-Ni-Mo external tube[2]. More recently, Saipem has developed *Omega-Bond* tubes for thermal stripping in collaboration with Allegheny Technologies Incorporated (ATI). These are made from a protective zirconium inner layer and a titanium outer tube. Five OmegaBonds units are currently in operation, two in Iraq and one each in Bahrain, Pakistan and China.

Saipem has also developed other innovative new technologies such as its *Super-Cups* solution. This proprietary design incorporates high-efficiency trays to improve the performance of the urea reactor.

Trend 4: product innovation

Improving nitrogen use efficiency (NUE) and developing multi-nutrient fertilizers have been two of the main trends in urea product innovation over the last decade. Yara, SKW, Abu Qir Fertilisers are three fertilizer manufacturers

Fig 6: **Layout of Stamicarbon Avancore synthesis section**



Source: Eijkenboom & Brouwer (2015)

who have been actively developing multi-nutrient urea products[1]. In terms of technology, Sandvik's *Rotoform* granulation system is well-suited to the production of a range of multi-nutrient urea products, being able to combine urea + sulphur, urea + ammonium sulphate and urea + magnesium sulphate.

Some of the world's largest urea plants should now be able to produce sulphur-enhanced urea fertilizers in future, following the recently-announced partnership between Uhde Fertilizer Technology (UFT) and Shell Sulphur Solutions. This partnership allows Shell Thiogro *Urea-ES* technology to be incorporated into UFT's proprietary fluid bed urea granulation process. *Urea-ES* technology is based on evenly dispersing an emulsion of tiny, micron-size sulphur particles in urea melt prior to granulation. Iranian company Zafaran Industrial Group also specialises in sulphur-coated urea granulation.

Other producers have focussed their efforts on developing innovative fertilizer technologies to improve the NUE of urea. Many of these inhibit the activity of the urease enzyme in soil using urea additives or coatings. These typically work to reduce nitrogen losses by delaying the hydrolysis of urea and ammonia volatilisation.

Koch Agronomic Services, LLC offers a number of proprietary nitrogen stabilisers for urea fertilizers, available in both liquid (*AGROTAIN ADVANCED 1.0*, *AGROTAIN ULTRA*) and dry (*AGROTAIN DRI-MAXX*) formulations. *AGROTAIN* products use urease inhibitor technology to reduce ammonia volatilisation and maximise crop nitrogen availability. The technology has successfully delivered yield improvements for millions of acres of crops worldwide since its introduction 20 years ago.

Koch also began offering *N-Tegration* process technology to the global urea industry last year. The technology enables urea plants to manufacture enhanced efficiency fertilizers (EEFs) in either prilled or granular form. Koch is currently using the *N-Tegration* process to produce *Super U* fertilizer at its 280,000 t/a Brandon, Manitoba plant, and plans to introduce the technology at its expanded Enid, Oklahoma urea plant. The urea product obtained from the *N-Tegration* process has a dual action, as it contains both an urease enzyme inhibitor and a nitrification inhibitor. This provides protection against ammonia volatilisation, denitrification and nitrate leaching.

Agrium manufactures *ESN® SMART NITROGEN*, a granulated urea fertilizer with a flexible polymer coating. The coating helps prevent losses by releasing nitrogen in response to soil temperature, providing crops "with nitrogen they need, when they need it", according to Agrium.

The Indian government is attempting to improve NUE by promoting the coating of urea with neem oil, and has mandated neem-coating for 75% of the country's urea production. A number Indian urea producers, including NFL, GNFC, TATA and IndoGulf, are currently producing neem-coated urea fertilizers[1]. ■

References

1. Eijkenboom, J. & Brouwer, M., 2015. Worldwide trends in urea process technologies. *International Fertiliser Society Proceedings*, 770.
2. Meessen, J., 2014. Urea synthesis. *Chemie Ingenieur Technik*, 86 (12), 2180-2189.
3. IFDC/UNIDO, 1998. *Fertilizer Manual*. The Netherlands: Kluwer Academic Publishers.

Acknowledgement

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Growing tomato, pepper and cucumber under glass

We report on the fertilizer needs of tomato, pepper and cucumber crops. These are well-suited to greenhouse growing using drip irrigation systems. Fertigation, by integrating crop nutrition with water management, has the advantage of providing greenhouse crops with exactly the right types and amounts of nutrients at each stage of plant development.

PHOTO: BORK/SHUTTERSTOCK.COM

Cucumber growing in a greenhouse environment.

Drip irrigation is widely used as a watering system for cultivating greenhouse crops such as tomato, pepper and cucumber. It provides growers with a number of distinct advantages:

- Drip irrigation is able to control crop growth by regulating the supply of both water and nutrients
- It reduces greenhouse relative humidity as not all of the soil is irrigated
- Humidity is further reduced if drip irrigation is combined with the use of a white, light-reflecting polyethylene film as a mulch
- In countries without a good water supply, drip irrigation ensures that water and energy are used efficiently, leading to major water and cost savings

Proper water management is essential for high yielding, high quality tomato, pepper and cucumber. The water requirement of outdoor grown tomatoes, for example, varies between 4,000-6,000 m^3/ha, rising to 10,000 m^3/ha for greenhouse growing. Watering also needs to be increased by 20-30% on light soils or when saline water is used. Consequently, a drip irrigation system equipped for fertigation is usually advisable, especially as 70% of tomato root systems are in the upper 20 cm of the soil. In tomato crops grown for processing, it is common practice to cease irrigation 2-4 weeks prior to harvest to increase the dry matter content of fruit and reduce soil compaction during harvest[1].

Fertigation – which combines the application of fertilizers with the management of water through an irrigation system – is also

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

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

Table 1: Role of nutrients at different tomato growth stages

	Growth stage/nutrient role			
Nutrient/role	**Establishment**	**Vegetative Growth**	**Flowering-Fruit Set**	**Fruit Ripening-Maturity**
Nitrogen	Strong early growth	Continued growth	Growth and flower numbers	Reduced to maintain fruit fill
Potassium	Strong early growth	Concentrates in leaf tissue prior to flowering	Growth and flower numbers	Minimise fruit disorders
Phosphorus	Root development	Continued growth	Fruit development	Boost nutritional quality
Calcium	Root and leaf growth	Vigorous plant growth	Reproductive development	Good fruit firmness and quality, reduced risk of blossom-end rot (BER)
Magnesium	-	Concentrates in leaf tissue prior to flowering	Flowering and crop production	Fruit quality
Sulphur	-	Vigorous plant growth	-	-
Micronutrients (B, Zn, Mn, Mo)	Good shoot growth	Ensure growth is not limiting	Flower set, development and fruiting (B & Zn)	Even ripening (B & Zn)

Source: Yara

widely used in greenhouse growing because it is efficient and easy to regulate. Fertigation has the advantage of providing tomato, pepper and cucumber with exactly the right amounts and types of nutrients they need at each stage of plant development during the growing season. One method is to dissolve fertilizers in a large holding tank and pump the resulting nutrient solution to the crop. Alternatively, nutrients can be added to irrigation water from concentrated stock solutions using fertilizer injectors.

Growing conditions, nutrient needs and crop sensitivities

Tomatoes are adaptable and can be grown at pH 6.0-6.5 in a wide range of soil types, from light, sandy soils to heavy, clay soils – although sandy soils are preferred if an early harvest is desired[2]. Peppers prefer more alkaline conditions (pH 6.5-7.5) and light soils rich in organic matter, such as well-drained loams, sandy loams or loams[3]. Cucumbers are adapted to a wide-range of soil types but, similar to peppers, prefer light, well-drained, organic-rich soils – and also produce earlier in sandy soils. Greenhouse cucumbers will grow over a relatively wide soil pH range (5.5-7.5), although pH 6.0-6.5 for mineral soils and pH 5.0-5.5 for organic soils are optimal ranges[4].

Nutrients are essential for plant establishment, vegetative growth, flowering, fruit set and fruit ripening (Table 1). Nutrient requirements of tomato, pepper and cucumber (Tables 2-4) depend on the growing system, and are typically much greater for greenhouse growing compared to open field conditions. This is largely due to differences in cultivation intensity, plant growth rates and yields. Nutrient requirements can be up to five times higher in some instances. Outdoor tomato crops, for example, require around 150-200 kg N, 80-100 kg P_2O_5, and 250-300 kg K_2O to achieve a yield of 40-50 t/ha. That compares to the 980 kg N, 300 kg P_2O_5, and 1,600 kg K_2O needed to obtain yields for greenhouse-grown tomatoes of 400 t/ha[5]. Nutrient removal rates (Table 5) also suggest that both nitrogen and potassium uptake by tomato fruit, on a per tonne basis, is greater than that of cucumber and pepper.

Ensuring nutrient applications are balanced is also important. Excess potassium can exacerbate phosphorous and magnesium deficiency and decrease yields in cucumber, for example. Potassium deficiency, in contrast, is linked with iron deficiency but improves nitrogen uptakes. For cucumber grown in greenhouses by fertigation, the highest yields are also generally obtained for a K-to-Ca nutrient ratio of 1.33.

Greenhouse crops have a number of known sensitivities. Salinity, for example, hinders the vegetative growth of cucumber and severely reduces crop productivity. Cucumber plants are also prone to chloride toxicity. The use of Cl-containing fertilizers such as MOP (potassium chloride, KCl) in cucumber growing is specifically avoided because of this. Pepper and tomato crops are also chloride-sensitive and saline-intolerant. This can be combatted by applying nitrate and calcium to supress chloride and sodium uptake, respectively. Zinc also improves tolerance to salt stress by blocking sodium uptake by roots in saline conditions. Peppers and tomatoes are particularly sensitive to calcium deficiency which causes blossom-end rot (BER) in fruit.

Growers commonly use leaf analysis to monitor whether plant nutrient requirements are being met during the growing season, and to help ensure there are no hidden nutrient deficiencies. Soil nutrient levels, measured using tests such as the Mehlich-1 index, are also used to determine application rates particularly for phosphorus and potassium.

Fertilizer recommendations: tomato

Generally, around 2.5 kg of available nitrogen needs to be applied to soils for each tonne of tomato fruit produced, based on an uptake efficiency of around 75%[6]. Yara recommends nitrogen application rates of 250 kg/ha or more for field crops at an average yield of 100 t/ha, although too much N can depress tomato yields. Ammonium sulphate or urea can be used as nitrogen sources for neutral and alkaline soils, and calcium ammonium nitrate or potassium nitrate on acid soils. The relative proportions of nitrate (NO_3-N) and ammonium (NH_4-N) sources should be kept to a ratio of between 0.3-0.7 when applying nitrogen to sandy soils or soils at low temperature[6].

The amount, timing and source of nitrogen applied to tomato crops is also partly determined by the production and irrigation system used[6]:

- **For mulched systems:** around half of N is applied before planting and remainder then applied in two to four applications over the rest of the season, depending on rainfall

Table 2: **Nutrient requirements of tomatoes grown under different conditions**

Growing method	Expected yield (t/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	CaO (kg/ha)	MgO (kg/ha)
Open field	80	241	62	416	234	67
	150	417	108	724	374	110
Processing	60	196	50	336	203	56
	100	303	78	522	295	84
Tunnels	100	294	76	508	279	80
	200	536	139	934	463	138
Greenhouses	120	328	85	570	289	86
	240	608	158	1,065	491	152

Source: Haifa

Table 3: **Nutrient requirements of peppers grown under different conditions**

	Expected yield (t/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	CaO (kg/ha)	MgO (kg/ha)	S (kg/ha)
Greenhouse	75-200*	390-920	200-330	640-1,530	100-210	60-150	40-50
Open field	11-140**	116-705	132-276	174-1,155	38-174	22-115	35-40

**Planting density 50,000-100,000 plants/ha*
***Planting density 30,000-50,000 plants/ha*
Source: Haifa

Table 4: **Nutrient requirements of cucumbers grown under different conditions**

Growing method	Expected yield (t/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	CaO (kg/ha)	MgO (kg/ha)
Greenhouse	300	450-500	200-250	800-1,000	300	130
Open field	High-yielding	170	130	270	-	-
Open field	30-40	100	100	200	-	-
Open field	30	50	40	80	-	-
Open field	15	47	13	65	-	-

Source: Haifa

Table 5: **Typical tomato, cucumber and pepper nutrient removal rates**

	Macronutrients (kg/t)					
	N	P_2O_5	K_2O	Ca	Mg	S
Tomato [ICL]	3.0	0.8	3.7	-	-	1.4
Tomato [Yara]	2.2-2.4	0.2-0.4	2.6-3.6	1.7	0.3-0.6	-
Tomato* [SQM]	2.2	0.5	3.9	1.6	0.4	0.6
Cucumber [ICL]	1.7	1.3	2.9	-	-	-
Cucumber [Haifa]	0.8-1.35	0.27-0.9	1.35-2.25	-	-	-
Pepper**	2.0	0.6	2.2	-	-	-
	Micronutrients (mg/kg)					
	B	Cu	Fe	Mn	Mo	Zn
Tomato [Yara]	10-50	1-10	30-100	10-50	0.1-1.0	10-50

**Greenhouse tomatoes, Netherlands* ***Fertigation in Mediterranean*

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 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

- **For full-bed polythene mulch production systems and furrow irrigation:** all of N is applied before planting.
- **For micro-irrigation:** 25-40% of N is applied as dry fertilizer prior to planting and remaining amounts applied in liquid form according to plant growth and development stages.

A phosphorus content of 0.2-0.4 g/kg in tomato leaves and fruit is enough for good tomato growth, yield and quality. Phosphate fertilizers are usually applied prior to planting when soil tests indicate low P levels (e.g. <31 on the Mehlich-1 Index). Typical P application rates for a fresh-market tomato crop harvested more than three times are:

- Up to 90 kg/ha for very low P soils (Mehlich-1 Index of <10)
- 44-55 kg/ha for low and medium P soils (Mehlich-1 Index of 10-30).
- 10-15 kg/ha for high or very high P soils (Mehlich-1 Index above 30)

Additional applications are only justified during the growing season when plants show signs of deficiency. Superphosphate, monoammonium phosphate (MAP), diammonium phosphate (DAP), monopotassium phosphate (MKP) and rock phosphate are commonly used sources of P. Highly-soluble forms, such as ammonium and potassium phosphates, are usually applied on calcareous soils [6].

Tomato crops have a high potassium requirement – as this nutrient is an important determinant of yield – and K applications of 300 kg/ha of potassium are typical[1]. A nitrogen to potassium ratio in the range of 1:1.15-1.66 is also necessary for good fruit colour, taste and firmness. For a good quality crop, the K content of tomato leaves needs to be around 2.5-4.5% at the first flowering stage and 2.0-3.0% at early harvest[6]. Potassium applications vary with soil K levels, cultivar type and production system. Typical K application rates for a fresh-market tomato crop harvested more than three times are:

- 235-360 kg/ha K on light sandy soils that are very low (Mehlich-1 Index of < 20) or low in K (Mehlich-1 Index of 20-35)
- 60-90 kg/ha K is sufficient for good yields on loamy soils with medium levels of exchangeable K (Mehlich-1 Index of 36-60)

Table 6: **Tomato fertilizer recommendations for fertigation**

	Product (kg/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	CaO (kg/ha)	MgO (kg/ha)
Pre-planting base dressing		134	127	332	126	73
Fertigation						
Ammonium nitrate 34-0-0	374.4	123.6	-	-	-	-
MAP 12-61-0	139.3	16.7	85	-	-	-
Potassium nitrate 13-0-46	1,080.4	140.5	-	497	-	-
Calcium nitrate (26% CaO)	119.2	17.9	-	-	31	-
Magnesium sulphate (16% MgO)	112.5		-	-	-	-
Total	**1,826**	**311**	**85**	**497**	**31**	**18**

Source: Haifa

Table 7: **Pepper fertilizer recommendations for fertigation**

	Product (kg/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	CaO (kg/ha)	MgO (kg/ha)
Pre-planting base dressing		92	115	234	76	49
Fertigation						
Ammonium nitrate 34-0-0	247.7	81.7	-	-	-	-
MAP 12-61-0	126.2	15.5	77	-	-	-
Potassium nitrate 13-0-46	760.9	98.9	-	350	-	-
Calcium nitrate (26% CaO)	73.1	11	-	-	19	-
Magnesium sulphate (16% MgO)	75	-	-	-	-	12
Total	**1,283**	**215**	**77**	**350**	**19**	**12**

Source: Haifa

Suitable sources of K for tomato crops include potassium nitrate, SOP (potassium sulphate) and MOP (potassium chloride). Good results can be obtained with all of these although MOP needs to be used cautiously due to its high salt index[6].

In tomato leaves, a calcium content of 0.8-2.0%, a magnesium content of 0.35-0.60% and a sulphur content of 0.3-0.8% are adequate for a good tomato crop.

Calcium is applied on acid soils (pH <5.6) to ensure normal plant growth and good fruit quality. Applying calcium carbonate on sandy soils at 1,300 kg/ha and on clay loams at 5,000 kg/ha before planting should ensure pH is neutral. Magnesium is applied to soils (35-50 kg/ha when the Mehlich-1 Index is <15) using sources such as dolomite, magnesium sulphate, magnesium carbonate or potassium magnesium sulphate. Tomato crops generally require a sulphur application of 34-45 kg/ha. Sulphur deficiency is relatively rare, however, as sufficient S is usually provided when sulphur-containing fertilizers are used as part of the nutrient programme.

Leaf tissue analysis is generally used to diagnose micronutrient deficiencies. These can occur in tomato plants grown on fine, sandy soils or when pH is high or low. The following application rates are advised for low micronutrient soils[6]:

- Boron, 2.0-2.5 kg/ha
- Copper, 2.0-2.5 kg/ha
- Iron, 5.0-6.0 kg/ha
- Manganese, 2.5-3.0 kg/ha
- Molybdenum, 0.02-0.025 kg/ha
- Zinc, 2.0-2.5 kg/ha

Boron has a significant effect on fruit ripening characteristics and is a key micronutrient, as is zinc. Foliar application of Cu, Fe, Mn and Zn can be used to correct micronutrient deficiencies during the growing season.

Fertilizer recommendations: pepper

Nutrient uptake is greatest in pepper crops during the first 60 days of growth and then peaks again after the first fruit is removed. Plants therefore require high N applications early in the growing season and additional applications during fruiting. Yield and nitrogen use efficiency are both improved by applying N under polyethylene mulches and using drip irrigation systems. Around 50-90% of the total nitrogen is also applied in nitrate form.

Table 8: **General cucumber fertilizer recommendation, based on soil analysis**

		Soil P level				Soil K level			
		Low	Med	High	V high	Low	Med	High	V high
Fertilizer timing	**N (kg/ha)**	**P_2O_5 (kg/ha)**				**K_2O (kg/ha)**			
Pre-planting broadcast	60	120	60	0	0	170	120	60	0
Band-place	30	60	60	60	30	60	60	60	60
Side-dress, when vines begin to run, or fertigate	30	0	0	0	0	0	0	0	0
Total recommended	**120-240**	**180**	**120**	**60**	**30**	**230**	**180**	**120**	**60**

Source: Haifa

In Israel, standard planting density is 30,000-35,000 plants/ha with average yields of 55-70 t/ha for open field cultivation and 90-110 t/ha for greenhouse-grown pepper crops. The growing practice in Israel is to apply 20-30 kg/ha of N, 27.5 kg/ha P_2O_5 and 48-50 kg/ha K_2O for every tonne of peppers harvested[3]. Nitrogen and potassium are also generally applied at a ratio of 1:1.5-2.0.

For both tomato and pepper fertigation, Haifa suggest a base dressing of ammonium nitrate, superphosphate, SOP, dolomite and magnesium sulphate prior to planting[2, 3]. Typical fertigation applications for tomato and pepper grown on a sandy loam for an expected yield of 65 t/ha are shown in Tables 6 and 7, respectively.

Fertilizer recommendations: cucumber

Typical fertilizer recommendations for cucumber are shown in Table 8. Base dressing prior to cucumber planting is advisable to ensure good development of seedlings and vegetation. Applications of around 50-70 kg/ha N, 10-120 kg/ha P_2O_5 and 10-170 K_2O are suggested, adjusted for soil type and soil test results. Base dressings are generally incorporated into greenhouse soils before planting after soil steaming and leaching[4]. Base dressings with a high proportion of potassium relative to magnesium are typically applied to ensure the K-to-Mg ratio of soils remains around 2:1.

Phosphate can be applied (1,700 kg/ha) to very low P soils well in advance of cucumber planting using triple superphosphate (TSP) or its equivalent. Alternatively, MAP can be incorporated within planting rows (25-30 cm depth) immediately before planting at the same rate (1,700 kg/ha). Calcium is applied on acid soils (pH <5.8) as agricultural lime (2,200 kg/ha) some 8-12 weeks before cucumber planting. Magnesium can be broadcast (170-220 kg/ha) in the form of magnesium sulphate if soils tests indicate low levels of Mg (<70 ppm).

Nitrogen is the most important element needed during cucumber plant growth and should be split into frequent applications. At least half of applied N should also be in nitrate form. In fertigation, N is supplied using soluble fertilizers such as potassium nitrate (13-0-46), calcium nitrate (15.5-0-0 + 26.5 CaO) or ammonium nitrate (33-0-0). In side-dressings, nitrogen is applied at 50 kg/ha in bands either side of the row when plants are rapidly vining. Additional dressings (35 kg/ha) are applied to fresh market cucumbers when these develop 2-4 leaves. Further side dressings are also recommended fortnightly from the onset of harvest. The following fertilizer options for cucumber are suggested by Haifa Group[4]:

- A 3:1 mixture of ammonium sulphate (21-0-0) and potassium nitrate (Haifa *Multi-K*, 13-0-46) at the rate of 220 kg/ha
- 1:1 mixture of urea (46-0-0) and potassium nitrate (Haifa *Multi-K*, 13-0-46) at a rate of 220 kg/ha
- NPK complex water soluble fertilizers (Haifa *Polyfeed*) for fertigation

For drip irrigation, a nitrogen base dressing (60 kg/ha) is recommended before planting. Nitrogen is then applied daily (0.6-1.1 kg/ha) or weekly (3.5-7 kg/ha) by the drip system over the growing season. Applications are reduced when plastic mulching is practiced. Nitrogen is broadcast (60 kg/ha) over the row before planting immediately prior to laying the plastic. A nitrogen side dressing (35 kg/ha) is then placed on either side of the plastic when vining starts[4].

Crop nutrition and product advice

A number of agronomic trials for tomato crops have demonstrated that greater fertilizer use, both as base dressings and water soluble fertilizers, can generate higher famer incomes, after deducting the extra costs involved. For a fresh market tomato crop grown by drip irrigation in an open field, switching to SQM's balanced nutritional programme, for example, raised farm income by an extra $4,700/ha. Every extra dollar invested in fertilizers generated over $5.10 dollars of extra income, a return on investment of more than 500%. The main benefits were:

- Higher yields
- Earlier harvest resulting in higher market prices
- Higher prices because of better colour, size and shape
- Better commercially-valuable traits such as more Brix and lycopene
- Less BER and reduced susceptibility to diseases such as *Verticillium*
- Increased stress resistance – no lost clusters during hot weather

Other fertigation trial results suggest it is possible to achieve similar or higher tomato crop quality by wholly or partly replacing potassium nitrate with SOP, such as Tessenderlo Group's chloride-free *SoluPotasse* product[5]. This provides tomato with both K and S in highly-soluble form and is an effective type of potash for fertigation after fruiting.

Haifa Group offers detailed crop nutrition recommendations for tomato, pepper and cucumber, and also markets the *Nutrigation* and *NutriNet* fertigation system and software[2, 3, 4]. The group's *Multi-K* (potassium nitrate), *Haifa MAP*, *Haifa Cal* (calcium nitrate), *Poly-Feed* (water soluble NPK and micronutrients), *Magnisal* (magnesium nitrate), *Haifa Bonus* (high-K foliar formulation), *Haifa SOP* and *Multicote Agri* (controlled release fertilizers, CRFs) products are suitable for greenhouse crops.

Yara International offers a comprehensive online crop nutrition guide for tomato[1]. Its tomato crop programme includes the use of soil-applied *YaraMila* (NPK compound) and *YaraLiva* (calcium nitrate) fertilizers and a number of micronutrient foliar fertilizers from its *YaraVita* range such as *Caltrac, Phoztrac, Mangazin, Kayphol* and *Stopit*. ICL Fertilizers also markets a range of fully-soluble greenhouse fertigation and foliar products for tomato and other greenhouse crops. Suitable speciality products include *PeaK* (mono potassium phosphate), *Mag-Phos* (0-55-19+7MgO), *NovaNPK* (water soluble NPKs and micronutrients), *NovaMAP* and *NutriVant* (foliar macro and micronutrients). ■

References

1. Yara, 2016. *Tomato*. Yara International. Available from: http://www.yara.us/agriculture/crops/tomato/ [Accessed 4 July 2016].
2. Haifa, 2016. *Nutritional recommendations for tomato in open-field, tunnels and greenhouse*. Haifa Group. Available from: http://www.haifa-group.com/files/Guides/tomato/Tomato.pdf [Accessed 4 July 2016].
3. Haifa, 2016. *Nutritional recommendations for pepper in open-field, tunnels and greenhouse*. Haifa Group. Available from: http://www.haifa-group.com/files/Guides/Pepper/Pepper.pdf [Accessed 4 July 2016].
4. Haifa, 2016. *Nutritional recommendations for cucumber in open-field, tunnels and greenhouse*. Haifa Group. Available from: http://www.haifa-group.com/files/Guides/Cucumber.pdf [Accessed 4 July 2016].
5. Tessenderlo, 2015. SoluPotasse: the preferred source of potassium for fertigated tomatoes. *Talking SOP fertilizers*, Autumn 2015. Tessenderlo Group.
6. Heuvelink, E., 2005. *Tomatoes*. Crop production science in horticulture: 13. CABI Publishing, UK

A demanding business

PHOTO: BANKSPHOTOS/ISTOCKPHOTO.COM

Left: Combine harvesting a soy bean field.

A sophisticated new approach to forecasting and understanding the main drivers of fertilizer demand is explained by **Oliver Hatfield** of Integer Research. This has revealed some unexpected and surprising underlying drivers of demand for primary nutrients. Predicting future demand also looks like it will become an increasingly complex task in the future.

The demand fundamentals of the fertilizer industry are robust, and demand for the primary nutrients has grown fairly steadily for decades. Demand also tends to be more stable than supply. The industry is cyclical but in general the main contribution to the ups and downs emanates from the supply side, tracking periods of over and under-investment which are very typical of commodity markets where adding new capacity takes years. It often feels like demand is having a strong market influence, but this is frequently exaggerated by the effect of stock build and withdrawal, a component of which will be speculators looking to gain from rising or falling prices.

How to confidently predict demand

Figuring out what drives fertilizer demand is not as simple as it seems. Over the last few years, Integer has developed a unique body of research to better understand demand fundamentals. The traditional approach was simple statistical extrapolation, looking back at historic trends and assuming they will more or less continue. This is probably good enough in the short-term, but has significant limitations over the medium- to long-term, when compounding will significantly amplify any errors.

Integer's approach has involved working alongside expert independent agribusiness consultancy LMC to better understand the links between fertilizer application rates and crop market developments. LMC prepares short- to long-term forecasts on crop production, demand, trade and prices. Integer then matches up historic fertilizer demand data, reported by the International Fertilizer Association (IFA) and other regional and national fertilizer associations, with LMC's crop numbers (type, area, yield). This allows us to generate fertilizer application rates by nutrient and by crop. The numbers arrived at enable us to run some insightful comparative analysis, understand better what has driven fertilizer demand historically, and more confidently predict fertilizer demand in the future.

Growing area and the changing crop mix

Using this approach, our analysis of the last 10-20 years reveals that the drivers of fertilizer demand are in many ways as expected, particularly at the macro and global level. Crop production has increased to feed a growing population, a significant proportion of whom are shifting toward more diverse and meat intensive diets. Crop yields have also needed to rise to deliver increased food production, with higher fertilizer applications being an important part of the yield increases achieved. Industrial demand for crops, for biofuels for example, has also been significant.

However, our research also reveals some other factors which were unexpectedly influential. It is commonly assumed that 'they don't make land any more', and that most of the growth in food production comes from increased crop yields instead. However, while harvested area has gradually declined in some countries, overall it has actually increased significantly. This is particularly true of countries like Brazil and Argentina, where 'frontier land' like the Brazilian Cerrado has been converted and made available for arable use. Also, in China and India, despite there being land availability constraints, harvested area has been increased through multi-cropping. So growth in harvested area has definitely been much more influential in driving-up crop production than commonly assumed. While yields have

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

Table 1: **A comparison of nitrogen use and corn production in the US and China, 2000-2010**

	Corn 2000	Corn 2010	Change 2000-2010
US			
Nitrogen application (million tonnes N)	4.8	5.4	+0.6
Crop production (million tonnes)	252	316	+64
China			
Nitrogen application (million tonnes N)	2.9	5.3	+2.4
Crop production (million tonnes)	106	178	+72

Source: Integer

grown, particularly for crops like maize in key countries such as the US, the overall yield growth trajectory was quite shallow.

A further misconception is that increased fertilizer demand can be explained simply by increased application rates to existing crops. However, analysis of recent historic data show that, alongside growth in area, fertilizer demand growth was in large part due to changes to the mix of crops in production. For example, there has been a significant increase in the production of fruits and vegetables. These have relatively high fertilizer application rates per unit of area and have displaced crops with lower application rates.

Stable, mature versus developing, dynamic markets

Geographically, fertilizer demand development can essentially be split between countries with relatively advanced and mature agriculture, like North America and the EU, and those with developing, less sophisticated, but often more dynamic agricultural sectors, like China, India and Brazil. In the mature countries, fertilizer demand has been relatively flat – in the case of Europe it has actually declined – with little change in crop area yet still rising crop yields. Countries in these regions have been able to achieve increased crop production by improving the efficiency of fertilizer application. This is one of the main themes we have to take account of when we look forwards, not only in developed countries but worldwide.

The mature country experience is in stark contrast to that of important countries like India and China which have targeted significant growth in crop production. Both countries have encouraged fertilizer use over a number of years through subsidy and boosting domestic supply to ensure affordable fertilizer prices to farmers. Yet they have paid relatively little attention to use efficiency, particularly for nitrogen. Consequently, application rates have quickly increased to a point where there is frequently major overuse resulting in environmental problems.

To illustrate this point, between 1990 and 2000, China increased nitrogen fertilizer consumption by around 10 million tonnes N, about two thirds of the global increase in that period. On the other hand, US nitrogen fertilizer consumption was relatively flat at around 11 million tonnes N, while in the EU, where there has been targeted efforts to boost use efficiency, nitrogen demand actually declined by around 1.5 million tonnes or nearly 15%. Chinese crop production increased substantially over that period, but the productivity of the additional nitrogen used was significantly lower than in the US and Europe. We can illustrate this by comparing developments at crop level (Table 1).

A contrast in corn

The US Midwest is the world's hub of corn and maize production. In the period between 2000 and 2010, US production of corn increased by around 64 million tonnes, due to a combination of increased area and yields, and we estimate that nitrogen applications to corn increased by around 600,000 tonnes N.

With Chinese consumers switching to more meat-intensive diets, corn demand has increased dramatically and the country has responded by targeting increased corn production. Over the same 2000-2010 period, corn production in China increased by around 72 million tonnes, or 20% more than the US increase. However, nitrogen applications to corn in China increased by 2.4 million tonnes, some four times more than the comparable US increase.

In 2010, China and the US were applying the same amount of nitrogen on corn, approximately 5 million tonnes N, but China had substantially lower crop productivity, generating only half of the US corn output. Each tonne of Chinese nitrogen produced around 37 tonnes of corn in 2000, but this had dropped to 34 tonnes by 2010. By contrast, each unit of nitrogen produced 59 tonnes of corn in the US in 2010.

What is clear from this comparison is that a significant part of the increase in nitrogen fertilizer demand has been associated with relatively inefficient application.

Phosphate demand and Brazil

There are also some interesting observations to make about phosphate and potash growth in recent times. The geography of phosphate demand growth is similar to that seen for nitrogen. Key countries in Asia and Latin America have accounted for the lion's share of the change in world demand, while demand in developed countries was generally flat or declining. World phosphate demand increased by 5-6 million tonnes between 2000 and 2010, with growth in China accounting for around 4 million tonnes P_2O_5, Brazil close to 1 million tonnes P_2O_5 and India around 2.5 million tonnes P_2O_5. It is interesting again to compare phosphate consumption between key countries at crop level.

In Brazil, more than half of the increase in phosphate fertilizer demand was associated with growth in area and increased applications to soyabeans. Brazil has of course rapidly become a key producer and exporter of soyabean and soymeal for feed use, and this in turn is associated with the rapid increase in global meat consumption. Brazil's soyabean production roughly doubled over ten years to close to 70 million tonnes in 2010. The US also increased soyabean production by around 15 million tonnes to 90 million tonnes over that period (Table 2), but we estimate that this was achieved with almost no change in phosphate applications to soyabeans.

Again, it's clear that there has been greater use efficiency of phosphate applications in the US, compared to Brazil, but the explanation is not quite the same as for nitrogen. In the US, the great majority of soyabeans are grown in the Midwest, where there is a long legacy of sophisti-

Table 2: **A comparison of phosphate use and soyabean production in the US and Brazil, 2000-2100**

	Soyabean 2000	Soyabean 2010	Change 2000-2010
US			
Phosphate application (million tonnes P_2O_5)	0.4	0.4	-
Crop production (million tonnes)	75	91	+16
Brazil			
Phosphate application (million tonnes P_2O_5)	0.6	1.1	+0.5
Crop production (million tonnes)	33	69	+36

Source: Integer

cated agricultural practices, and consistent and balanced applications of nutrients, including phosphate, and the soil nutrient content is generally high. Because phosphate is relatively immobile in the soil, fresh applications are added in the US simply to maintain or top-up residual levels. In Brazil, on the other hand, the conversion of frontier Cerrado land, which is relatively nutrient poor, was a major part of the increase in growing area. Significant build-up applications of phosphate and other nutrients were therefore necessary in Brazil to counter inherent low nutrient levels, along with liming to overcome high soil acidity.

Potash under-use

When looking back at demand growth for potash in the relatively recent past, there are notable differences compared to nitrogen. While nitrogen fertilizer demand grew fairly steadily over time, potash demand increased too but has been comparatively volatile. There is also little evidence of potash overuse. Indeed, the relatively narrow geographic concentration of potash demand points to significant under-use in many locations.

Whereas governments in populous countries frequently encourage nitrogen use through intervention and subsidy, this is much less the case for potash. Potash demand had been growing fairly steadily during the first half of the 2000s until the spike in potash prices in 2008. A significant contraction then followed at the end of the 2000s. This was due to the effects of the financial crisis, but also, to a significant degree, because consumers rationed their purchases in response to higher potash prices.

When we look at the most influential potash-consuming countries and crops, state intervention is generally lower and less likely to be supportive. A significant part of the global increase in potash demand took place in Brazil. Like phosphate, this was associated with new soyabean production, but it was also linked to increased production of sugar cane and corn. Intervention from the Brazilian government in agriculture is relatively minimal.

Potash demand in China also ramped up significantly. While potash applications to staple grains like rice increased, much of the growth was applied to fruits and vegetables which took a growing share of arable land, as Chinese diets became increasingly varied. In Indonesia and Malaysia, the key potash consuming crop is oil palm grown on commercial plantations, and this crop played a central role in driving up consumption in both countries.

Looking ahead

Understanding these recent drivers of demand is essential in order to better track future demand patterns. It is also clear that predicting fertilizer demand growth in the future is unlikely to be as simple as extrapolating from the past.

The medium- to long-term macro drivers of agriculture and crop production are likely to remain much the same, and are reasonably predictable. For example, we know that the global population will grow, from around 7.3 billion today to around 8.8 billion in 2035. Arable area will increase in some locations like sub-Saharan Africa and Latin America, but in other locations it will decline. Perhaps most importantly, arable area per capita will also decline substantially.

The global economy will continue to grow, with high-income economies growing at a slower rate than low- to medium-income economies. As a result, we will see rising demand for meat and more diverse diets continuing to drive crop demand. The productivity of land will, therefore, also need to continue to increase. This will require yield growth, for which GM and new technologies are likely to play a role. Increased usage of fertilizers will also be essential to support growth in food production. However, we believe that future drivers will be subtly different from those in the past, particularly at a nutrient level.

A sophisticated, complex future

Efficiency of use is likely to be an increasingly prominent theme as we look forwards, particularly for nitrogen but also for phosphate in some important countries. Nations like China are aware of, and increasingly willing to tackle, the issue of fertilizer overuse. Although the country has been the main engine of fertilizer demand growth for decades, China is now targeting zero growth in the use of fertilizers as soon as 2020.

More broadly, the fertilizer industry is raising awareness and educating farmers about '4R nutrient stewardship'. This approach seeks to boost crop production while improving soil health, and ensuring clean air and water. The 4R model is to use the right fertilizer, at the right rate, at the right time and with the right placement. So in future we can expect to see the required increase in crop production delivered with proportionally smaller increases in fertilizer use.

The 4R model will also require fertilizer applications that are more balanced. For this reason, we expect to see potash demand growing at a faster rate than for nitrogen, especially as appropriate use of potash actually increases nitrogen efficacy. More balanced applications do not just apply to primary nutrients. They will also be necessary to ensure that micronutrients are not a crop yield limiting factor.

All of this points toward a greater need to deliver nutrients in increasingly sophisticated fertilizer products. In some countries, where there is a preference for multi-nutrients to be delivered in compound form, formulas will become increasingly elaborate. Whereas, in other countries, greater demands will be placed on blending equipment instead.

This trend for increased sophistication and complexity will need to be mirrored by us, as market analysts, if we are to improve the accuracy of our fertilizer demand projections! ■

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July-August 2016

phosphates & potash INSIGHT

Simon Inglethorpe (left) presents this year's recipient Paul Smith (right) with the Pierre Becker Memorial Award.

Pierre Becker Memorial Award 2016

Paul Smith received the 2016 Pierre Becker Memorial Award on 23 June. His career was celebrated by friends and colleagues in a presentation ceremony at the International Fertiliser Society's Annual Technical Conference in Budapest.

"In recognition of your outstanding contribution to the understanding, exploitation and application of phosphate resources, the directors and staff of *Fertilizer International* magazine honour **Paul Smith**. Your long standing commitment to the practical application of phosphoric acid technology globally has justly earned you the lasting admiration of many colleagues and friends in the fertilizer world."

This is the citation on the 2016 Pierre Becker Memorial Award presented to Paul Smith in Budapest in June by Simon Inglethorpe, editor of *Fertilizer International*. Paul is a highly deserving recipient of this much-valued, long-established award. Over a long and distinguished career, Paul has been an influential figure in the huge expansion of the phosphates industry that has taken place in the last 40 years.

The untimely death of Pierre Becker in 2001 was widely mourned by the international fertilizer industry. This was not simply because Pierre was a renowned world authority on the phosphoric acid process and phosphate fertiliser production technology. In addition to these unique talents, he was also a person of deep humanity who inspired great affection, loyalty and friendship.

To perpetuate Pierre's memory, *Fertilizer International* launched the Pierre Becker Memorial Award in 2004 to celebrate originality and excellence in the phosphates sector. This year, the International Fertiliser Society (IFS) kindly hosted the presentation ceremony at their annual technical conference in Budapest on 23 June. This summer conference, held at the magnificent Hungarian Academy of Sciences building, was the perfect backdrop to present the 2016 Pierre Becker Memorial Award to Paul in person.

Pierre Becker Memorial Award winners

2016	Paul Smith, P Smith & Associates
2014	Theodore 'Tip' Fowler, JDCPhosphate
2012	G Michael 'Mike' Lloyd Jr, FIPR
2010	John Sinden, JSA
2008	Robert De Coster, Prayon
2006	Heinz Huyer, Intertrade Group
2005	Dr Milkha Aulakh, Punjab Agricultural University
2004	Dr Norman S H Chien, IFDC

Luc Maene, the former director general of IFA and current IFS vice president, knew Pierre Becker personally, and was kind enough to make some opening remarks explaining the history of the award and why Pierre was so widely admired.

Our congratulations to Paul Smith

Simon Inglethorpe, editor of *Fertilizer International*, paid tribute to Paul Smith and his career in the following short speech at the presentation ceremony on 23 June:

"Good afternoon, I'd like to thank Luc Maene for his kind introductory words about the Pierre Becker Memorial Award – and, most importantly, about Pierre Becker, both the man and engineer, and why he's so sadly missed.

The Pierre Becker Memorial Award dates back to 2004 when the inaugural award was made to Doctor Norman Chien of the IFDC. In the intervening years the award has been presented to eight individuals, including the 2016 recipient who we are announcing today.

The Pierre Becker Award is about celebrating originality and excellence in the field of phosphates. This year's award recognises an individual who hopefully will be familiar to many of you, by reputation alone if not personally.

His career in the industry spans more than 40 years. It's been a stellar career. One that is impossible to do justice to in a few short minutes. So I'll just pick out several highlights.

His 15-year long stint at Prayon in Belgium in the 1980s and 1990s, firstly as Sales Manager and then as Director of Licensing, illustrates both the success this individual has enjoyed and his major contribution to the phosphates sector. During a time of great expansion in the phosphates industry, he was responsible for the sale of acid technology in Brazil, Indonesia, South Korea and Morocco.

Later as a consultant, he has travelled the globe, working extensively on major phosphoric acid projects in India, Venezuela, Florida, South Africa, Canada and finally Brazil – where he currently lives and works. It's difficult to pick out a particular highlight. But his participation in the team which selected the phosphoric acid technology for Ma'aden's massive Waad Al-Shamaal project in Saudi Arabia gives you a flavour of his high standing and respect within the industry.

Finally, this individual has a personal link to Pierre Becker, having written the section on the non-dihydrate process for Pierre's landmark book on Phosphates & Phosphoric Acid.

Ladies and gentleman, with great pleasure, on behalf of Fertilizer International, I announce that the 2016 Pierre Becker Memorial Award goes to Paul Smith of consultancy P Smith & Associates." ■

BCInsight would like to thank the International Fertilizer Society, particularly Luc Maene, Antoine Hoxha and Steve Hallam, for hosting this year's awards ceremony and the society's kind help in its organisation.

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Innovators feeding a growing market

Belgium's EcoPhos is a growing force in the European feed phosphates market with production sites spread across three EU member states. We profile the company and its innovative production technology as it opens a centre of excellence in Bulgaria and gears up to enter the fast-growing Asian feed phosphate market.

Table 1: **EcoPhos: reference plant list***

	Aliphos Bulgaria	UCCI	Phospac25/ Quimpac	Namfos
Location	Varna, Bulgaria	Homs, Syria	Lima, Peru	Luderitz, Namibia
Start-up	2008	2010	2014	2014
Capacity	DCP/MCP: 60,000 t/a	DCP: 60,000 t/a	DCP: 60,000 t/a Phos acid: 25,000 t/a (P_2O_5) technical grade	Demonstration plant: 350 kg/hr
Modules	Two production lines From rock: ● Module 1A, rock digestion ● Module 1B, DCP precipitation From phos acid: ● MCP/DCP, phosphoric acid, $CaCO_3$	● Module 1A, rock digestion ● Module 1B, DCP ● Module 4, HCl regeneration	● Module 1A, rock digestion ● Module 1B, DCP ● Module 3, phos acid production	● Module 1A, rock digestion ● Module 1B, DCP ● Module 3, phos acid production ● Module 4, HCl regeneration
Technology provider	EcoPhos	EcoPhos	EcoPhos	EcoPhos
Designer	EcoPhos / Worley Parsons	SNC-Lavalin	Temco = EcoPhos Industrial Services	Temco = EcoPhos Industrial Services
Raw material(s)	● Algerian low grade phosphate rock ● Phos acid (Agropolichym, OCP)	Syrian low grade phosphate rock	Bayovar low grade phosphate rock	Namibian marine rock
Yield	90-95%	90-95%	93%	95%

**Excludes the Aliphos Rotterdam plant purchased in 2013 and the TechnoPhos demonstration plant in Varna, Bulgaria, opening in September.* *Source: EcoPhos*

TechnoPhos, the technology demonstration centre for the EcoPhos customers.

Innovative phosphates producer EcoPhos S.A. was founded in 1996 by Mohammed Takhim. During the last 20 years, from fairly modest beginnings, this relatively young Belgium-based company has grown into a €150 million turnover business employing over 250 people. Impressively, EcoPhos now has two production plants in operation (Table 1) and two under construction, ambitiously, a further five plants are at the design/construction phase currently. What is unique about these plants – which range from 60,000 to 660,000 t/a capacity – is their ability to consume low-grade sources of phosphate using exclusive, proprietary technology developed by EcoPhos.

Three brands, two business models

The company owns three distinct corporate entities: *EcoPhos* is the company's technology and project services arm, *Aliphos* is an animal feed phosphate producer and *TechnoPhos*, a relatively new venture, is a technology demonstration centre for the company's customers. The firm is truly European with sites spread across three EU member states.

EcoPhos, located in Louvain-la-Neuve in Belgium, serves as both the company's headquarters and its principal research and development centre. Aliphos owns two production plants and describes

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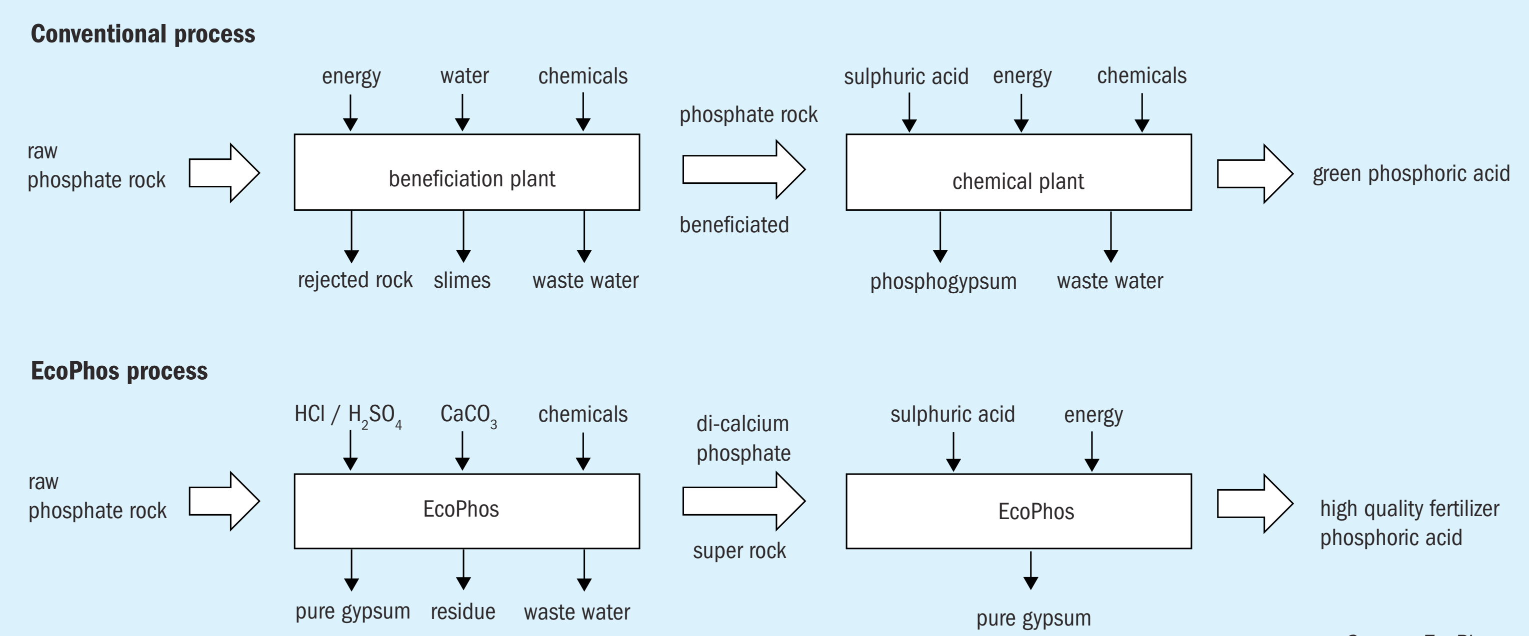
Fig 1: **The EcoPhos process versus a conventional production route**



Source: EcoPhos

itself as the European leader in animal feed phosphates. It acquired its largest production site, the 250,000 t/a capacity plant at Vlaardingen near the port of Rotterdam in the Netherlands, from Aliphos in 2013. The plant produces a range of products (DCP, MDCP, MCP, MAP and MGP) for the feed phosphates market. Unlike the Rotterdam plant, the smaller 60,000 t/a capacity *Aliphos Bulgaria* plant at Varna in Bulgaria is based on the EcoPhos process (Table 1) and produces DCP and MCP. The Varna plant is said to be one of the leading producer of animal feed phosphates in the Balkans. TechnoPhos, also located in Varna, Bulgaria, is a newly-created centre of excellence and research and development facility. Due to open this September, the site's semi-industrial scale demonstration plant will be used to show customers how EcoPhos technology and processes perform for their phosphate raw materials.

Over the last two decades, EcoPhos has continuously developed and expanded its intellectual property (IP) to the extent that it now owns 10 technology patents covering three specific industrial processes:

- The production of dicalcium phosphate (DCP) and or/phosphoric acid from a variety of phosphate sources, regardless of quality, including low-grade phosphate rock and secondary phosphates
- The purification of phosphoric acid to produce high quality technical grade, food grade, feed grade and electronic grade phosphates
- The efficient and economical production of speciality phosphates such as NPKs, MAP, DAP, SSP, NKP and TSP

EcoPhos operates using two separate business models and is able to offer customers two distinctly different sales packages. The company's standard package (BM1) provides projects with a technology licence and a basic engineering service. Its other more comprehensive package (BM2) combines the sale of a technology license with a full engineering, procurement and construction (EPC) contract delivered by the company's Belgium-based engineering subsidiary Temco. EcoPhos' expansion plans involve targeting two market areas in particular:

- Exploiting low grade phosphate rock resources and unlocking their value through the production of fertilizer products, animal feed and phosphoric acid
- Phosphorus recovery from sewage sludge ash

> **"The EcoPhos process does not require a beneficiation step and produces a saleable pure gypsum co-product.**

Super rock and pure gypsum

The innovative production technology developed by the company is based on a modular, two-stage process (Figure 1). This process initially produces *Super rock* (dicalcium phosphate, DCP, $CaHPO_4$) from calcium carbonate, phosphate rock and hydrochloric acid. *Super rock*, after further treatment with sulphuric acid, is then converted into high-quality phosphoric acid suitable for NPK, SSP and TSP production. Advantageously, and unlike conventional phosphates production, the EcoPhos process does not require a beneficiation step to upgrade phosphate rock. It also produces a saleable pure gypsum co-product instead of phosphogypsum waste. The fertilizers produced are also low in cadmium and comply with the new EU fertilizer regulation. EcoPhos technology is based on four modular units (see box) which can be combined to produce DCP, fertilizer-grade phosphoric acid and high-purity phosphoric acid for the food, feed, pharmaceutical and electronic markets.

Turning wastes into resources

Another key advantage of the EcoPhos process is its flexibility and "extremely high tolerance" for impurities. The ability to accept low-grade phosphate sources as a feedstock has the potential to drastically reduce productions costs, as Mohamed Takhim, the founder and CEO of EcoPhos explains: "In the first place, cheaper raw materials are used, and raw materials account for 80% of primary costs. In addition, our system is simpler. We use the rock in the condition it was mined, treat it with acid and crystallise it." The EcoPhos process is also less wasteful and the feed phosphate produced is more

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 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

readily taken-up by animals, adds Takhim: "the bioavailability with di-hydrate DCP is greater and the eco-footprint much lower."

Because it can consume rejected beneficiation plant tailings and slimes, EcoPhos technology can also be incorporated into existing phosphate fertilizer plants, boosting phosphoric acid plant capacity, lowering energy and sulphuric acid consumption and reducing the amounts of phosphogypsum produced. For a phosphoric acid plant, switching from conventional phosphate rock [$(Ca_3(PO_4)_2]$ to Super rock [$CaHPO_4$] feedstock offers the following production benefits:

- A reduction in sulphuric acid consumption of at least 30%
- An increase in production capacity of at least 30%
- A reduction of phosphogypsum waste of at least 30% by producing pure gypsum instead

Having a process technology capable of directly accepting either unprocessed phosphate rock or beneficiation wastes, says EcoPhos, offers a number of clear competitive advantages, compared to conventional phosphate fertilizer production:

- **Increased rock reserves:** no beneficiation, no rejected phosphate rock/slimes
- **Reduced production costs:** no beneficiation, lower beneficiation losses
- **Fewer environmental impacts:** lower water and energy consumption, no beneficiation wastes, pure gypsum co-product
- **Consumption of waste HCl:** from SOP, TDI and chloralkali plants

To illustrate these advantages, EcoPhos has calculated the inputs and outputs for its innovative process versus those of the conventional phosphate process under a typical production scenario (Table 2).

A growing presence

2014 was an important milestone year for EcoPhos – both in terms of its continuing expansion into the European feed phosphates market and its plans to gain a foothold in the Asian market. A joint venture with India's Gujarat Narmada Valley Fertilizers & Chemicals Ltd (GNFC) and the construction of a new €75 million Aliphos plant in Dunkirk, France, were both announced towards the end of that year.

The new French plant will be the highest capacity facility built by EcoPhos to date, being expected to produce up to 220,000 t/a of DCP di-hydrate when it is commissioned early next year. The new plant will expand the company's total European

EcoPhos: flexible, modular technology

In the patented *EcoPhos* process, four process modules are firstly used to produce dicalcium phosphate (DCP) and/or phosphoric acid. A final purification process is then used to convert fertilizer-grade phosphoric acid into technical/food grade phosphoric acid.

DCP and/or phosphoric acid production

Low-grade phosphate rock or secondary phosphate is digested with dilute hydrochloric acid that selectively dissolves P_2O_5. The resulting slurry (Module 1A, Figure 2) is firstly treated to remove dissolved impurities such as fluoride and cadmium. Other impurities present as a solid residue are then removed by liquid/solid separation.

In the next stage (Module 1B, Figure 2), the liquid phase from rock digestion is treated with calcium carbonate to crystallise dicalcium phosphate (DCP). A second liquid/solid separation is then used to separate DCP from calcium chloride solution and dissolved impurities. In the third stage (Module 3, Figure 2), solid DCP is digested in sulphuric acid, producing 'fertilizer grade' phosphoric acid (42% P_2O_5) and pure gypsum. An optional stage (Module 4, Figure 2) can be used to generate hydrochloric acid for rock digestion if an external source is unavailable. This involves treating calcium chloride solution recycled from Module 1B with sulphuric acid to produce dilute hydrochloric acid and a very pure gypsum co-product.

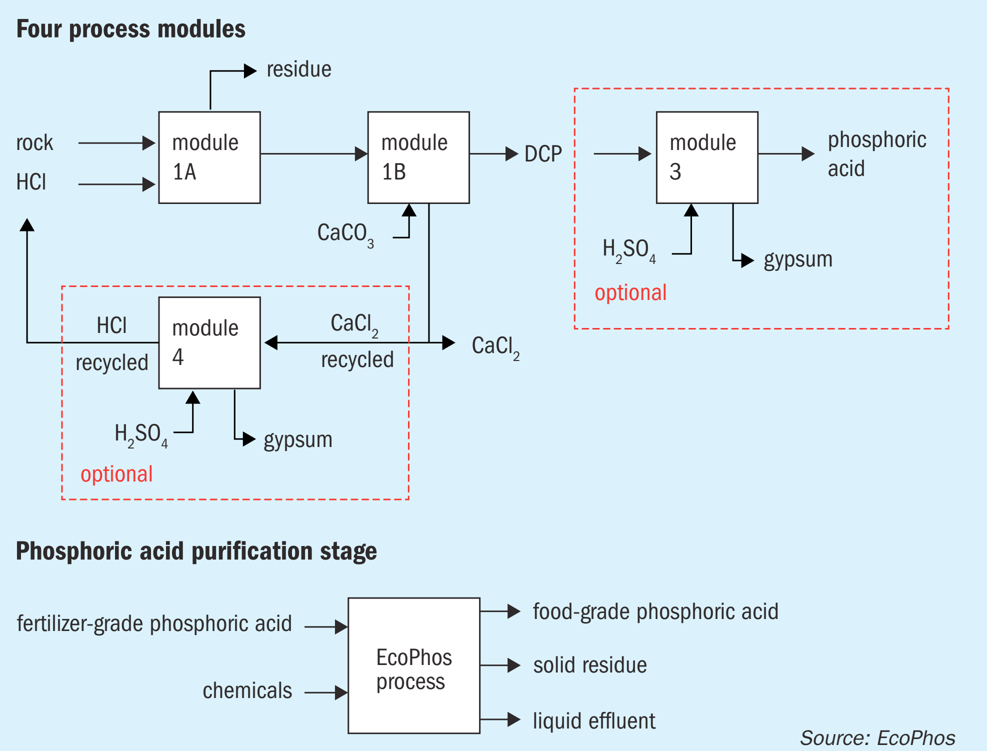
Phosphoric acid purification

Modules 1A, 1B and 3 produce technical grade phosphoric acid of good enough quality for fertilizer production. But an extra polishing stage is necessary for production of higher quality food grade or electronic grade phosphoric acid (Figure 2). This involves a purification step for cation removal followed by an evaporation step to increase phosphoric acid concentration to 62% P_2O_5.

Speciality phosphate production

The *EcoPhos* process is also an "efficient and economical" manufacturing route for a variety of speciality fertilizers. The company broadened its technological capabilities in May by securing the supply of specially designed press and vacuum filters for EcoPhos plants as part of a strategic cooperation agreement with Andritz Separation. ■

Fig 2: **EcoPhos process modules (top) and phosphoric acid purification stage (bottom)**



Source: EcoPhos

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INTERVIEW

Yannick Vancoppenolle, business development and marketing manager at EcoPhos spoke to *Fertilizer International* about the company's future ambitions in an exclusive interview.

Cost savings

The Ecophos process is based on low-grade rock phosphate and hydrochloric acid whereas the conventional process needs high-grade rock and sulphuric acid. On top of that, although the EcoPhos process generates roughly the same amount of residue as the conventional process, it's split into three different products, two of which – pure gypsum and calcium chloride – are valuable.

Definitely, across the whole of production, EcoPhos is cheaper. Beneficiation losses and phosphogypsum waste require intensive waste management and make conventional production more costly. When you know that the phosphate rock represents 70-80% of the production cost, to have the option to work with alternative sources of phosphate brings to Ecophos technology a huge advantage in terms of cost of production (20 to 40% lower).

For the EcoPhos process, technically, there's no lower limit on phosphate content – we can work with a phosphate rock or raw material with a 5% P_2O_5 content, for example. In practice, the phosphate content that is economically acceptable is linked to logistical costs, transport distances and capex.

Scalable, modular technology

We have three basic design capacities – 60,000, 110,000 and 220,000 tonnes. At the moment, when customers request more capacity we simply duplicate the lines. So our 660,000 tonne capacity DCP fertilizer project for EuroChem Karatau in Kazakhstan has three parallel 220,000 tonne production lines. It's a flexible, modular approach, not only in capacity but also in terms of product. With relatively small equipment changes, we can change the recipe of the process and switch lines between feed phosphate and fertilizer production – and we don't need to build a completely new plant to do that. In response to requests for bigger capacity, EcoPhos is offering tailor-made designs to meet these demands.

Targeting the feed phosphates market

Our strategy for Europe's feed phosphates market has three objectives. Firstly, to restore Aliphos to its position as the European market leader with a production capacity of 0.5 million tonnes. Presently, we have around 310,000 tonnes of capacity from our Rotterdam and Bulgarian plants. So the project under construction in Dunkirk, France, by adding over 220,000 tonnes, should take back our market share. Secondly, we want a large European plant operating with our own technology, something we don't have currently. Thirdly, the DCP di-hydrate produced by our Dunkirk plant is highly unusual in Europe – and will provide us with a major competitive advantage because it is a more effective and biodigestible type of feed phosphate.

Globally, our target is to reach one million tonnes of production capacity by 2020. Hopefully, we will shortly reach 800,000 tonnes capacity, with 530,000 tonnes coming from Europe, 220,000 from Gujarat, India with the GNFC joint venture plus 60,000 from the Evergrow project in Egypt. We are currently working very hard to secure the 'missing' 200,000 tonnes we need to hit this target.

Healthy project pipeline

The next two years should see EcoPhos complete four projects. Construction is in progress at our Dunkirk plant. Vertical erection began at the end of July and we plan to start operating in September 2017. The planned start-up for our project with Evergrow in Egypt is in the middle of 2018. Basic engineering is coming to an end and we have already started purchasing equipment. We are also busy completing the process design package (PDP) and basic engineering for the Gujarat plant, and working to an end of 2018 start date for that project. Our France II project – the second production line at Dunkirk for incinerated sewage sludge ash – also has an end of 2018 start-up date. Phase two construction at Dunkirk should begin around the end of 2017 when the phase one work is finished. We have finished extended basic engineering work for EuroChem in Kazakhstan. An outside engineering contractor will execute this project for EuroChem and carry out the detailed engineering.

Looking further ahead, we are in deep discussions about potential projects in Africa and the Middle East and expect to make an announcement on this in the coming months. Also, to reach our one million tonne capacity target for feed phosphates, we are studying options for a plant in either Brazil or the United States.

Future direction and innovation

We hope to announce some new technological innovations at the end of this year – and it could be a very big one for the fertilizer industry. Protecting our intellectual property (IP) is a difficulty, particularly when we licence our technology to third parties. Selling our technology as a 'black box' turn key production plant has now become our preferred business model, as it helps prevent our proprietary equipment being copied.

And last but not least, the grand opening of our new €9 million TechnoPhos technology centre in Bulgaria will take place on 8-9 September. This is a one-tonne-per-hour capacity, semi-industrial scale facility which gives our customers the option of testing EcoPhos technology and modules with their own raw materials. ■

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Table 2: Typical production input and outputs for the EcoPhos process versus a conventional phosphate production route*

EcoPhos process	
Inputs	**Outputs**
4.8 tonnes phosphate rock	1 tonne P_2O_5
4.0 tonnes sulphuric acid	7 tonnes pure gypsum
1.7 tonnes calcium carbonate	1.4 tonnes residue
0.6 tonnes steam	
Conventional route (beneficiation and wet phosphoric acid)	
Inputs	**Outputs**
18 tonnes phosphate rock	1 tonne P_2O_5
3 tonnes sulphuric acid	15 tonnes beneficiation losses
2 tonnes steam	5.2 tonnes phosphogypsum

**In both cases, this assumes the production of 54% phosphoric acid from 23% P_2O_5 phosphate rock*

Source: EcoPhos

production to half a million tonnes per annum, equivalent to roughly half the size of the continent's feed phosphates market.

Valuably, the 220,000 t/a capacity Gujarat DCP plant will provide EcoPhos with a presence in the Asian feed phosphate market when it enters production in 2018. This market is expected to grow at around 4-5% per annum, driven in part by demography and increasing dairy products demand. "EcoPhos' target is to reach a production capacity of one million t/a within the next 5-10 years," comments Yannick Vancoppenolle, business development and marketing manager at EcoPhos. "Increasing our presence in Asia and India will get us closer to that goal."

Being a player in Europe's emerging secondary phosphate and phosphorus recycling industry also remains a priority. In March 2015, for example, EcoPhos signed a contract with energy and waste treatment company HVC and SNB to recycle phosphorus from fly ash produced by two sewage sludge incineration plants in Dordrecht and Moerdijk in the Netherlands. EcoPhos also plans to construct a 30,000 t/a feed phosphate production line – also designed to use incinerated sewage sludge fly ash – as part of the second phase of its Dunkirk Aliphos project.

The new Dunkirk plant is a key part of the company's European expansion strategy. "The acquisition of Aliphos by EcoPhos in 2013 included only the production site in Rotterdam but not the one in Ham [in Belgium]," explains Vancoppenolle. "That means we had to rapidly find a new site that would compensate for a lack of production of about 300,000 t/a. The difference is that this new capacity will be based on EcoPhos technology, giving us a significant cost advantage in regard to our competitors." The Dunkirk plant's construction was financed by a €62 million loan and €15 million credit facility agreed with three Belgian banks last December.

EcoPhos is single-mindedly pursuing the ambition of its CEO Mohamed Takhim to become "the global market and cost leader in animal feed phosphates". The company is aiming to increase its production capacity outside of Europe by 300,000 t/a or more. As well as building more plants, EcoPhos remains equally committed to becoming a major technology provider/licensor for the fertilizer and food industries.

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The Sheraton Sand Key Resort, Clearwater, Florida.

40th Annual Clearwater Convention

This year's 40th AIChE Annual Clearwater Convention was held at its usual venue, the Sheraton Sand Key Resort, on Florida's Gulf coast on 10-11 June.

For four decades now, industry engineers have gathered at Florida's idyllic Clearwater Beach for the AIChE's two-day annual convention on sulphuric acid and phosphoric acid technology. The convention, which runs on a Friday and Saturday, is renowned for its relaxed atmosphere and ability to combine business with friendship, food and family. An impressive 370 international and US delegates attended the 2016 convention.

Rick Davis of Davis & Associates and Crystal Alonso of The Mosaic Company opened proceedings by chairing the longstanding **sulphuric acid workshop** on Friday afternoon. The theme of this year's workshop was advances in process control. This workshop aimed to cover the collection and interpretation of process data and the very latest in analyser technology.

"What we try to do with these workshops is have an open forum to talk about one aspect of the sulphuric acid process, hit it from different points and hope it all comes together," explained Davis. "Today we're going to be talking about advances in process control. I believe one of the areas that have made the most significant changes is the control systems for the sulphuric acid process."

Digitalisation: the Holy Grail?

Digitalisation is about using digital technology to generate new revenue streams, create opportunities to add value and transform business models, a definition that Outotec's **Hannes Storch** described as "all or nothing".

Storch was positive but pragmatic in his assessment of the potential for digitalisation at sulphuric acid plants: "Digitalisation is some sort of Holy Grail right now in the industry, one which never fails. But I can tell you, from my experience, it can fail. Although everybody's quite positive about it, if you don't do it the right way, analogue systems sometimes have an advantage."

Digitalisation has two main areas of application at sulphuric acid plants: static or dynamic process simulators and expert systems. In practice, digitalisation can mean the adoption of distributed control systems (DCS), acid-specific instrumentation and enhanced process controls.

One example of an expert system is the Plant Operability, Reliability and Safety System (PORS) used in heat recovery systems such as Outotec's HEROS technology. This "black box solution", by incorporating operational data and process know-how, improves awareness of key operational trends. PORS can be used in acid coolers to check pH trends and calculate heat and mass (acid and water) balances, for example.

Storch summed up the case for digitalisation: "Plants are getting more complex. Plant equipment can fail and certainly does fail. Sometimes you have operators without sufficient experience, or sufficient documentation at the plant to gain that experience. Here, there is certainly an advantage to using digitalisation, in whatever form. Digitalisation can support operational maintenance. But no system can make up for good operating and maintenance practice, that's for sure."

On the prospects for fully-automated sulphuric acid plants, Storch concluded that "there are many hurdles to be overcome, be it on instruments, be it on plant layout, but digitalisation can certainly support operations".

Building on things we know about

Brian Lamb of MECS elaborated on one particularly valuable example of digitalisation in the sulphuric acid industry – dynamic process simulation. The MECS operator training simulator (OTS) was an example of an innovation that "builds on things we already know", said Lamb. This was because OTS combines three existing technologies – the sulphuric acid process, the PC platform and DuPont's *TMODS* dynamic simulator software.

A key strength of the OTS is its ability to create a virtual plant environment that "works and feels" like a sulphuric acid plant. Training using this type of simulator is also very rapid with one operator commenting "we can do 10 years of experience in eight hours". Lamb emphasised how valuable skilled operators are for the industry, particularly the importance of equipping them with "the right skills to prevent emergencies". OTS is able to meet this need, said Lamb: "It solves the training paradox by simulating emergencies so that when operators see that event in the future they're ready for it."

"By combining sulphuric acid process know-how with existing PC hardware and the dynamic simulation software that DuPont invented back in 1988," summed-up Lamb. "We've combined these tools in

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A view of downtown Tampa, Florida.

PHOTO: FIGHTINGRAVEN531

an interesting way to make operator training simulators that marry dynamic simulation to real knowledge about the sulphuric acid process. By doing that we can help operators to train faster and help sulphuric acid plants run better."

Early moisture leak detection

Breen Energy Solutions originally developed its *AbSensor* measurement device in 2005 as an ammonium bisulphate detector in the energy sector. The dew point-based device can, however, also be applied to sulphuric acid measurement. The company was bought by US company HBM Holdings last year. "In 2016, our goal is to expand our international coverage and start working with sulphuric acid manufacturing facilities with our technology," commented Breen's **Chetan Chotani**.

He explained more about the AbSensor and its applications: "It offers in-situ, real time measurement of condensable dew point. We can measure sulphuric acid in coal-fired power plants anywhere from 1-100 ppm roughly. We were then asked to make extremely low-level sulphuric acid measurements in combined cycle gas turbine applications, we're talking about 0.001 ppm measurements, and we were successful in those measurements as well."

The company has developed a new *AbSensor-ADM-SA* design for sulphuric acid plants. This completely sealed unit can measure acid dew point "pretty much across the entire range", according to Chotani. The sensor is able to withstand 20 psi, resist high H_2SO_4 concentrations and operate over a 32-800 fahrenheit temperature range. Chotani listed its potential sulphuric acid plant applications: "In reality, sulphuric acid dew point measurement is essentially about early moisture leak detection. Various failure points exist in the sulphuric acid plants where moisture can come into the process. The moisture can come from drying tower malfunctions, waste heat boiler tube leaks, cleaning system malfunctions, and other things potentially."

Measuring H_2SO_4 at high concentration

Current sensor technology for detecting sulphuric acid concentration is typically based on measurement of conductivity, density or refractive index. But all three approaches have limitations at the upper H_2SO_4 concentration range, as **Sebastian Vreemann** of German-based SensoTech explained.

Sonic velocity based measurement, in contrast, is sensitive between 80-100% H_2SO_4, as sound speed changes dramatically over this concentration range. SensoTech has developed an immersion sensor using a piezoelectric transmitter and receiver to measure sonic velocity at frequencies >1 Mhz. Sonic velocity measurements are extremely accurate at high H_2SO_4 concentrations compared to conventional technology, according to Vreemann, with a typical accuracy of +/- 0.05 wt.% H_2SO_4 being typical.

Sonic velocity sensors provide in-line measurement, do not drift, are insensitive to colour or transparency, are easy to mount, virtually maintenance-free as they have no moving parts, are corrosion resistant, able to withstand both vibration and pressure shocks, and can operate over a -90-200 centigrade range. Absorption towers in sulphuric acid plants generally make an ideal site for these types of sensors.

Ultrasound vs refractive index measurement

Another German company, Berlin-headquartered Flexim, offers two types of H_2SO_4 sensor technology: *PIOX R*, a refractive index based detector, and *PIOX S*, a non-intrusive ultrasound device. **Brian Reynolds** explained how the two types of sensor complemented one another and their distinct sulphuric acid industry applications.

PIOX S, a clamp-on process analyser, uses two transducers to measure average speed of sound within a pipe and exploits differences in the sonic velocity of water and H_2SO_4. As with SensoTech's technology, Flexim's *PIOX S* device is suitable for sulphuric acid measurement at concentrations above 80%. More than 20 *PIOX S* sensors have been installed at a major Central Florida phosphate fertilizer plant for concentration monitoring and hot acid mass flow measurement. *PIOX S* is also well-suited to heat recovery systems and ultrapure sulphuric acid measurement.

Flexim's *PIOX R* device measures the refractive index of sulphuric acid and is suitable for H_2SO_4 mass flow metering over a concentration range of 0-85%. "No one else has it" commented Reynolds, as its design is based on patented transmitted light technology. The device is pre-programmed and calibrated, can be mounted on a flange and has the advantage that it doesn't drift with fouling or scale build-up.

The big data challenge

The sulphuric acid industry is already gathering a lot of data, pointed out **Chris Davis** of Ion247, as its process sensors are digital and monitored. The industry's problem is not the data itself, in his view, but what to do with it and how to turn it into actionable information.

In future, it should be possible to share data across the industry, submit data anonymously to bigger databases, and eventually make strategic decisions based on real time, historical and outside sources of data. However, a number of hurdles and industry knowledge gaps are preventing this currently, such as data integration costs and question marks over compliance with cyber security guidelines. The development of open standards is another unresolved issue. Enabling systems to pull data from sources such sulphuric acid plants also requires a type of standard interface called an application programming interface (API). The sharing, exchanging and understanding of data also requires the adoption of data standards.

There are clear rewards for businesses in accessing big data, though, suggested Davis. Those enterprises able to turn big data into actionable information in future will save money, by reducing waste and improving efficiency, and have a competitive advantage in his view.

An industry data standards committee is being formed to hep meet the big data challenge. Having the ability to talk to systems and gather information was the next priority. "We need to look at documenting what is a standard API," urged Davis. Better IT help and more advice on identifying suitable control systems was also necessary. "What that means is discussing with your vendors what control systems would be best to start with. And, of course, reaching out to IT application specialists to connect these systems together – IT should be your friend," concluded Davis.

Innovation breakthrough

The convention's lively and well-attended **phosphoric acid session** on Saturday morning featured the following eight presentations.

It is nearly 100 years since phosphoric acid production by the kiln route was first patented in the US by Guernsey and Yee in 1922. Clearwater convention delegates were therefore heartened to learn that Florida's JDCPhosphate, Inc is edging ever closer to achieving one of the industry's long-held ambitions – the commercial realisation of the kiln phosphoric acid (KPA) process.

James Trainham revealed that JDCPhosphate has made five key production innovations and breakthroughs this year, as it seeks to bring its technology, the improved hard process (IHP), to market. The company has managed to "finish the puzzle" by solving a number of process problems in recent months. Key breakthroughs include:

- A high silica/calcium ratio in the feed to avoid melting
- A high silica content in the feed to lower the temperature of the phosphate reduction reaction
- Adoption of a ported rotary kiln to improve yields and production rates
- Introduction of a low oxygen reducing burner to heat the rotary kiln
- Process refinements to produce low-dust feed agglomerates and remove impurities prior to phosphate reduction

As a consequence, the latest runs at JDCPhosphate's Central Florida demonstration plant have achieved dust-free operation, successfully removed impurities during heat treatment and produced 6,000 gallons of 20% P_2O_5-grade phosphoric acid at a maximum yield of 72%. Trainham is confident that the company has now demonstrated at a multi-tonne scale most of the key technological innovations required for full-scale commercialisation of IHP.

Controlling and reducing scale

The reaction between phosphate rock and sulphuric acid inevitably produces suspended and dissolved solids. As a consequence, the build-up of scale in phosphoric acid plants – and how to control and reduce this – has been a major problem for the industry for decades, particularly in evaporators. **Paul Wiatr** of Nalco explained how inhibiting scale formation can deliver clear benefits for phosphoric acid plant operators. Reducing the extent of scaling allows heat exchange capacity to be maintained for longer and extends production time, leading to less frequent cleaning shutdowns. Furthermore, cleaning can be made easier by altering the chemistry of the scale.

Several trials in Asia last year successfully demonstrated how to control the build-up of scale on evaporators at a plant concentrating phosphoric acid from 28% to 54%. Each trial lasted about a month. Measures to inhibit scale formation and manipulate scale chemistry were tailored to the type of scale produced at the plant.

Phosphogypsum: a co-product, not hazardous waste

Phosphogypsum is generated in large amounts by phosphoric acid production, with roughly five tonnes generated for every tonne of P_2O_5 produced. Nearly half the world's phosphogypsum – 1.4 billion short tons of it – is piled high in gigantic waste stacks in Florida. Yet, as consultant **John Wing** reminded delegates, very little of this material is used commercially in the US, and none at all in Central Florida, following a ban on its use by the EPA in 1989. Managing phosphogypsum stacks is also a major industry expense and cost burden, equivalent to around \$125/t P_2O_5.

All of this might be about to change, however. In a highly positive presentation, Wing outlined how phosphogypsum is finding increasing use as co-product outside of the US. About a quarter of phosphogypsum produced worldwide is being utilised currently – as a building material, in roadbed construction, for soil conditioning and as a calcium sulphate fertilizer. Most of Brazil's phosphogypsum is used in agriculture applications, for example. In China, Wengfu uses two-thirds of its phosphogypsum for construction and agricultural purposes. Impressively, all of the phosphogypsum produced in Indonesia is consumed as either a cement retardant or reacted to make ammonium sulphate and lime.

One spur to increasing global utilisation was the change to International Atomic Energy Agency (IAEE) classification in 2013. This resulted in phosphogypsum being classed as a co-product rather than as hazardous waste. China's 'Green Mine' policy also promotes phosphogypsum use, as does the EU's waste hierarchy policy.

> "Selling phosphogypsum as a co-product could enable the industry to reap tens of billions in profits.

The phosphate industry spends billions of dollars annually managing waste stacks. By selling phosphogypsum as a co-product, this situation could be turned around, enabling the industry to reap tens of billions in profits instead, concluded Wing. A comprehensive report on the many uses of phosphogypsum by the Phosphogypsum Working Group – due to be published by the International Fertilizer Industry Association in mid-2016 – is keenly awaited.

Balancing investment and performance

Wet di-hydrate phosphoric acid production requires the effective mixing of phosphate rock and sulphuric acid in a reactor. Proper agitation within the reactor is the key to optimising the process. This is because unequal mixing, by causing hyper-saturated zones to form within the reactor, can lead to poor filtration rates and low yields. Poor mixing In a reactor, explained **James Byrd** of Jacobs, can also affect recirculation ratio, one of the primary drivers in reactor control.

Agitators represent a significant investment cost. That makes size-selection particularly important, especially as over-design can result in needless extra cost. Over-agitated reactors will have a higher Capex and Opex than is necessary. Under-agitated reactors, in contrast, offer less sulphate control, which over the course of a year can affect both recovery and total production. Striking a balance between Capex/Opex and performance is therefore critical.

Byrd recommended computational fluid dynamics (CFD) as a tool to help reactor engineers find the right balance between agitator design and investment. Jacobs' annular reactor CFD model, for example, is a useful optimisation tool as it can reveal how small investments yield large benefits. It also allows existing plants to be evaluated for optimum performance.

Channelling cooling pond water

Phosphoric acid production inevitably generates large volumes of pond water. PotashCorp recently began rebuilding a 365-metre cooling pond recovery trench and sump system at its Aurora phosphate complex in North Carolina. The trench forms part of an extensive system of channels and pits which collect and recycle cooling water from evaporators in phosphoric acid plants. Some of the site's existing trenches and sumps were relined, and additional trenches built, to expand capacity, improve reliability and provide better maintenance access.

Installation of the trench liner at the Aurora site is an on-going project which began in 2014 and will continue into next year. After considering a range of alloy, thermoplastic and polymer systems, *Acroline*, an anchored polypropylene material, was selected as a protective concrete liner for the project. *Acroline* technology was first developed in Europe but has been in use in the US for about 20 years. **Gary Hopkins** of Corrosion Engineering explained how *Acroline* was prefabricated and installed as part of the trench upgrade at Aurora. He also described the quality control procedures used by the project.

Innovative beneficiation

The results of two P_2O_5 recovery trials were presented by **Curtis Griffin** of PegasusTSI. The first trial involved phosphate recovery from clay slimes by dissolution with dilute hydrochloric acid and precipitation as dicalcium phosphate (DCP). The trial was part of a collaboration between PegasusTSI and Belgian company EcoPhos. The DCP obtained was of animal feed quality and batch tests results confirmed that a P_2O_5 recovery of 76% was possible.

PegasusTSI joined forces with the Florida Industrial and Phosphate Research Institute (FIPR) to carry out the second trial. This used a Denver flotation cell with a fatty acid collector to recover phosphate from mine tailings (2.5% P_2O_5 content). This flotation method produced a 26.4% P_2O_5 grade concentrate from the tailings at a recovery of 82.1%.

Assuming a 10% loss from a one million tonne P_2O_5 production site, the ability to recover phosphate from both tailings and slimes could potentially deliver economic benefits worth $17.9 million/year, based on these initial results, according to Griffin.

Keeping plants stable

Cooling systems are needed to remove the heat generated from the exothermic reaction between sulphuric acid and phosphate rock and maintain a stable temperature. The design of a reactor cooling system is important as it regulates reactor temperature, a key parameter which in turn controls phosphogypsum crystallisation, filtration rates, cleaning cycles and P_2O_5 losses. **Eric Ramella** of Jacobs described the role cooling systems plays in plant stability, and how good design can enhances operational control, minimise maintenance and maximise profitability.

The trend for larger size reactors is leading to the use of cooling systems incorporating a vacuum cooler, a cooler pre-condenser, a cooler condenser and a cooler vacuum system. In designing effective cooling systems, Ramella stressed the importance of adapting to plant-specific and site-specific requirements, especially whether a plant was located on the coast or inland. Effective communication, respect for the owner's situation and "knowing your phosphate rock" were all critical in Ramella's view.

Advanced agitator design

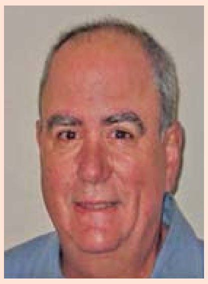
Agitators are used at various process stages in modern fertilizer production. This means they often play a key role in the successful and economic operation of entire plants, argued **Sebastian Abredadt** of Ekato Fluid Sales. He described some of the advanced types of agitators used in the phosphates industry, including the draft tube designs used in sulphur melters. Ekato's *Viscoprop* impeller design is suitable for blending in both sulphuric and phosphoric acid plants. The company's *Torusjet* agitator is currently used in draft tube baffle (DTB) crystallisers but could be adapted for other fertilizer industry applications in Abredadt's view.

The parallel **sulphuric acid session** on Saturday morning included the following eight presentations*:

- *Best practices utilizing FRP and elastomeric liners for steel and concrete tanks.* **Michael Yee**, RT Consults
- *Recent advances in sodium based sulphuric acid tail gas emission control.* **Leonard Friedman**, Acid Engineering & Consulting
- *Upgrading a sulphuric acid plant: project execution strategy and performance evaluation.* **Andrés Mahecha-Botero**, Noram
- *Understanding dynamics and emissions during sulphuric acid converter start-up.* **Per Sørensen**, Haldor Topsøe
- *Keys to successful internal gas-gas heat exchanger replacement, a case study.* **J. Huebsch**, MECS
- *Control systems migrations in phosphate plants: a road map for success.* **John O'Toole**, Hatch
- *Cost and performance benefits of dual laminate pipe over lined steel.* **Kira Townsend**, RPS Composites

*Only the presentation's lead author is listed. ■

2016 Engineer of the Year

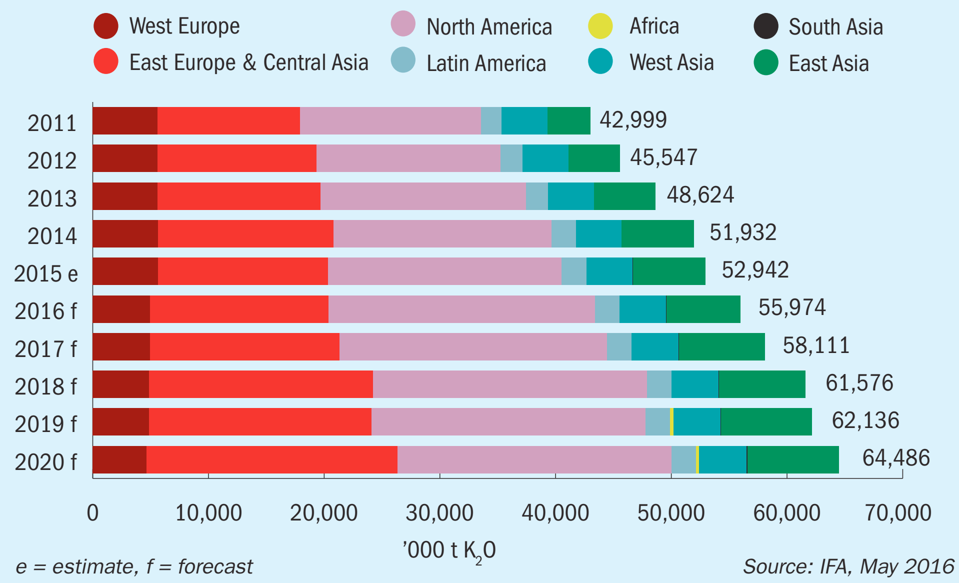


Rick Davis (left) of Davis & Associates was named this year's *Hero of the Industry* whilst **Lian Blackwelder** (below, left) of The Mosaic Company was announced as *Young Engineer of the Year*. The accolade *2016 Engineer of the Year* went to **James Byrd** (below, right) of Jacobs. Delegates will convene again in Florida for the 41st Annual Clearwater Convention on 9-10 June next year.

Potash growth shifts east

Large-scale additions to potash supply in Canada, Russia and Belarus between now and 2020 will create massive regional surpluses in North America and the Former Soviet Union. Much of this extra potash supply will be exported to meet growing demand in East Asia, Latin America and South Asia. The East Asian region, and China in particular, is facing a growing supply deficit and is likely to remain the world's largest potash import market over the medium-term.

Fig 1: **World potash capacity by region,** 2011-2020



e = estimate, f = forecast *Source: IFA, May 2016*

Table 1: **World potash capacity by region: 2011-2015 growth versus projected growth 2015-2020**

Region	2011	2015 e	Change 2011-2015	2020 f	Change 2015-2020
			Potash capacity ('000 tonnes K_2O)		
Western Europe	5,590	5,630	40	4,640	-990
East Europe & Central Asia	12,310	14,700	**2,390**	21,690	**6,990**
North America	15,660	20,180	**4,520**	23,655	**3,475**
Latin America	1,760	2,125	365	2,125	0
Africa				300	300
West Asia	3,960	3,995	35	4,080	85
South Asia		65	65	65	0
East Asia	3,719	6,247	**2,528**	7,931	**1,684**
World	42,999	52,942	9,943	64,486	11,544

Note: capacity and supply figures are not equivalent. IFA defines supply as (potential) maximum achievable production, as derived by multiplying capacity with the highest achievable operating rate.

e = estimate, f = forecast *Source: IFA, May 2016*

Recently released potash industry figures and forecasts suggest a surprising switch around in regional trends. Particularly interesting was the contrast between where growth in world potash capacity has largely come from in the last four years – principally North America – compared to where it will mainly come from between now and 2020 (Figure 1). Regionally, it will be expansions in the Former Soviet Union (FSU) which are likely to drive global potash capacity growth in the medium-term, as investment in a raft of large-scale greenfield and brownfield projects comes to fruition.

Although North America will remain the dominant regional producer of potash, the capacity gap with the FSU is set to shrink fast, falling from 5.5 million tonnes currently to just 2.0 million tonnes K_2O by 2020. At the same time, the FSU's share of global potash capacity is forecast to rise to a third over the next five years. Collectively, North America's potash producers can take some comfort from the fact that expected growth in FSU production capacity will not be quite enough to eclipse their current world-leading status.

Global capacity outlook: three regional players

World potash capacity has grown strongly over the last four years, increasing by almost a quarter from 43.0 million tonnes in 2011 to 52.9 million tonnes K_2O last year (Table 1). Three regions – North America, East Europe & Central Asia and East Asia – accounted for 95% of the 9.9 million tonnes K_2O expansion in global capacity over this period.

1 47 2 48 3 49 4 50 5 51 6 52 7 53 8 54 9 55 10 56 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

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
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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

It has been North America, particularly Canada, which has driven potash capacity growth since 2011, accounting for not quite a half (4.5 million tonnes K_2O) of global expansion, albeit supplemented by signification capacity additions in China (2.5 million tonnes K_2O in East Asia) and the FSU (2.4 million tonnes K_2O in East Europe and Central Asia) as well (Table 1).

Looking further ahead, it will be FSU countries such as Russia, Belarus, Uzbekistan and Turkmenistan where potash capacity will grow most strongly over the next five years. Global potash capacity is expected to rise by around a fifth (11.5 million tonnes) to 64.5 million tonnes K_2O between 2015 and 2020. FSU countries are forecast to contribute more than half (7.0 million tonnes K_2O) to global capacity expansion, whilst North America will contribute (3.5 million tonnes K_2O) over this period. Significant Chinese potash industry expansion (1.7 million tonnes K_2O in East Asia) is also expected by 2020. Western Europe's long-established potash industry, however, will continue its relative decline, with almost one million tonnes of capacity likely to be removed from production over the next five years (Table 1).

Fig 2: **Leading global potash producers,** 2015-2020 capacity changes

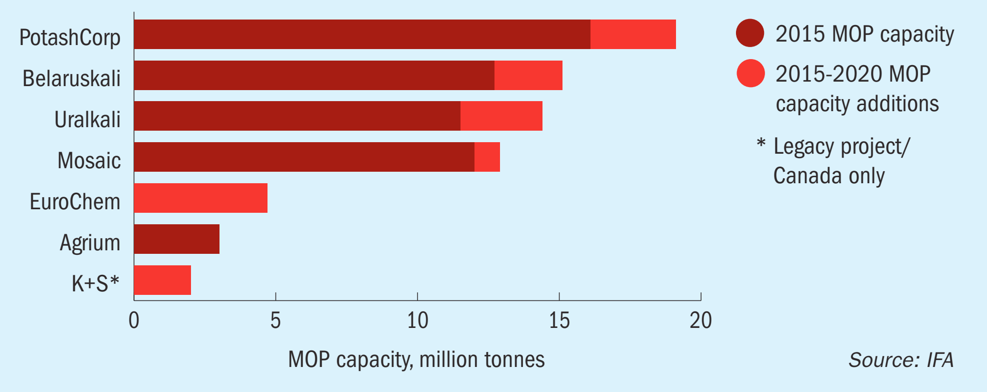

Table 2: **Selected major MOP capacity additions, excluding China,** 2015-2020

Company and project	Type	Date	MOP* capacity (million tonnes)
North America			
PotashCorp, Canada			
Rocanville	Brownfield	2017	3.0
Mosaic, Canada			
Esterhazy K3	Brownfield	2018	0.9
Agrium, Canada			
Vanscoy	Brownfield	2015	1.0
K+S, Canada			
Legacy	Greenfield	2017	2.0
Former Soviet Union			
Belaruskali, Belarus			
Soligorsk	Brownfield	2020	0.5
Petrikov	Greenfield	2019	1.5
Total (company wide)			**2.4**
Uralkali, Russia			
Solikamsk-2	Greenfield	2020	-
Ust Yayvinsky	Greenfield	2017	-
Berezniki	Brownfield	2020	-
Solikamsk-3	Brownfield	2020	-
Total			**2.9**
EuroChem, Russia			
Usolskiy	Greenfield	2017	2.3
VolgaKaliy	Greenfield	2018	2.3
Total			**4.7**
Garlyk, Turkmenistan	Greenfield	2017	1.4
UzKimyoSanoat, Uzbekistan			
Dehkanabad	Brownfield	2015	0.3

** Muriate of potash, KCl* *Source: IFA*

Major supply additions

Capacity expansions out to 2020 will come from a roughly equal split of brownfield and greenfield projects. An analysis of potash projects scheduled for completion by 2020[1] suggests the following breakdown for the 11.5 million tonne of capacity additions:

- 6 million tonnes K_2O from six greenfield projects in Russia, Canada, Turkmenistan and potentially Belarus and Ethiopia.
- 6.7 million tonnes K_2O from brownfield expansions and debottlenecking projects by potash majors in Canada, Russia, Belarus and China supplemented by smaller projects elsewhere. (This rises to 8 million tonnes K_2O if Agrium's 1.3 million tonne expansion at Vanscoy in late 2015 is factored in.)

These project additions will be slightly offset by a 1.2 million tonnes K_2O capacity contraction resulting from closures in Germany and the United States.

Leading potash producers – PotashCorp, Belaruskali, Uralkali, Mosaic and K+S – will all invest in new capacity over the next five years (Figure 2). EuroChem will also make a dramatic entrance into the potash market in two years time, on completion of its new Usolskiy and VolgaKaliy mines in Russia.

Canada consolidates

Canada remains the world's largest potash producing nation. The country's MOP (muriate of potash, KCl) capacity of around 30 million tonnes is largely split between PotashCorp (16.1 million tonnes), Mosaic (12.0 million tonnes) and Agrium (3.0 million tonnes). Yet only one major Canadian greenfield project – the CAN 4.1 billion K+S Legacy solution mine at Bethune, Saskatchewan – and two brownfield projects, PotashCorp's Rocanville expansion and Mosaic's Esterhazy K3 expansion, are likely to enter commercial production between now and 2020 (Table 2). These large-scale developments mean Canada's MOP capacity should increase by almost a quarter (7 million tonnes) to 37 million tonnes MOP over the next five years[1].

The operational capacity of PotashCorp, the world's largest potash producer, is expected to rise to 19.1 million tonnes MOP by 2020. The Rocanville expansion, which involves two new production shafts, a new processing plant and new warehousing, will double the mine's MOP capacity to 6 million tonnes by 2017. Potash Corp's Picadilly New Brunswick plant – upgraded from 0.8 to 2 million tonnes MOP capacity after a recent CAD 2.2 billon brownfield expansion – was shutdown for an indefinite period at the end of last year (*Fertilizer International*, 469 p8).

Mosaic's Canadian potash capacity will rise to 12.9 million tonnes MOP by 2018 on completion of the 1.5 billion Esterhazy expansion. Agrium's production capacity is expected to reach a ceiling of three million tonnes MOP over the medium-term, following commissioning of its one million tonne Vanscoy brownfield project late last year.

FSU surges

The total MOP capacity of East Europe and Central Asia stood at 24.5 million tonnes MOP in 2015, making it the world's second largest potash producing region. Regional capacity is largely in the hands of three established producers in three countries currently, namely Belaruskali (12.7 million tonnes) in Belarus, Uralkali (11.5 million tonnes) in Russia and UzKimyoSanoat (0.3 million tonnes) in Uzbekistan.

We reviewed the large-scale greenfield and brownfield investment currently underway in the FSU potash industry in detail at the end of last year (*Fertilizer International*, 469 p48). A surge of investment by incumbent potash producers and new entrants will see regional MOP capacity grow by a massive 11.7 million tonnes – a rise of almost 50% – to 36.2 million tonnes by 2020[1].

Belaruskali is the world's second largest potash producer. The Petrikov greenfield project and debottlenecking at Soligorsk is likely to see the company's MOP capacity increase by some 2.4 million tonnes to 15.1 million tonnes by 2020. In Russia, two EuroChem greenfield projects, namely the $2.9 billion Usolskiy and $4.6 billion VolgaKaliy mines, will add an additional 4.7 million tonnes to that country's MOP capacity in around two years time. Elsewhere in Russia, potash capacity at Uralkali, the world's fourth largest producer, is likely to expand by 2.9 million tonnes to 14.4 million tonnes by 2020 as part of its $4.5 billion development strategy. Additionally, UzKimyoSanoat's Dehkanabad expansion and the greenfield Garlyk project will bring on an extra 0.3 million tonnes and 1.4 million tonnes of MOP capacity in Uzbekistan and Turkmenistan, respectively.

China emerges

China has become an increasingly important potash supplier in recent years and is on course to more than double its potash capacity in under a decade (Figure 1). Since 2011, the country has emerged as the world's third largest producer and currently provides more than 10% of global capacity. Chinese production is more diverse than that of Canada and Russia, coming from a roster of around 30 producers, although two-thirds of output is concentrated in the hands of just three major companies.

China is also a significant producer of SOP (sulphate of potash, K_2SO_4) and SOPM (sulphate of potash magnesia). Of the country's 10.4 million tonnes of product capacity in 2015, MOP made up more than three-quarters (8.0 million tonnes), around a fifth of was dedicated to SOP (2.1 million tonnes) with the remainder (0.3 million tonnes) attributable to SOPM.

China's potash product capacity is set to rise by three million tonnes to 13.4 million tonnes by 2020, an increase of almost 30%[1]. Expansions planned by four firms in Qinghai Province – Qinghai Salt Lake Co, Zangge Potash, Mangya Kangtai and Wukuang Salt Lake – will see Chinese MOP capacity grow by nearly a quarter to 9.8 million tonnes by 2020. SOP capacity is due to ramp up even more dramatically. Projects announced by three producers, Bingdi and Jintai in Qinghai and Luobupo in Xinjiang, should result in SOP capacity increasing by almost 60% to 3.3 million tonnes by 2020. China's SOPM capacity, in contrast, is expected to remain static over the medium-term.

Regional mismatches in supply and demand

Between 2015 and 2020, the overall growth in global potash supply (17%) is expected to outstrip world potash demand (11%) over this period. Consequently, the global potash surplus will potentially rise from 9% of supply in 2016 to 15% of supply in 2020. Excess supply is, however, likely to contract initially, to 3.9 million tonnes K_2O in 2016, due to capacity shutdowns. It will then rise to 4.8 million tonnes K_2O in 2017, before accelerating to 8 million tonnes K_2O in 2020, as large-capacity projects enter production. Production from potash capacity installed up to 2020 will potentially be sufficient to meet global demand until 2027, assuming 2.4% annual demand growth.

In conclusion, the changing pattern of potash supply and demand out to 2020 is likely to have the following consequences for world trade and production[1]:

- **Supply:** Potential supply increases over the next five years will mainly take place in just three regions: North America, East Europe & Central Asia (EECA) and East Asia.
- **Exports:** The large-scale supply expansions expected in North America and EECA will be highly export-oriented, creating potentially massive regional surpluses.
- **The East Asian deficit:** Increases in Chinese potash capacity will be more than offset by East Asian demand growth, leaving the region with a growing potash supply deficit.
- **High demand growth:** Three regions will account for 75% of demand growth over the next five years, namely East Asia (+1.3 million tonnes K_2O), Latin America (+1.1 million tonnes K_2O) and South Asia (+0.7 million tonnes K_2O).
- **Trade:** East Asia will remain the largest importing potash region globally, a situation which will be fuelled by a growing deficit over the medium term.
- **Import prospects:** Between 2015-2020, increasing demand in South Asia and Latin America of 22% and 15%, respectively, will need to be met by significant annual imports. ■

Author's note

It is important to recognise that supply and capacity, although interrelated, are not equivalent (see Table 1 notes), as industry operating rates affect potash output. This can lead to large disparities between supply changes and capacity additions. The latest 2016-2020 supply outlook from the International Fertilizer Industry Association (IFA) suggests, for example, that North American supply will grow from 13.7-16.7 million tonnes K_2O – a three million tonne increase – whilst capacity will rise from 23.1-23.7 million tonnes K_2O, an increase of just 0.6 million tonnes.

References

1. Prud'homme, M., 2016. Fertilizers and Raw Materials Global Supply 2016-2020. *84th IFA Annual Conference*, Istanbul, 30 May – 1 June 2016.

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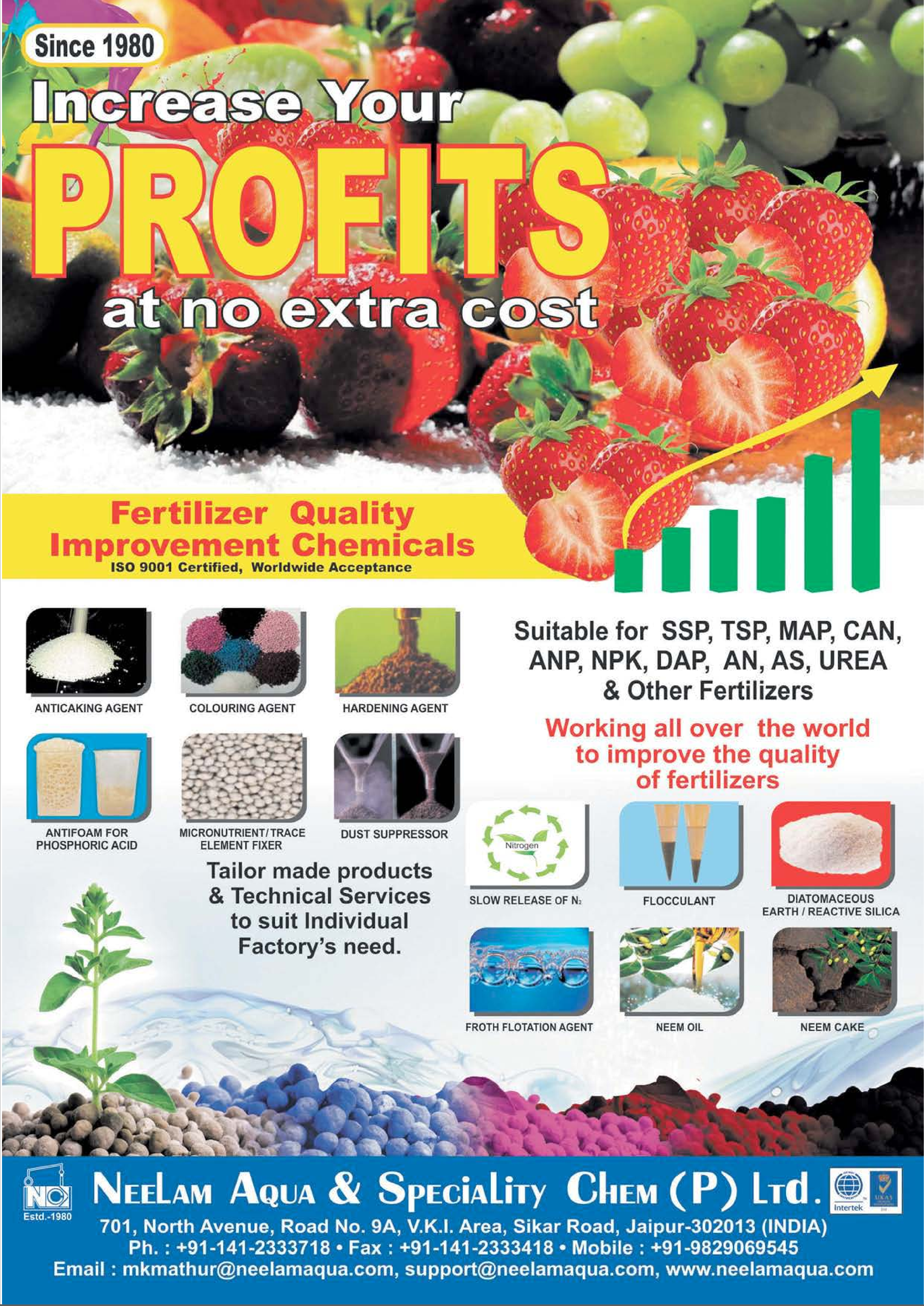
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