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Cover: *Sweet potatoes*
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REGULARS

Read this issue online at:
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Published by:
BCInsight

Soyami

Resurgent nationalism, protectionism and trade wars disfigured the 1930s. They were the prelude to slump, depression and conflict. That low dishonest decade saw the world and nation states slide inexorably into what the writer Piers Brendon memorably called “the dark valley”.

The 1930s have a spectral power that still haunts economists. Yet fears for the world economy – and the rules-based system of international cooperation that has been the guarantor of stability and prosperity for the last 70 years – have grown this year. And it’s not only economists who are worried.

In June, the International Fertilizer Association (IFA), in the aftermath of its 86th Annual Conference in Berlin, released a public summary of its latest fertilizer outlook.

For me, one headline in IFA’s outlook leapt off the page: “Financial uncertainty, trade tensions and political developments cloud the horizon,” the outlook warned.

“The escalation of trade friction could impact global economic coordination. Ongoing tensions for the global economy remain a key uncertainty,” advised IFA, adding: “The trade tensions and economic sanctions that have been emerging since the beginning of 2018 risk generating ripple effects on global fertilizer trade and future investments.”

In April, Abdolreza Abbassian, secretary of Agricultural Market Information System (AMIS), went much further. He warned: “If the US-China trade dispute extends to soybeans, it will hit international food markets like a tsunami, with first prices moving apart, then amplifying before a run-up stage threatening global food security.”

> **“If the US-China trade dispute extends to soybeans, it will hit international food markets like a tsunami, threatening global food security.”**

Amusingly, Abbassian went as far as to coin a phrase for this frightening phenomenon: #Soyami – yes, it even had its own twitter hashtag.

But such forebodings should not to be taken lightly. Abbassian is the FAO’s senior economist and AMIS has a roster of heavyweight international backers, including the FAO, World Bank, OECD and WTO.

Depressingly and inevitably, rhetoric finally turned into reality in the first week of July when Beijing imposed a 25 percent tariff on US soybeans, in retaliation for President Trump’s levies on Chinese-made goods. As a consequence, commodity markets at present are delicately balanced, caught somewhere between IFA’s ripple effect and the AMIS tsunami. The latest July issue of *AMIS Market Monitor* warns:

“In the past few weeks, trade tensions between the United States and China have introduced considerable uncertainty in global commodities markets. China’s announcement of retaliatory tariffs on imports of US soybeans triggered a plunge in world soybean and soymeal prices, with strong spillover effects across the oilcrops complex as well as most other agricultural commodities.”

Why is all of this important? Well, as AMIS explains, China currently accounts for two-thirds of the world’s soybean imports, with the US providing roughly 40 percent of the annual volume sent to China. Overall, about 25 percent of soybeans produced in the United States end up being consumed in China.

The economic consequences are potentially large. Soybeans account for 60 percent of the $20 billion generated by US agricultural exports to China. Before the tariffs were announced, the University of Tennessee forecast that the 25 percent duty would cause a $4.5 billion drop in American soybean shipments.

There could be potential upsides though. Brazil is the world’s top soybean exporter – exporting 48 million tonnes to China versus 37.5 million tonnes from the US. Brazil therefore looks well-placed to capitalise on China’s imposition of tariffs on the US.

And Brazil’s soybean growers, due to the country’s depleted soils, apply and consume 3-4 times as much potash and phosphate as US farmers. (Brazil’s NPK application rate to soybean is around 140 kg/ha versus 37 kg/ha in the US.) Also, if soybean demand from China were to rocket, Brazil has access to tens of millions of hectares of arable land, not planted or in pasture, that could enter production, adding further to fertilizer demand.

Perversely, the initial beneficiaries of the ‘soyami’, therefore, could well be US phosphate producers such as The Mosaic Company, also the owner of Brazil’s Mosaic Fertilizantes, and Canpotex, the North American potash export consortium.

But such a silver lining will be of little consolation to the fertilizer industry if Abdolreza Abbassian’s premonition proves prescient and world food security becomes imperilled. That’s a chilling prospect that risks engulfing the whole of global agriculture.

Simon Inglethorpe, Editor

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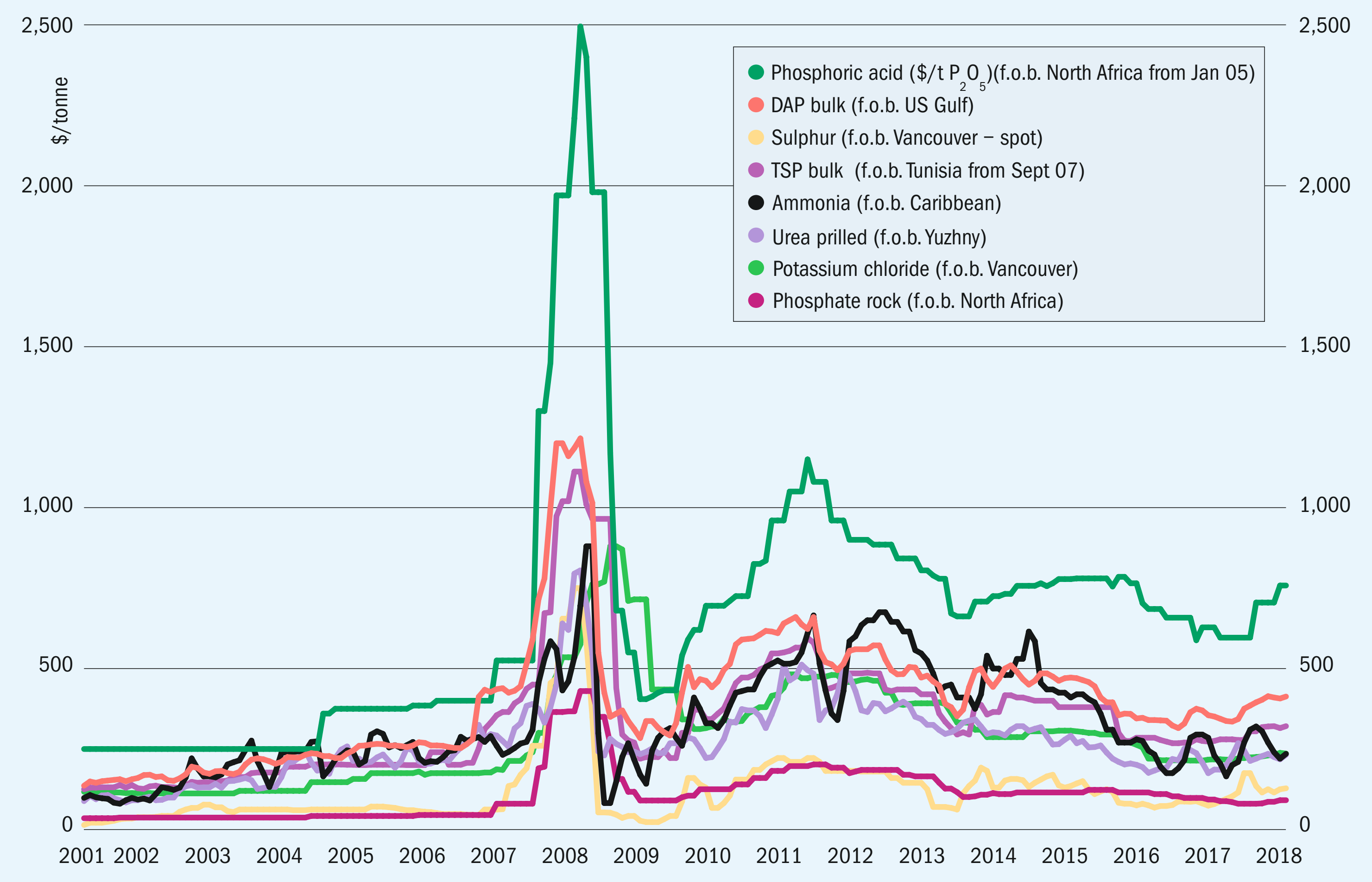
Historical price trends $/tonne



Source: BCInsight

Market insight courtesy of Integer Research

AMMONIA

Ammonia prices started to increase in May, after falling for most of the year. Ammonia's upwards price drift continued in June as urea moved above $250/t at most major f.o.b. markets. Ammonia still remains heavily discounted against urea, despite these price improvements. With gas prices dramatically increasing to $7.50/MMBtu in Europe, OCI found it cheaper to buy ammonia and upgrade it to nitrates rather than run Geleen's ammonia plant. This plant has been kept offline since scheduled maintenance was completed in mid-June. Achema in Lithuania also switched off one of its ammonia trains after suffering cash losses due to high gas prices.

UREA

Urea markets have been relatively buoyant since mid-May. Early Indian tenders and delayed European buying combined to limit second quarter MENA availability. Elsewhere, strong domestic urea pricing in China – above $300/t for most of the season – capped monthly export availability at 100,000 tonnes. In the US, strong end of season urea buying for rice unexpectedly tightened NOLA barge markets in June, while Brazilian pre-buying has kicked off ahead of the application season there. Gas prices are also rising in Europe, squeezing producer margins and adding to the positive pricing fundamentals. New capacity in Central Asia and Indonesia is due to enter commissioning over the summer – although we are not expecting this to place significant downward pressure on prices.

PHOSPHATE

Finished phosphates prices continued to hold in May and June with demand strong and supply relatively tight. Spot market availability is scarce with many producers committed months ahead. Firm ammonia prices have helped lift finished phosphate prices. DAP averaged $398-428/t f.o.b. at major benchmarks through May, compared with $398-418/t during March-April.

Indian buyers returned from the sidelines and imported around two million tonnes of DAP in May-June. Buying sentiment is also strong in Pakistan and Bangladesh, with the latter closing a tender for a one million tonne cargo of DAP, TSP and MAP in late May.

POTASH

Prices continue to rise in spot markets. The absence of major supply contracts in the year's first half has done little to curb MOP demand. Low stocks in India could mean it settles ahead of China, according to news circulating at IFA's Annual Conference. Price expectations are still wide-ranging, suggesting it could be some time before Chinese buyers and suppliers agree on a common price. BPC is heard to be targeting $292/t cfr, while Chinese buyers countered with a $242/t cfr offer.

A handful of unplanned supply outages in recent weeks has kept the potash market balanced. Nutrien reduced Canadian MOP output in the second quarter by laying off more than 600 workers at its highest cost Vanscoy and Allan mines. The production ramp-up at the K+S Bethune mine also appears to be slow with output stopping completely for four days in June. Manpower issues for K+S in Germany are also thought to have reduced Werra's output by 100,000 tonnes.

SULPHUR

Sulphur prices have been relatively stable so far this year, in contrast to the volatility at the end of 2017. The monthly average price of sulphur delivered to China fluctuated within \$135-150/t between January and May. While substantially lower than the +\$200/t peak at the end of 2017, first half prices this year have been at their highest since 2015.

Focussing on prices alone masks considerable underlying uncertainty. The market has been kept guessing about levels of demand from the big importers, China and Morocco, for example, while disruption has affected major supply sources like Russia. The perennial guessing game about new project timings and volumes has also added to the uncertainty. China imported 2.6 million tonnes in 2018's first quarter, down from 3.1 million tonnes over the same period in 2017 and 2016. On the other hand, export volumes from the Kashagan project in Kazakhstan have been below capacity, while Russian export shipments via Black Sea ports have been disrupted by a shortage of barges.

Market price summary \$/tonne – End-June 2018

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phosphoric Acid
f.o.b. Caribbean	245	n.m.	f.o.b. E. Europe 110-120	f.o.b. US Gulf	420	n.m.	n.m.
f.o.b. Yuzhny	245-250	245-253	-	f.o.b. N. Africa	420-440	335-340	655-860
f.o.b. Middle East	250-260	265-275**	-	cfr India	430-432	-	730*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	207-263	-	cfr US Gulf	95-105	f.o.b. Vancouver	125-130	
f.o.b. Middle East	206-252	-			f.o.b. Arab Gulf	130-138	
f.o.b. Western Europe	-	€420-440			cfr North Africa	110-132	
f.o.b. FSU	194-254				cfr India	150-155+	

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:** Scheduled plant shutdowns should keep the market balanced and price movements upwards. Russia's TogliattiAzot will have two plants down over July and August. OCI have stopped production at one Netherlands plant due to rising feedstock costs. Algeria's Fertial has cut ammonia exports by 10 percent. Nutrien Trinidad and Yara Pilbara in Australia are also both down for maintenance. However, the 660,000 t/a capacity PAU ammonia plant in Indonesia will give some relief to the market when it finally starts exporting. EuroChem is also scheduled to commission its Kingisepp plant in Russia in the fourth quarter. The extra output should keep the ammonia market oversupplied, although rising energy prices are likely provide a cost-push to ammonia values over the next 6-12 months.
- **Urea:** The expected end to the Chinese domestic season in mid-July should coincide with the emergence of significant Brazilian buying. There remain concerns around Brazilian consumption this year: urea consumption could fall by 2-3 percent due to increased soybean planting at the expense of corn. The market impact of Brazil's recent truck strike is also still unknown. Chinese monthly exports should move towards 250,000 tonnes, once the domestic season ends. Looking ahead, the greatest risk to urea prices in 2018 will be the imposition of Iranian sanctions by the US government later this year. If Iran cannot sell to India and Turkey from November, as it did under the last sanctions regime, prices will come under immense upwards pressure in the fourth quarter.
- **Phosphate:** The finished phosphates market is currently supported by strong demand fundamentals. India is likely to need another 2-3 million tonnes of DAP imports during the remainder of 2018, most of being met by Chinese and Saudi product. There should be better Saudi DAP availability in coming months as Ma'aden continues to ramp up production at Wa'ad al Shamal. This could keep a lid on prices if Ma'aden, as a low-cost producer, prioritises volume and market share over netbacks.

  Brazilian MAP demand is poised to take off as farmers start buying for the upcoming crop season. Although local currency weakness and truck strikes have kept Brazilian buyers on the sidelines, they will now need to act sooner rather than later.

  Sulphur and ammonia are both expected to firm over the summer on supply tightness in key regions. The resulting increase in raw material prices could result in a \$10-15/t increase in average DAP/MAP prices in the run up to August.
- **Potash:** The potash outlook will remain bullish for the remainder of 2018, if demand continues to be strong. We project the MOP market to stay balanced or moderately tight for most of this year and into next. The emergence of new potash supply will be offset by planned FSU curtailments. Russia's Uralkali is curtailing production by 290,000 tonnes as planned maintenance continues until August. Availability from Belarusian Potash Company (BPC) will also fall as Belaruskali begins three months of maintenance from July onwards.
- **Sulphur:** The sulphur market is likely to remain reasonably well balanced over the next few months. On the demand side, OCP recently started-up its latest finished phosphate plant. At full capacity, the latest unit will eventually add around 40,000 tonnes of sulphur per month to OCP's import demand.

  Reports suggest as much as 0.75 million tonnes of stock has accumulated inland in Russia this year. Sulphur export availability from Russia should improve, however, with the ending of seasonal bottlenecks.

Fertilizer Industry News

UNITED STATES

PHOTO: PURSELL

Pursell Agri-Tech launches innovative CRF plant

Pursell Agri-Tech officially opened an innovative new fertilizer coating plant in Sylacauga, Alabama, in June with its partner and shareholder Stamicarbon.

The low-cost, modular plant applies an innovative polymer coating to fertilizers using a proprietary coating process. The plant will produce the latest generation of low-cost controlled-release fertilizers (CRFs) and will target broad-acre crops, as well as other higher-value and speciality fertilizer markets.

Three products will be produced at Sylacauga: *Transcend*™ for broad-acre crops, *Transcend SA*™ for the speciality ag market, and *PurKote*™ for the golf, turf, landscape and ornamental segment.

This new, first-of-its-kind coating plant is designed to be placed close to agricultural end-markets to further minimise costs. Pursell Agri-Tech and Stamicarbon's ultimate ambition is to deliver significant improvement in nutrient-use efficiency – and limit the environmental impacts of fertilizer use – by producing affordable CRFs at scale in North America and other regions.

Stamicarbon will license this technology to fertilizer producers, traders, blenders and distributors globally outside of North America, under its partnership arrangement with Pursell Agri-Tech.

"We are proud to have Pursell Agri-Tech as our partner and want to congratulate them with the launch of their first controlled-release fertilizer plant. It is a wonderful feeling for a company to work alongside a strong partner sharing the same vision and values," said Pejman Djavdan, Stamicarbon's managing director.

"The Pursell name has been synonymous with innovation in the fertilizer industry," said Nick Adamchak, CEO of Pursell Agri-Tech. "We're proud of our history, but we're even more excited about what lies ahead. We're delighted to be part of a larger team – and a larger effort – that is focused and committed to developing and delivering new sustainable, yield-enhancing technologies that can have a significant, lasting impact on global food security and the environment." ■

Mosaic HQ to move

Mosaic is to move its corporate headquarters from Plymouth, Minnesota, to Hillsborough County, Florida, the company confirmed in mid-May

Mosaic's senior executives and corporate activities will transfer to Florida as part of the move, although the exact timing of the relocation, the site of the new headquarters, and the number of relocated employees have yet to be decided.

The move is expected to yield several benefits, including significant long-term cost savings. The new HQ will also be closer and provide better access to Mosaic Fertilizantes, the new Brazilian subsidiary created by Mosaic's recent purchase of Vale Fertilizantes. This has doubled Mosaic's workforce and significantly increased its presence in Brazil. The company also says that relocation to Central Florida will help it to become more engaged and work more closely with the communities in which Mosaic operates.

"Mosaic is among the largest employers and most significant corporate economic drivers in Central Florida," commented Joc O'Rourke, Mosaic's president and CEO. "With the cost savings we expect to achieve and the closer proximity to our Mosaic Fertilizantes business in Brazil, this move will drive improved efficiency and good value."

Mosaic is reviewing its US office locations as part of the move, including the Plymouth, Minnesota office and those at Fish Hawk and Highland Oaks in Florida.

"We will execute this move with as little disruption as possible and with sensitivity to our employees' personal situations," O'Rourke said. "Mosaic is fortunate to have a deeply talented workforce, and we fully intend to maintain that competitive advantage."

ITALY

Maire Tecnimont invests in U-Coat

Maire Tecnimont will invest in and own half of U-Coat (Urea Coating) S.p.A, a new company established to produce and market innovative biodegradable fertilizers.

U-Coat will manufacture 100 percent bio-based and biodegradable coatings for urea-based fertilizers. These will allow the controlled release of nutrients to crops without leaving any soil residues.

The investment agreement with the bioplastics company Bio-on was made through its Maire Green Chemicals subsidiary. Under the terms of the deal signed at the end of May, Bio-on and Maire Green Chemicals will each own 50 percent of the shares in U-Coat.

U-Coat will enable the two partners to commercial exploit and market PHA (polyhydroxyalkanoates), an innovative type of bioplastic developed by Bio-on. Maire Tecnimont will act globally as the turn-key contractor for production plants using PHA coating technology on an exclusive basis.

Pierroberto Folgiero, Maire Tecnimont Group's CEO, said: "With this agreement Maire Tecnimont strengthens its presence in green chemistry technologies. The Group leverages its leadership while confirming its role as a pioneer, anticipating the evolution of international environmental regulations."

Marco Astorri, Bio-on's president and CEO, said: "I am extremely proud to share this new and important market opportunity with Maire Tecnimont. Being able to develop new fertilizers for the agricultural world together allows us to build a more sustainable future, full of new bio products."

ERITREA

EuroChem signs take-or-pay potash contract

EuroChem has entered into a deal to buy all of the future sulphate of potash (SOP) output from an East African greenfield project.

EuroChem will have the rights to purchase up to 100 percent of the future SOP output of the Colluli potash project in Eritrea, under the terms of a take-or-pay agreement signed on 12 June. The contract is for 10 years initially with an option for a three-year extension.

The Colluli project is owned by the Colluli Mining Share Company (CMSC), a 50:50 joint venture between Australian mining junior Danakali Limited and the Eritrean National Mining Corporation (ENAMCO). The agreement with EuroChem is based on an annual SOP output of 472,000 tonnes, although it provides CMSC with an option to sell up to 13 percent of its output via alternative channels.

The deal is a vote of confidence in the Colluli project and should help secure its future. It is also something of a coup for Danakali's outgoing CEO Danny Goeman. The agreement will also benefit EuroChem by providing access to the output from a leading and economically-attractive SOP project, one that is favourably-positioned to supply fast-growing potash markets in the Asia-Pacific region.

SOP is a premium fertilizer widely-applied to fruit, vegetables and coffee and will add to EuroChem's premium product portfolio. The company's other premium products include *Nitrophoska*® complex fertilizers and the nitrogen-stabilised *ENTEC*® fertilizer range.

EuroChem may use some of the SOP from Colluli for NPK fertilizer production at its plants in Antwerp, Belgium, and Nevinnomyssk, Russia. The rest will be sold internationally.

The ability to market and sell SOP will complement EuroChem's recent emergence as a large-scale muriate of potash (MOP) producer. The company's Usolskiy and VolgaKaliy MOP projects in Russia are both entering production this year.

EuroChem's CEO, Dmitry Strezhnev, said: "We are excited about participating in this project with CMSC, as part of our growing global presence. Colluli is one of the closest SOP deposits to a coastline anywhere in the world."

Danakali's CEO, Danny Goeman, said: "We could not be happier with this result. EuroChem is an outstanding partner for the project. EuroChem has a wealth of experience and expertise in the fertiliser sector."

INDIA

TechnipFMC awarded two fertilizer plant contracts

TechnipFMC has won major engineering, procurement, construction and commissioning (EPCC) contracts for two state-of-the-art nitrogen fertilizer plants in Eastern India.

The two natural gas based plants are located at Barauni, Bihar state, and at Sindri, Jharkhand state, respectively. They will each have the capacity to produce 2,200 t/d ammonia and 3,850 t/d of urea.

The contracts were awarded by Hindustan Urvarak and Rasayan Limited (HURL) in late May. HURL is a joint venture between three Indian public sector companies, IOCL, NTPC and CIL.

TechnipFMC will deliver the contracts as part of a consortium with L&T Hydrocarbon Engineering (LTHE), a wholly-owned subsidiary of Larsen & Toubro. Both projects will be carried out concurrently. The TechnipFMC-led consortium will be responsible for project licensing, basic engineering, detailed engineering, construction and commissioning of the two plants, all within a 36-month period.

Nello Uccelletti, president of onshore/offshore business at TechnipFMC, said: "We are honoured to be entrusted [with] the execution of these prestigious projects in consortium with LTHE. The projects are of great national importance to India to address the demand for urea in the domestic market and thereby boost the economic growth of the country."

NIGERIA

IFC bankrolls Indorama expansion

Indorama Eleme Fertilizer & Chemicals Limited has secured $1 billion of finance for a new 1.4 million t/a capacity fertilizer production line. The expansion will effectively double urea production capacity at its Port Harcourt complex to more than 2.8 million tonnes annually.

The debt financing package was confirmed in June by the International Finance Corporation (IFC), part of World Bank Group.

IFC will directly lend Indorama $100 million and mobilise additional loans worth $850 million from other financial institutions and commercial banks. A further $50 million in financing will be provided by IFC's Managed Co-Lending Portfolio Program.

Among the lead lenders and arrangers of the finance package are: European Investment Bank, YES BANK, CDC Group PLC, African Development Bank, Bank of Baroda and Standard Bank. Providing additional finance are: Standard Chartered Bank, Bangkok Bank, FMO, DEG, PIDG company, the Emerging Africa Infrastructure Fund, PROPARCO, ICICI Bank Limited and Citibank.

The large number of participating banks is a strong endorsement of both the project and Indorama, as well as being a vote of confidence in the economy and governance of Nigeria, according to IFC.

Sérgio Pimenta, IFC vice president for Middle East and Africa said, "IFC aims to support Nigeria's efforts to strengthen its manufacturing base and improve stability of its financial system through greater foreign exchange earnings from exports. With Indorama Eleme, IFC is also a partner in helping farmers in West Africa increase their food production and incomes."

"Nigeria has become a major hub for urea exports. With Line 2, we aim to further expand our ability to provide competitively-priced and high-quality fertilizer to farmers in West Africa and across the globe," said Manish Mundra, CEO, Indorama Africa.

"This project will build upon the success of Line 1 in increasing the domestic supply of urea fertilizer in Nigeria, making it easily available and leading to cheaper prices for the Nigerian farmer," said Abdu Mukhtar, industrial and trade development director at the African Development Bank. "It will also help further address labour issues in the region by creating high paying technical jobs and will count towards climate change abatement by reducing amounts of flared gas."

Large volumes of natural gas are wasted in Nigeria due to gas flaring. Nigeria has flared 750 million cubic feet per day of associated gas over the past three years, according to the World Bank. Downstream use of this gas for basic chemicals and fertilizer production will reduce flaring, a significant contributor to greenhouse gas emissions and climate change.

UKRAINE

PhosAgro and EuroChem withdraw from Ukraine

PhosAgro and EuroChem have both announced they will cease trading fertilizers with Ukraine. Their withdrawal coincided with the introduction of new Ukrainian government sanctions against Russian producers which came into effect on 19 May.

The sanctions were formally announced by the National Security and Defense Council of Ukraine (NSDC) on 24 May. They apply to a number of major Russian producers such as Acron Dorogobuzh, EuroChem, PhosAgro, Uralchem and their subsidiaries. The sanctions were imposed for three years and include asset freezes, restrictions on business and prevent the withdrawal of funds from Ukraine. The sanctions do not apply, however, to Minudobreniya (Rossosh), one of Ukraine's major NPK suppliers.

EuroChem Group reacted ahead of the new sanctions by announcing its withdrawal from the Ukrainian fertilizer market on 16 May. The company has offloaded its Ukrainian subsidiary, although the terms of this sale have not been disclosed.

"Recent actions in Ukraine to restrict foreign suppliers of fertilizers, and expectations of a further deterioration of the business climate, prompted the Group's decision," EuroChem said in a statement.

The company withdraws from Ukraine after operating there for more than 15 years. Its Ukraine subsidiary supplied a network of more than 1,000 local customers, ranging from major agricultural wholesalers to retailers and private farms.

PhosAgro followed suit by announcing that it was stopping all product sales and shipments to Ukraine on 25 May. The company's CEO Andrey Guryev said: "The discriminatory measures taken by Ukraine will not have a meaningful negative impact… PhosAgro can quickly re-direct volumes originally bound for Ukraine to other countries and markets where the business climate is more welcoming, including to our domestic Russian market."

Guryev added: "It is our deep conviction that these measures will harm Ukrainian farmers first and foremost. Ukraine remains a net importer of a wide range of phosphate-based fertilizers and supplies from Russia have proven to be the most efficient way to meet demand from Ukraine's domestic agricultural producers."

Russian ammonia producers Rossosh, TogliattiAzot and KuibyshevAzot are not included on the latest sanctions list. Ukraine relies on these suppliers for ammonia used in downstream fertilizer manufacturing. Urea imports from major Russian producers are, however, expected to be cut by up to 400,000 t/a as a result of the fresh sanctions, according to analysts CRU.

The impact of the sanctions are expected to mainly fall on Ukraine's phosphate fertilizer consumption and its large and rapidly-growing NPK market. Ukraine imported 2.2 million tonnes of NPKs in 2017, some 1.7 million tonnes of this being Russian-supplied. Major Russian NPK supplier Rossosh should benefit from the exclusion of its competitors, as its name was notably absent from the new sanctions list. More than 85 percent of the Ukraine's 250,000 tonne import volume for monoammonium phosphate (MAP) also came from Russia in 2017, being supplied by companies such as PhosAgro. The country's MAP market is therefore also likely to experience a sanctions hit.

BRAZIL

Acron sets up subsidiary

Major Russian fertilizer producer Acron is establishing a Brazilian subsidiary company, Acron Brasil Ltda, in São Paulo. The move will strengthen Acron's access to Brazil and its ability to distribute in the country, one of the world's major and fastest-growing fertilizer import markets.

Setting up the subsidiary should allow Acron to: "Deeper penetrate the market, provide comprehensive service to customers in Brazil and promote sales of its own and third-party products," the company said in a statement.

Dmitry Khabrat, Acron Group's overseas vice president, said: "Latin America is the largest sales market for our products. Total mineral fertiliser sales to Latin American countries in 2017 alone exceeded 1.3 million tonnes. Brazil is the key outlet for ammonium nitrate and NPK produced by Acron. The Group has broad interests and long-standing reliable partners in this country. Opening a company in Brazil is another step towards a stronger position in this growing fertiliser market. We intend to pursue a strategy for increasing and diversifying sales to all key countries in Latin America"

Yara closes Cubatão deal

Yara International closed the deal to purchase Vale's Cubatão Fertilizantes complex in mid-May.

The acquisition was finally approved by Brazil's Administrative Council for Economic Defence (CADE) in early May, a decision that cleared the way for Yara to proceed and close the $255 million deal.

The Cubatão nitrogen and phosphate complex provides Yara with around 200,000 tonnes of ammonia, 500,000 tonnes of nitrates and 700,000 tonnes of phosphate fertilizer production capacity in Brazil. The complex employs some 1,015 permanent workers and 970 contract staff.

"This acquisition marks the start of an exciting new phase in Brazil for Yara as the acquisition brings nitrogen production assets into our growing portfolio in Brazil, strengthening and growing our integrated position within both industrial and fertilizer [markets]," said Svein Tore Holsether, Yara's president and CEO.

SOUTH AFRICA

Omnia buys Oro Agri

South Africa's Omnia Holdings Limited completed its acquisition of Oro Agri SEZC Limited at the end of April.

The purchase should help Omnia expand its sales and marketing capabilities in agricultural markets around the world. Oro Agri manufactures biopesticides and foliar nutrients for agricultural, greenhouse, nursery and turf applications, with sales in over 80 countries.

Omnia's agriculture division is already the market leader in plant nutrition products in South Africa and Southern Africa. It is also an international player in the biostimulants market with product sales in 28 countries.

"The Oro Agri purchase puts Omnia's agricultural business on an accelerated growth path. Their established global distribution network will provide additional channels for Omnia's products and… we see a great opportunity to take advantage of Oro Agri's experience in these global markets," commented Adriaan de Lange, Omnia Group's managing director.

Erroll Pullen, Oro Agri CEO, said: "The companies' operations complement each other. Omnia is particularly strong in Africa while Oro Agri has well established operations in the US, Brazil and Europe. We will also support each other in shared markets such as South America, Australia and South Africa."

Pullen added: "In addition, Omnia's products mesh very well with our existing product line globally and [our] product development efforts around the world. Being part of Omnia will not only strengthen our R&D capabilities but also allow us to immediately market a more complete product portfolio including plant nutrients. This is not only a great deal for both companies globally but also for our distributor and grower customers around the world."

INDONESIA

AMUREA II plant commissioned

Petrokimia Gresik's new AMUREA II ammonia-urea unit entered commissioning in May.

Prilled urea production tests began in the middle of May with commercial operations expected to commence from July. The second unit's urea capacity of 569,000 t/a will increase total annual urea capacity at the complex to one million tonnes from next year.

PT Gresik signed a two-year contract with four gas operators to supply the plant with 63 MMscfd of gas from March 2018 onwards. This could result in lower operating rates, however, as the plant's gas requirements are estimated to be closer to 80 MMscfd.

The unit will target its urea output at farmers in East Java, suggest analysts CRU, where the market demand is thought to be around 1.2 million t/a.

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People

Gregory Ebel is the new chairman of The Mosaic Company. His appointment was announced at the company's annual shareholders meeting on 10 May. He succeeds **Robert Lumpkins** who has served as Mosaic's chairman since the company's inception in 2004. Mr Ebel has served on Mosaic's board since 2012. He currently chairs the corporate governance and nominating committee and also serves on the audit committee. Mr Ebel was previously chairman, president and CEO of Spectra Energy Corp, and chairman, president and CEO of Spectra Energy Partners, until his retirement in February 2017. He is also a director and chairman of Enbridge, Inc.

"Mosaic and its board of directors have benefitted immensely from Bob's dedication, leadership and insight in his role as chairman," said Mr Ebel. "Bob was instrumental in the transactions that formed Mosaic, and his deep knowledge of the fertilizer and agriculture industries helped build Mosaic into the thriving company it is today. I'm thankful that Bob will remain on the board, and I welcome his experience and guidance in the year ahead."

Mr Lumpkins will remain as a director to ensure a smooth transition.

Mosaic also made two other board changes at May's annual shareholders meeting. **James Popowich** retired as a director and **Oscar Bernardes** was newly elected to the board. Mr Bernardes currently serves as managing partner at Yguaporã Consultoria e Empreendimentos Ltd, a consulting and investment firm in São Paulo, Brazil. He has held a number of executive level roles and was previously CEO of Bunge International, the global agribusiness and food company. Mr Bernardes brings to Mosaic important knowledge of Brazil and its agriculture industry.

Clint Freeland also became Mosaic's senior vice president and chief financial officer (CFO) in June. Freeland will lead Mosaic's global finance and information technology teams and also joins the company's senior leadership team. He has 26 years of global business experience, most recently as executive vice president and CFO for Dynegy, Inc. "Clint's wealth of experience and proven leadership will be great assets to Mosaic," said Joc O'Rourke, Mosaic's president and CEO. "I look forward to building a strong working partnership with him as we advance Mosaic's long term strategy."

Freeland holds a bachelor's degree in political science from The University of the South and an MBA in finance from the Owen Graduate School of Management at Vanderbilt University.

"I am thrilled to join the team at Mosaic at this time of growing business momentum and significant opportunity," Freeland said. "I look forward to helping Mosaic realize its remarkable potential."

Garrett Lofto was promoted to the role of president and CEO of the JR Simplot Company in May. He succeeds **Bill Whitacre** who announced his retirement in April. Lofto has worked for Simplot for 26 years and has led the company's AgriBusiness group for the last nine years.

As president of Simplot's AgriBusiness group, Lofto was responsible for a diverse and complex $2.5 billion division. He successfully initiated and oversaw several major capital expansions which have helped ensure the long-term success and prosperity of the company. Major accomplishments include the building and launch of the ammonia plant in Rock Springs, and the continued growth and expansion of the Simplot Grower Solutions and Simplot Partners retail arms.

"Garrett is an outstanding leader and has the vision to guide the company into an exciting future," said Scott Simplot, chairman of the company's board of directors. "We're well positioned for success across our organization and the Simplot family and board of directors are confident in his ability to lead us in achieving great things."

Lofto is the seventh individual to helm Simplot since company founder Jack Simplot retired in 1973. He was raised on a farm in southern Manitoba, Canada, and has lived in Idaho since 2001. Lofto attended the University of Manitoba and holds a BSc in Agriculture. He was awarded an MBA in 2005.

He is currently a director of the Ronald McDonald House Charities of Idaho, The Fertilizer Institute, Nutrients for Life Foundation and the International Plant Nutrition Institute.

"I'm honored and humbled that the board and the Simplot family has entrusted me to lead this great organization as part of the senior leadership team," said Lofto. "The company is filled with tremendous talent and leaders and I'm committed to ensuring they have the support they need to make the JR Simplot Company the best we can be."

The company says Lofto will assume his role of president and CEO as soon as the transition can be completed. Simplot also says it will embark on a thorough search to fill the now-vacant AgriBusiness leadership role.

Calendar 2018/2019

SEPTEMBER

18-20

9th GPCA Fertilizer Convention,
MUSCAT, Oman
Contact: Ammara Shahiryar
Tel: +9714 4510666, Ext. 102
Email: ammara@gpca.org.ae

24-26

CRU Africa Fertilizer Agribusiness 2018,
CAPE TOWN, South Africa
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

OCTOBER

1-3

TFI World Conference,
SAN FRANCISCO, California
Contact: Valerie Sutton
Fax: (202)-962-0577
Email: vsutton@tfi.org

23-25

2018 IFA Crossroads Asia-Pacific
Conference, SINGAPORE
Contact: IFA Conference Service,
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

NOVEMBER

5-8

Sulphur 2018 Conference,
GOTHENBURG, Sweden
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

MARCH 2019

4-7

Nitrogen+Syngas 2019 Conference,
BERLIN, Germany
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

Biofertilizers in crop production

Microbial-based fertilizers can be applied as inoculants to seeds, seedlings or soil to aid crop growth by improving nutrient access and uptake. They include nitrogen-fixing bacteria and microorganisms able to dissolve and mobilise soil phosphorus and potassium.

Biofertilizers are naturally-occurring soil microorganisms able to boost crop productivity by increasing access to nutrients and improving immunity to disease and stress.

Fixing, dissolving & mobilising

Biofertilizers function by either fixing, mobilising or dissolving (solubilising) nutrients. They include the free-living soil bacteria *Azotobacter* and symbiotic *Rhizobia* bacteria, as well as strains of fungi such as *Arbuscular Mycorrhiza* (Table 1).

Rhizobia are root-colonising and form a symbiotic relationships with many plants, typically colonising the surface of roots to form nodules. They are best known for their nitrogen-fixing abilities in legumes such as soybean, clover, pea and alfalfa.

Rhizobia have been used as effective inoculants for soybeans for decades, and are able to provide up to 90 percent of plant nitrogen requirements via atmospheric fixation. They also show potential as plant growth-promoting rhizobacteria (PGPR) in non-legumes such as maize, wheat, rice, and canola[1]. Several types of PGPR have found successful use worldwide as biofertilizers, improving soil fertility and crop yields[2].

Biofertilizers are most commonly applied by seed inoculation (legumes), although inoculation methods such as seedling dipping (tomato, rice, onion, flowers), tuber dipping (potato) or localised field application (fruit, tea, coffee, sugarcane) are also common practice.

Biofertilizers promote plant growth via four main mechanisms[2]:

- The mobilisation of plant nutrients
- The synthesis of substances directly assimilated by plants
- The prevention of plant diseases
- Improving resistance to plant stress

Table 1: Main types of biofertilizer microorganisms

Groups	Examples
Nitrogen fixing biofertilizers	
Free-living	*Azotobacter, Bejerinkia, Clostridium, Klebsiella, Anabaena, Nostoc*
Symbiotic	*Rhizobium, Frankia, Anabaena, Azollae*
Associative symbiotic	*Azospirillum*
Phosphate solubilising biofertilizer	
Bacteria	*Bacillus megaterium var, Phosphaticum, Bacillus subtilis, Bacillus circulans*
Fungi	*Penicillum Spp. Aspergillus awamori*
Phosphate mobilising biofertilizers	
Arbuscular Mycorrhiza fungi (AMF)	*Glomus Spp., Gigaspora Spp., Acaulospora Spp., Scutellospora Spp., Sclerocystis Spp.*
Ectomycorrhiza	*Laccaria Spp. Pisolithus Spp, Boletus Spp.* and *Amanita Spp.*
Ericoid Mycorrhiza	*Pezizella ericae*
Orchid Mycorrhiza	*Rhizoctonia solani*
Biofertilizers for micronutrients	
Bacillus Spp	Silicate and zinc solubilizers
Plant growth-promoting rhizobacteria	
Pseudomonas	*Pseudomonas fluorescens*

Source: Ritika & Uptal (2014)

What is a biofertilizer?

Clearly and precisely defining what is a biofertilizer is not necessarily straightforward, although the following definition has been proposed: "A formulated product containing one or more microorganisms that enhance the nutrient status (the growth and yield) of the plants by either replacing soil nutrients, and/or by making nutrients more available to plants and/or by increasing plant access to nutrients."

Biofertilizer microorganisms

Nitrogen-fixing biofertilizers have been shown to enhance nitrogen uptake by 7-58 percent in cereals and by up to 60-80 percent in sugarcane. *Arbuscular Mycorrhiza* fungi (AMF) also have the potential to supply more than 50 percent of plant nitrogen requirements[1]. Some examples of nitrogen-fixing bacteria are[2]:

- *Azotobacter*: a free-living bacteria that plays an important role in nitrogen fixation in rice crops and is used as a biofertilizer for wheat, barley, oat, rice, sunflowers, maize, beetroot, tobacco, tea, coffee and coconuts
- *Azospirillum*: commonly associated with cereals in temperate zones as well as improvements in rice yields

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- *Beijerinckia*: associated with sugar cane plantations in tropical zones
- *Gluconacetobacter, Azospirillum* and *Herbaspirillum*: all contribute to nitrogen fertilization in sugarcane

Phosphate-dissolving and mobilising microorganisms include *Micrococcus, Pseudomonas, Bacillus* and *Flavobacterium*. A number of bacterial strains are reportedly able to mobilise soil phosphate and promote growth in carrots, lettuce, strawberries, tomatoes and peppers[2]. *Arbuscular Mycorrhiza* fungi (AMF) are also able to mobilise phosphate and promote plant uptake[1]. *Mycorrhiza* forms a symbiotic relationship with host plants, providing phosphorus and zinc in exchange for carbohydrates.

Other microorganisms are able to dissolve and mobilise potassium in soils. They include:

- *Bacillus edaphicus*: able to increase potassium uptake in wheat
- *Paenibacillus glucanolyticus*: found to increase the dry weight of black pepper
- *Bacillus mucilaginosus*: promotes the growth of aubergine, pepper and cucumber and delivers higher biomass yields in Sudan grass

Some microbial types (*Pseudomonas, Burkholderia, Acidothiobacillus* and *Paenibacillus*) are able to release potassium from minerals such as mica and feldspar, increasing potassium availability by as much 15 percent[1].

A selection of leading biofertilizer companies and products are profiled below.

North America

In the US, where wheat, corn, soybean, cotton and forage crops predominate, farmers have generally been slow to adopt biofertilizers, outside of the application of *Rhizobia* to legumes. However their profile is being raised due to a rise in products being placed on the market[2].

Loveland Products makes and markets the biofertilizer product *Accomplish*®. This also contains enzymes, organic acids and chelators, and is registered as organic by some US states. *Accomplish*® improves the availability of nutrients from fertilizers and soil, according to the company. It is also said to increase root size and branching, enabling plants to take up more nutrients and water. The product increased corn and soybean production in a 2010 University of Minnesota field trial.

Novozymes manufactures a range of biofertilizers that solubilise phosphates and/or fix nitrogen. The company produces and distributes throughout Asia, Australia, Brazil, Canada, Europe and the US. Popular lines include *Cell-Tech*® and *Nitragin Gold*®, which contain nitrogen-fixing *Rhizobia* strains for legume nodulation, and *TagTeam*®, which combines *Rhizobia* with the fungal species *Penicilliumbilaii*. These products are sold in peat, granular and liquid formulations.

Novozymes has gone into partnership with Monsanto to form the BioAgAlliance. This will allow the two companies to jointly screen hundreds of microbes and select those which deliver the greatest and most consistent crop benefits[2].

BASF Canada manufactures a range of products containing *Bacillus subtilis* and *Bradyrhizobium japonicum*. It markets these throughout North America, Africa, South America, Australia and Europe under the *Nodulator*® brand.

Brett-Young Seeds offers three *Delftiaacidovorans*-containing biofertilizer products under the *Bioboots*® marque. Two are designed for canola, one being peat-based and the other a liquid product. Its remaining biofertilizer is designed for soybean and combines *D. acidovorans* with *Bradyrhizobium sp.*

EVL markets a biofertilizer which combines *Lactobacillus helveticus* and a proprietary biostimulant *EVL coating*®. The product contains several microbial strains and was developed to be used with mineral fertilizers. The company also licences the technology to third parties such as fertilizer companies.

Latin America

The use of nitrogen-fixing inoculants on soybean is widespread in South America. Around 70 percent of the 30 million hectares of soybean crops sown in Argentina, Paraguay, Bolivia and Uruguay every year are inoculated with *Bradyrhizobium sp.* Some wheat and maize plantations are also inoculated with *Azospirillum* and *Pseudomonas*.

Argentina's **Rizobacter** was founded in 1977 and is a long-standing player in the international biofertilizer market. It markets and distributes *Rhizobia*-based biofertilizers for legume crops in Argentina, Brazil, Bolivia, Paraguay, Uruguay, the US, Europe and Africa.

Brazil has been an early adopter of biofertilizers. The country applies around 60,000-70,000 tonnes of biofertilizers to beans, maize, rice, sugarcane, soybean, carrots, tomatoes, cotton, forage, citrus and eucalyptus every year, according to a 2011 study by the International Plant Nutrition Institute (IPNI).

Brazil is also home to several large commercial biofertilizer producers, including Embrafós, Instituto de Fosfato Biológico (IFB), Biofosfatos do Brasil and Liderfós. **IFB** manufactures the nitrogen-fixing and phosphate solubilising biofertilizer *Bioativo*®. This contains a mix of microorganisms, organic matter, major nutrients and micronutrients.

Europe/Russia

Spanish-headquartered **Symborg** is a leading EU and global player. It sells products in over 40 countries and operates subsidiaries in Europe, the US, South America and Asia. The company manufactures the biofertilizer *VitaSoil WP*®. This is marketed as a microbial soil regenerator and can be applied through a drip irrigation system. The product targets the horticultural market and flowers, fruit trees, cereals, tobacco plantations and vineyards. Symborg's other products include:

- *MycoUp*®: a biological inoculant for horticultural crops that contains *Arbuscular Mycorrhizal* fungus (AMF) in a clay substrate. It promotes root growth and consequently higher water and nutrient uptake.
- *MycoUp Activ*®: a biological inoculant product for horticultural crops that can be applied via irrigation. It is based on the mycorrhiza-forming fungus *Glomus Iranicum* and is designed to promote root growth and improve plant vitality.
- *Resid HC*®: a biological inoculant for coating the seeds of cereals and grain crops. It is based on the mycorrhiza-forming fungus *Glomus Iranicum* and is designed to promote root growth and improve plant vitality.
- *Resid MG*®: a biological inoculant for cereals and grains that contains AMF. It is applied directly during seeding using a micro-granular applicator. It improves the growth of plants by increasing uptake of soil phosphorus.

Based in Novomoskovsk in Russia's Tula region, **JSC Industrial Innovations** manufactures the *Azospirillum*-based biofertilizer *Azotobacterin*®. This can deliver a yield increases of up to 20 percent in wheat, barley, maize, carrot and cabbage, according to the company.

Table 2: **Selected commercial biofertilizer products**

Product	Company	Bacterial strains
Cell-Tech®	Novozymes	*Rhizobia*
Nitragin Gold®	Novozymes	*Rhizobia*
TagTeam®	Novozymes	*Rhizobia + Penicillium bilaii*
Accomplish®	Loveland Products, Inc	PGPR + enzymes + organic acids + chelators
Nodulator®	BASF Canada Inc.	*Bradyrhizobium japonicum*
Nodulator® N/T	BASF Canada Inc.	*Bacillus subtilis MBI 600 + Bradyrhizobium japonicum*
Nodulator® PRO	BASF Canada Inc.	*Bacillus subtilis + Bradyrhizobium japonicum*
Nodulator® XL	BASF Canada Inc.	*Rhizobium leguminosarum biovar viceae 1435*
Bioboots®	Brett-Young Seeds	*Delftia acidovorans*
Bioboots® (soybean)	Brett-Young Seeds	*Delftia acidovorans + Bradyrhizobium sp.*
EVL coating®	EVL Inc.	PGPR
Nitrofix®	Labiofam S. A.	*Azospirillum sp.*
Bioativo®	Instituto de Fosfato Biológico (IFB) Ltda.	PGPR
VitaSoil®	Symborg	PGPR
Azotobacterin®	JSC Industrial Innovations	*Azospirillum brasilense* B-4485
Mamezo®	Tokachi Federation of Agricultural Cooperatives (TFAC)	*Rhizobia* (in peat)
R-Processing Seeds®	Tokachi Federation of Agricultural Cooperatives (TFAC)	*Rhizobia* (coated legume seeds)
Hyper Coating Seeds®	Tokachi Federation of Agricultural Cooperatives (TFAC)	*Rhizobia* (coated grass legume seeds)
Life®	Biomax	PGPR
Biomix®	Biomax	PGPR
Biozink®	Biomax	PGPR
Biodine®	Biomax	PGPR

Source: Garcia-Fraile et al., 2015

Asia-Pacific

India spends around $1.5 billion on biofertilizers and biopesticides annually. The subcontinent is home to more than 100 biofertilizer producers, according to some estimates[2].

Founded in 1998, Mumbai-based **Biomax** has emerged as a major world supplier of biofertilizers. Its product range includes *Life*®, *Biomix*®, *Biozink*® and *Biodine*®. These contains microbes which can fix nitrogen, and solubilise a range of soil nutrients (phosphorus, iron, magnesium and zinc) to make them plant-available.

Other large Indian biofertilizer manufacturers include:

- Ajay Biotech National Fertilizers
- Madras Fertilizers
- Gujarat State Fertilizers & Chemicals
- T Stanes & Company
- Camson Bio Technologies
- Rashtriya Chemicals & Fertilizers

In Japan, **Tokachi Federation of Agricultural Cooperatives** (TFAC) produces and distributes the following *Rhizobia*-based biofertilizers:

- *Mamezo*®: contains *Rhizobia* mixed with peat
- *R-Processing Seeds*®: legume seeds inoculated with *Rhizobia*
- *Hyper Coating Seeds*®: legume seeds coated with a capsule of calcium carbonate containing *Rhizobia*

The Chinese government first began to regulate the biofertilizer industry and started to register companies in the mid-1990s. Over 500 Chinese biofertilizer companies are currently registered. **China Bio-Fertilizer** (CBF) is one of the country's leading manufacturers, producing and marketing two biofertilizers able to solubilise phosphorus and potassium. These products can reduce mineral fertilizer demand by 30 percent and boost crop yields by a similar percentage, according to company field trials.

Contested results

The agricultural application of microbial-based fertilizers is still in its infancy and has been hindered by the following factors[2]:

- Unpredictable/inconsistent results
- Problems identifying and tracking inoculated strains in the field
- Poor understanding of the interactions between microorganisms and plants
- Production technology

Demonstrating if and how well biofertilizers work has been particularly problematic. This is because biofertilizer microorganisms, once introduced into soil, may face stiff competition that severely reduces their beneficial effects. Their performance can also vary greatly under different agronomic conditions. The efficacy of microbial-based products – already regarded with scepticism by many within the fertilizer industry – has become contested because of this[1].

A recent investigation found that 40 percent of the 65 commercial bacterial biofertilizers tested did not contain the claimed strain. Another survey of AMF-based biofertilizer products revealed very low propagation and limited colonisation potential. Several other studies have also demonstrated the decline of microbial populations in inoculants over time, particularly under non-ideal storage conditions, resulting in lower inoculation efficiency[1].

Legal definition, market regulation and quality standards

To address these failings, there is pressure for an agreed, legally-binding definition for biofertilizers, as well as legal standards for registration and marketing to ensure mini-

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

mum quality standards are met. Indeed, some argue that the potential of biofertilizers will not be fully realised without production quality standards and a clear legal framework with guarantees for farmers[1].

Although supposedly designed to work alongside conventional fertilizers, there is some evidence that mineral fertilizers can behave antagonistically and strongly affect inoculated microorganisms. Long-term nitrogen applications have been linked to lower soil microbial activity, for example, negatively affecting the natural mycorrhizal colonisation of roots. Phosphate accumulation in soils from fertilizers can also affect AMF microbes negatively[1].

As a recent review concluded[1], transforming twenty-first century fertilization by making biofertilizers a common agriculture practice is going to require much better performance guarantees. In particular, there needs to be assurances about: "The efficacy of a biofertilizer in a particular soil with a specific crop variety. A complex task which… [needs to] be considered by researchers, manufacturers, agricultural advisors and farmers when designing and applying a specific biofertilizer."

Encouraging new evidence

In the past, organisations such as IPNI have been scathing about the efficacy of biofertilizers. "Most of the biofertilizers showing up in North America have been largely discredited," IPNI concluded in 2011, adding: "Microbial inoculants are an interesting area of study. But it is difficult to predict efficacy for products other than *Rhizobia* inoculants for legumes."

However, new evidence about the ability of biofertilizers to improve crop yields and nutrient use efficiency (NUE) emerged in a comprehensive global review published in January[3]. This measured the crop benefits of biofertilizers (yield increase, nitrogen and phosphorus use efficiency) based on an analysis of 171 peer-reviewed publications.

The review concluded that:

- Biofertilizers perform significantly better in dry climates
- Biofertilizers greatly improved nitrogen and phosphorus use efficiency
- Biofertilizers which possess both P-solubilising and N-fixing traits have the highest potential to increase crop yields
- The efficacy of biofertilizers increased at higher soil phosphorus levels
- *Arbuscular Mycorrhizal* fungi (AMF) performance improved the most followed by P-solubilising, and N-fixing microbes
- AMF inoculation was most successful at neutral pH and when soil organic matter content was low
- AMF have big potential as a sole biofertilizer for most crops and climate types

"It was found that dryland agriculture can benefit most from biofertilizers," concludes the review. "Due to climate change, in the future there will be even more dryland areas globally. Biofertilizers are thus a promising option for sustainable agriculture." ■

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PHOTO: UGIS RIBA/SHUTTERSTOCK.COM

Ukraine's booming NPK market

Growing demand from Ukraine's large agricultural sector saw imports of NPK products rise by more than fifty percent during 2017 to hit a record high. This fertilizer import boom is being fuelled by a market preference for lower cost NPKs, rising application rates and changes to the country's crop mix. Limited domestic availability and anti-dumping measures have also fuelled Ukraine's NPK boom.

Ukraine occupies a strategic location at the crossroads between Europe and Asia. But being positioned between two rival power blocs – Russia to the east and the EU to the west – has presented Ukraine with difficult choices in recent years.

The country's economy went into free-fall in 2014 after Russia's annexation of Crimea provoked a simmering military conflict in east Ukraine and an escalating trade war with Russia. As a consequence, GDP plummeted, inflation rocketed and foreign reserves fell. Ukraine's economy is, however, on the mend – having returned to modest growth in 2016 and 2017 after contracting sharply in 2014 and 2015. The country has also managed to successfully forge new trading relationships, with the EU symbolically replacing Russia as Ukraine's main trading partner following the negotiation of a free trade deal.

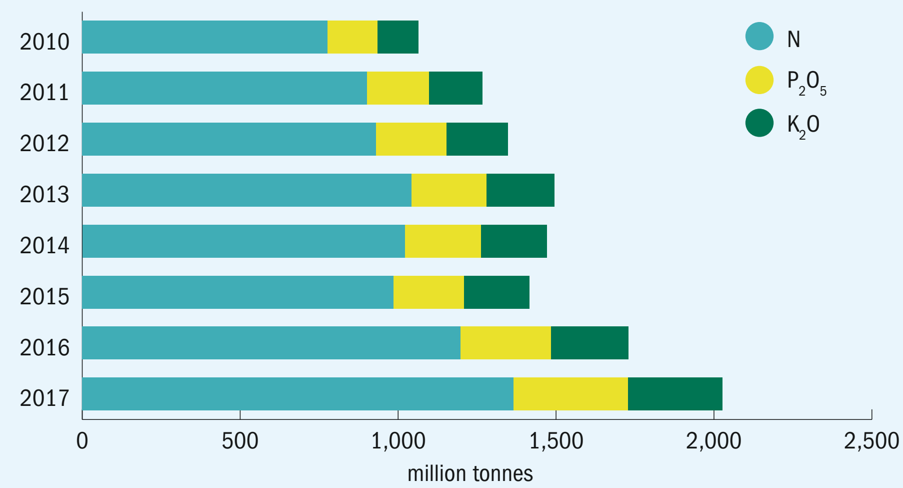
A vast and fertile steppe

Agriculture is a key pillar of Ukraine's economy. Estimated to be worth $13.5 billion, the sector generates more than 10 percent of GDP and employs nearly one-fifth of the country's workforce. Ukraine is the second-largest country in Europe after Russia, with more than 40 million hectares of land devoted to agriculture, some 70 percent of the country's total area.

The country has long been called the bread basket of Europe, thanks to its famously fertile black soil (chernozem) and vast tracts of arable land. Agricultural goods are a major foreign revenue earner, accounting for more than 40 percent of exports. Ukraine has kept its place as the world's largest exporter of sunflower oil and the third largest exporter of grains, despite the loss of Crimea.

Ukrainian agricultural and food export sales reached $14.7 billion during January-October 2017, according to the latest trade statistics, an increase of $2.7 billion on the same period in 2016. Ukraine's main agricultural exports by value last year were sunflower, safflower and cotton oil (25 percent), corn (17 percent), wheat (15 percent), rapeseed (5 percent), soy (5 percent) and barley (4 percent).

Fig. 1: **Ukraine's rising nutrient consumption, 2010-2017**



Source: State Statistics Service of Ukraine

Rising fertilizer use

Nutrient consumption (N, P_2O_5 and K_2O) has risen steadily in Ukraine, almost doubling to more than two million tonnes since the turn of the decade (Figure 1). Demand has accelerated over the last three years, pushing up nutrient consumption by more than 40 percent between 2015 and 2017.

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Wheat, corn, sunflower, soybean, rape and sugar beet are the main fertilizer-consuming crops (Figure 2). Cereals and legumes generate a large demand for fertilizers with wheat and corn jointly accounting for around half of Ukraine's nutrient use. Ukraine has also emerged as the world's leading sunflower grower, making the crop an increasingly important end-market for fertilizers. The growing area for this lucrative cash crop – 12.2 million hectares in 2017 – has expanded five-fold over the last two decades.

World's top NPK importer

Ukraine has become an increasingly important market for NPKs over the last three years, with imports tripling since 2015 to meet a dramatic upturn in demand. The country's NPK imports hit a record high of 2.2 million tonnes last year, a 52 percent year-on-year rise. That made Ukraine the world's top NPK importer in 2017, with import volumes around double that of Brazil (1.1 million tonnes), China (1.1 million tonnes) and Thailand (1.0 million tonnes), the three next largest global NPK importing countries.

Strong demand for NPKs helped push up Ukraine's total fertilizer imports from 1.9 million in 2015 to 3.7 million tonnes in 2017.

The rapidly growing requirement for NPKs in Ukraine (Figure 3) has largely been met by Russian producers such as Acron, PhosAgro, Uralchem, Rossoh and EuroChem. The 1.7 million tonnes of NPKs supplied by Russia in 2017 – up by 63 percent on 2016 – satisfied over three quarters of Ukraine's import requirements. In neighbouring Belarus, producers Gomel and Belaruskali supplied Ukraine with a further 350,000 tonnes of NPKs last year, around 16 percent of the country's import needs. Lithuania, Finland and Poland contributed an additional 120,000 tonnes of NPKs, giving EU suppliers an import share of just five percent.

The rapid rise in NPK imports has also depressed domestic production. Ukraine's NPK output has fallen by more than 50 percent in three years, dropping from 245,500 tonnes in 2014 to 105,300 tonnes in 2016.

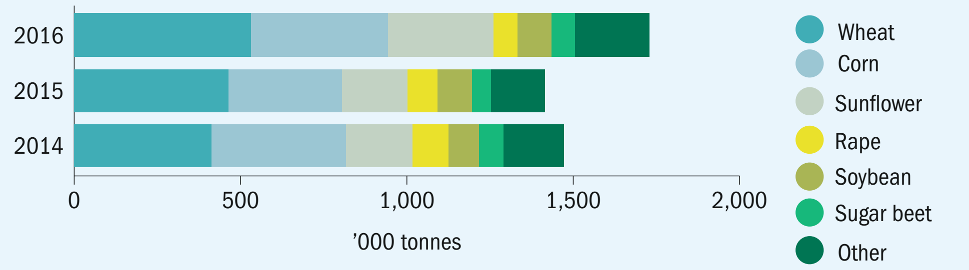
NPKs preferred

Excluding compound NPKs, Ukraine consumed around 3.5 million tonnes of fertilizers in 2016. Nitrogen fertilizers, such as ammonium nitrate, urea, ammonium sulphate and calcium ammonium nitrate, collectively accounted for almost 90 percent of this volume (Figure 4).

When it comes to meeting the P and K requirements of crops, Ukraine's farmers favour the application of NPK products over MAP (monoammonium phosphate) and potash (MOP, muriate of potash). For example, Ukraine consumed over 1.4 million tonnes of imported NPKs in 2016, supplemented by around 150,000 tonnes of domestically-produced NP/NPKs. That compares to consumption of 226,000 tonnes of largely Russian-sourced MAP and 86,000 tonnes of mainly Belarussian MOP by Ukraine in 2016.

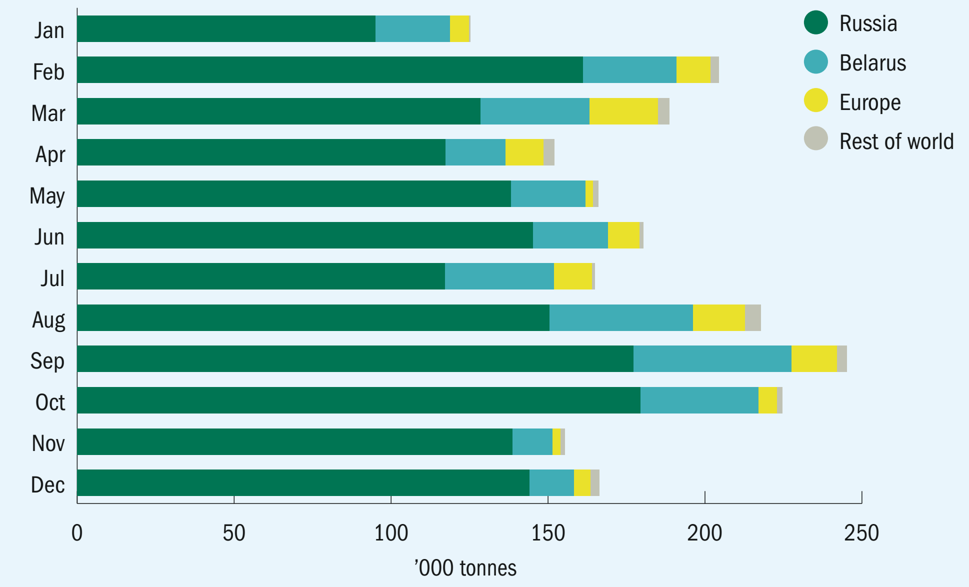
The relatively high price of MAP and MOP deliveries in Ukraine is one factor behind this preference. In mid-2017, rail cargoes (cpt, big bags) of 10-26-26 grade NPK were available in Ukraine at \$422-432/t, for example, versus \$509-516/t for MAP and \$339-343/t for MOP, according to analysts Argus The other advantage of NPKs, points out Argus, is that only a single application is necessary each season, compared to several for MOP and MAP[1].

Fig. 2: **Ukraine's nutrient consumption by crop, 2014-2016**



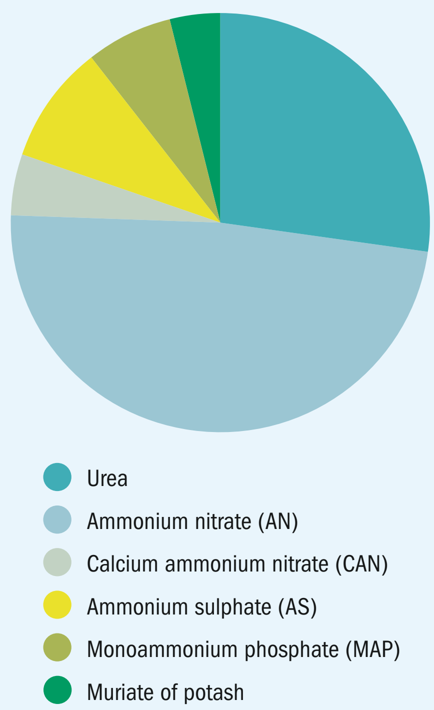
Source: State Statistics Service of Ukraine

Fig. 3: **Ukraine's NPK imports, January – December 2017**



Source: IHS

Fig. 4: **Ukraine's apparent fertilizer consumption, 2016***



Total: 3,548,000 tonnes

** Excludes compound NPK products, estimated at 1.6 million tonnes*

Source: IFA

While potash imports have been largely static in recent years, imports of MAP – similar to NPKs – have been on an upward trend. Ukraine's MAP imports, having risen more than 86 percent year-on-year in 2016, rose by a further 12 percent in 2017 to 252,000 tonnes, with volumes from Russia up five percent to 217,000 tonnes.

Domestic NPK production

Sumykhimprom is the country's main NP and NPK producer. The company has two NPK production units with annual capacities of up to 275,000 tonnes and 300,000 tonnes, respectively. DZMU – Ukraine's only other NP and NPK producer – can produce up to 180,000 tonnes annually.

Domestic NPK producers have struggled to compete with rival producers in Russia and Belarus. Sumykhimprom, reported a total fertilizer production of 120,400 tonnes for 2017, including NP, NPKs and ammonium sulphate. This was 37,000 tonnes down on 2016, the company having shutdown production for eight months between November 2016 and June 2017, blaming unfavourable market conditions. Sumykhimprom was reported to have produced 103,000 tonnes of NPKs and 25,000 tonnes of NPs in 2016, a significant drop on its 127,000 tonne NPK and 86,000 tonne NP output in 2015.

DZMU only produces NPs during the high season with output of just 20,000 tonnes expected in 2017. That compares with the 35,000 tonnes of NPs produced in 2016.

Circumventing anti-dumping duties

Ammonium nitrate (AN) has traditionally been Ukraine's most widely-applied fertilizer product, typically accounting for around half of the country's total fertilizer consumption. This preference is partly a reflection of supply availability.

Ukraine's nitrogen fertilizer industry produces AN on a large scale, although output has been on a downward trend in recent years. The country's AN production declined by more than 40 percent between 2012 and 2016, falling from 2.5 million tonnes to 1.4 million tonnes. Production at Ostechem's Severodonetsk plant, in particular, has been severely curtailed by the conflict which began in east Ukraine in 2014.

Long-standing anti-dumping duties have also depressed AN imports by pricing them out of the market. These duties – having been raised once in July 2014 – were raised again in March this year, in an attempt to lock Russian products out of the Ukrainian market. The duty imposed on AN from Acron's Dorogobuzh plant was raised from 20.51 percent to 29.25 percent, for example, while duties on other Russian AN producers were hiked from 36.03 percent to 42.96 percent.

However, Russian producer Acron has been able to circumvent Ukraine's anti-dumping duties by supplying 33-1-1 grade NPK – a nitrogen-rich, bulk blended product – as a substitute for AN. Indeed, a surge in the supply of 33-1-1 was one of the main factors behind last year's increase in Ukraine's NPK imports. Prior to this, triple 16 (16-16-16) and 10-26-26 were Ukraine's most popular NPK import grades.

Acron's Dorogobuzh plant in Russia's Smolensk region began to ship the 33-1-1 NPK blend to Ukraine in December 2016 in readiness for the spring 2017 season. Imports of blended 33-1-1 made up 28 percent of the 1.05 million tonnes of NPKs imported into Ukraine during the first half of 2017, with Dorogobuzh supplying almost all of this (292,000 tonnes).

Strong import demand for blended 33-1-1 was also boosted by the tight domestic supply situation for AN at the start of last year. Ostchem was forced to shutdown its Cherkassy and Rivne nitrogen fertilizer plants for several months between March and July 2017 due to the suspension of gas supplies.

Agricultural intensification

The intensification of Ukrainian agriculture and changes to the country's crop mix have been key drivers of fertilizer demand. The area planted to many crops types – including cereals, legumes, sugar beet, potatoes, vegetables and forage crops – has either fallen or remained static (Figure 5). Yet Ukrainian farmers have still been able to markedly improve their crop production (Figure 6) and yields over the last ten years by applying fertilizers in increasingly large amounts. This has enabled Ukraine to more than double the production of cereals and legumes from a shrinking land area since 2007.

Profitable sunflower cultivation in Ukraine has also rapidly expanded. Grown for the export market, the area planted to this valuable cash crop almost doubled in the last decade, rising from 3.6 million hectares in 2007 to 6.0 million hectares last year.

Acron: key NPK market player

Acron Group has been able to capitalise on strong NPK demand in Russia, China and Ukraine. NPKs and bulk blends generated 45 percent of the Group's revenues in 2017. Acron has responded to buoyant market demand by ramping up its NPK production by almost one million tonnes last year to 2,894,000 tonnes. As part of this production increase, Acron raised the output of NPK bulk blends such as 33-1-1 at its Dorogobuzh plant from 71,000 to 671,000 tonnes, with much of this product being destined for Ukraine.

Acron currently has a total NPK production capacity of around 1.8 million tonnes, and appears to be confident of the long-term growth prospects for NPKs. The company is investing $320 million between 2017-2021 in a new one million tonne capacity NPK/DAP/MAP production unit at Dorogobuzh. Another recently-announced RUB 700 million project will also increase the total capacity of the two NPK units at Acron's Veliky Novgorod site by over one-third to 1.7 million tonnes by the third quarter of next year.

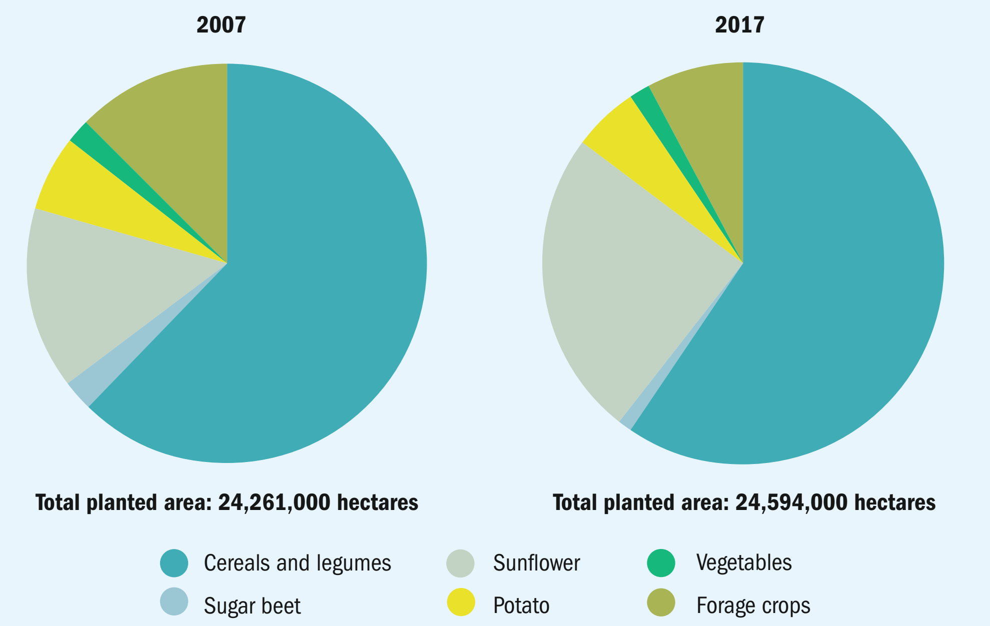
Sanctions: the end of the NPK boom?

Despite the growth in demand for NPKs in Ukraine and the ability of suppliers such as Acron to meet this, the political and economic rift between Ukraine and Russia widened further this spring. Indeed, the recent announcement by Ukraine of fresh sanctions on Russian producers could well bring the country's recent NPK import boom to a sudden halt and even throw it into reverse.

New sanctions on Russian fertilizer producers including Acron Dorogobuzh,

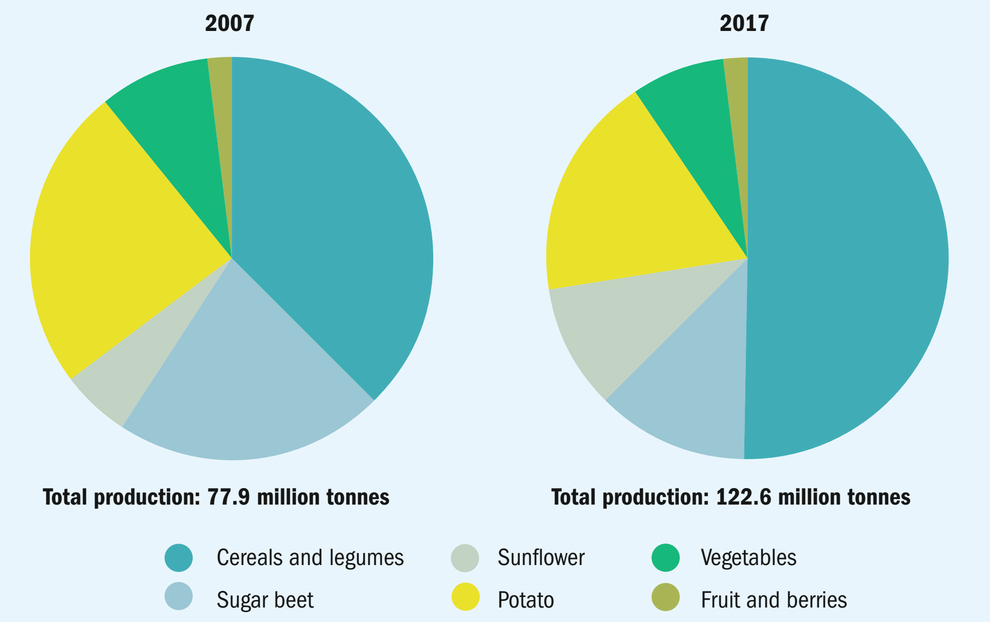
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

Fig. 5: **Ukraine: planted area for crops, 2007 vs 2017**



Source: State Statistics Service of Ukraine

Fig. 6: **Ukraine: crop production, 2007 vs 2017**



Source: State Statistics Service of Ukraine

EuroChem, PhosAgro and Uralchem were announced by Ukraine's National Security and Defense Council (NSDC) in mid-May. The sanctions have been imposed for three years and include measures to freeze assets and limit business transactions. They also prevent Russian companies listed by the NSDC from withdrawing funds from Ukraine.

The decision is likely to dramatically limit availability and shrink the market for NPKs and phosphate fertilizers in Ukraine. The companies covered by the new sanctions currently supply most of the country's NPK/NP and MAP fertilizer imports. In 2017, some 77 percent of the country's NPK imports and 85 percent of MAP imports were Russian-supplied. However, Russian producer Rossosh (Minudobreniya), a major NPK supplier to the Ukraine, is notably absent from the DSDC's sanctions list – and should therefore greatly benefit from the exclusion of its Russian competitors.

Ukraine previously imposed sanctions on parts of EuroChem Group and other Russian fertilizer suppliers last September for allegedly supplying ammonium nitrate to the separatist-controlled eastern territories of Donetsk and Lugansk without Ukrainian customs clearances.

In May, just ahead of the imposition of the latest round of sanctions, EuroChem Group announced its withdrawal from Ukraine's fertilizer market and the sale of its local Ukrainian subsidiary. "Recent actions in Ukraine to restrict foreign suppliers of fertilizers, and expectations of a further deterioration of the business climate, prompted the Group's decision," EuroChem said in a statement. Prior to the decision, EuroChem had been investing and operating in Ukraine for more than 15 years, serving over 1,000 local customers in the country, ranging from major agricultural wholesalers to retailers and private farms.

Russia's PhosAgro also reacted to the latest round of sanctions by ending all sales and shipments of fertilizers to Ukraine. "It is our deep conviction that these measures will harm Ukrainian farmers first and foremost," said Andrey Guryev, PhosAgro's CEO. "Ukraine remains a net importer of a wide range of phosphate-based fertilizers and supplies from Russia have proven to be the most efficient way to meet demand from Ukraine's domestic agricultural producers."

Where might Ukrainian farmers turn for replacement supplies of NPKs? Suppliers in Belarus to the north should be well-placed to capitalise on the exclusion of Russian competitors from Ukraine's market.

Looking westwards, Europe with its multi-million tonne NP/NPK production capacity is geographically well-positioned and has the necessary scale to supply Ukraine's large NPK import market. Ukraine might well initially turn to Grupa Azoty in neighbouring Poland as an alternative NPK supplier, for example. Elsewhere in Eastern Europe, Elixir commissioned a 250,000 tonne capacity NPK plant at Prahavo in Serbia last year, and Bulgaria's Agropolychim has also invested in NP/NPK production.

Other major European NPK producers such as Yara are also likely to take advantage of any new opportunities in Ukraine arising from reccently-imposed sanctions against Russia. OCP Group could also potentially increase NP/NPK and phosphate fertilizer sales in Ukraine via its long-standing distribution arm in the region, Black Sea Fertilizer Trading, a joint venture with Turkey's Toros. ■

References

1. Argus, 2017. Ukraine's NPK import boom: Here to stay or gone tomorrow? Argus FMB white paper.

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

IFS conference dinner by the Vlatava River, Prague.

2018 IFS Technical Conference

Prague's Crop Research Institute played host to the 2018 International Fertiliser Society (IFS) Technical Conference in May. **Steve Hallam**, IFS Secretary, provides a personal conference diary.

The 2018 IFS Technical Conference once again demonstrated the event's unique ability to offer up highly practical insights and useful knowledge for fertilizer production professionals. The delightful Prague setting and the conference's trademark informal atmosphere made it a valuable and stimulating experience for delegates attending the two-day event.

The usual mix of informative and high-quality presentations also provided ample opportunity for discussion and debate. Held at Prague's Crop Research Institute on the outskirts of the city, delegates were even serenaded by Nightingales on their walk from the hotel!

A friendlier, informal feel

For me, it was striking how many delegates mentioned the open discussion and informal networking, when asked about their highlights of the event. IFS conferences do have a different and much friendlier feel, compared to many of the industry's larger, more commercial conferences.

As a non-commercial membership society whose aims are to disseminate and discuss technical information, IFS keeps its costs and fees low, providing excellent value for money. Importantly, most conference presentations are permanently available, being published in the society's proceedings. The absence of a commercial element and any salesmanship at the conference is also welcome, as it allows delegates to focus on the theory and practice of making and handling fertilizers.

Topical and commonly-occurring industry issues were debated in Prague, new ideas were picked up, and good practice was disseminated. The impact of existing and forthcoming regulations, and how best to respond to these, featured prominently in discussions. It became clear that not everyone shares the same views on these issues!

As with other conferences, new contacts were forged and existing business relationships nurtured, but in a much more relaxed way. The traditional conference dinner, this year held on the bank of the Vlatava river, overlooking the Charles Bridge, made such networking even more enjoyable than usual!

It's about the content

Nevertheless, people came to Prague to listen to and discuss the presentations, and this year's programme proved as strong as ever. Feedback from delegates suggests there was a presentation for almost everyone, with no clear favourite garnering more praise than others. Indeed, most presentations were enjoyed and welcomed by someone. Part of the attraction of the conference has always been the wide variety of topics covered, and the potential for picking up unexpectedly valuable information and ideas, as several delegates to this year's event confirmed.

Presentations

Elio Strepparola of Casale S.A. described the opportunities created by revamping a methanol plant in the conference's opening presentation. He outlined an innovative approach to implementing an integrated fertilizer project. This benefitted from the longstanding relationship between the plant's owner and Casale, together with the availability of all the required technologies from a single licensor.

This was followed by a presentation on the construction of a calcium nitrate plant in the Czech Republic by **Branislav Brežný**, of VUCHT A. S. This uses a new calcium nitrate fertilizer production process developed by VUCHT's R&D centre in Slovakia. The process involves the treatment of limestone with nitric acid, followed by neutralisation with ammonia. The process was tailored to the quality of raw materials, product properties and the demands of government regulators.

Stamicarbon's new dual-pressure nitric acid technology with high energy recovery was presented by **Paz Munoz**. She explained how dual-pressure single-train capacities can range between 600 t/d and 1,600 t/day (100% HNO_3). The relatively high tail gas temperature (up to 480°C) is a critical process feature. This favours the decomposition of N_2O in a tertiary abatement reactor. It also allows higher power generation by the expansion turbine, and an extra heat recovery step, before releasing the tail gas to atmosphere. This translates into high steam export.

Christian Renk of thyssenkrupp Industrial Solutions described a new process for producing granulated ammonium sulphate from dilute solutions. The process incorporates fluidised bed granulation and has taken four years to develop. Initial trials started with a laboratory batch-scale plant (~5 kg/hr), followed by larger technical-scale continuous operation (~20 kg/hr). This subsequently enabled a pilot plant to be designed, constructed and commissioned (~500 kg/hr). The presentation outlined key process features and properties of the new product.

Michal Baji of Lovochemie A.S. revealed how the company's innovative wet electrostatic precipitator (WESP) has been successfully installed for de-dusting at a calcium ammonium nitrate (CAN) plant. WESP is particularly effective for gas mist SO_2 and SO_3 elimination. The advantages of the technology are its low operational costs, high efficiency, low pressure drop, temperature resistance and low maintenance requirements, relative to scrubbers and filters. The disadvantages are a relatively high investment cost and a large space requirement.

Michal explained that a new CAN/ASN fertilizer plant had been approved by the Czech authorities in 2013, with strict limits placed on solid particle emissions (<8 mg/Nm^3). Scrubber technology cannot achieve such a low limit so Lovochemie decided to use WESP instead. This is first time that WESP technology has been used for de-dusting at a fertilizer plant of this type.

Thomas Henry of Prayon Technologies compared and evaluated four different approaches for improving phosphoric acid quality. Users are increasingly interested in phosphoric acid purification. This is because of the need to cope with the wide range of raw phosphoric acid qualities generated from different phosphate rock types, and the growing demand for high-quality end products. The phosphoric acid purification methods covered by Thomas included: ion exchange on selective resins, solvent extraction, impurities precipitation by potassium addition, and acid neutralisation. The working principles of each of the four processes were described and simplified schematics presented. The pros and cons of each process were reviewed, as was the handling of the main waste streams.

Aida Idrissi Kaitouni of Argus Media presented the main findings of a recently-completed major review of the global supply situation for phosphate rock. This covered the key trends and developments affecting the volume and quality of phosphate rock, together with the supply outlook for the next 15 years.

Mike McLaughlin of the University of Adelaide presented findings of work to develop rapid analytical screening methods for controlled-release fertilizers (CRFs). CRFs and slow-release fertilizers (SRFs) help to minimise nutrient losses. Evaluation of CRF/SRF performance can however be time consuming and costly. Rapid evaluation techniques are therefore needed, both to screen existing products and to help develop new ones. Quick evaluation methods for CRFs/SRFs were described, and their ability to predict nutrient losses in runoff compared.

Laurent Ruhlmann of Yara International gave a provocative and brave presentation which asked, "Why do companies with strong process safety records still have accidents?" It was brave because it included several examples of incidents from Yara's own operations.

Laurent explained how even chemical companies with excellent safety management have experienced significant lapses. Serious multi-fatality accidents have happened in companies such as BP (Texas City in 2005 and Grangemouth in 1987), DuPont (2016) and BASF (2016). Process safety accidents are far rarer and much less predictable that occupational safety incidents. Furthermore, the outcomes can be much more serious than occupational safety events – which in general involve single individuals – when they do occur.

History has shown that many process safety accidents are linked to poor management of change (MOC). Modification and replacement of equipment, organisational change, lack of resources and the re-sizing of plant output are the primary root causes of many accidents. The presentation discussed why accidents are still happening in companies with strong safety records.

Peter Scott of Origin Fertilisers (UK) Ltd evaluated fertilizer blending technologies and ways of ensuring product consistency. The company's blending plants in the UK and Ireland use a variety of technologies and different types of equipment. Based on this experience, Peter described the various approaches to blending and the machinery options available. The choice of technology, machinery, bagging and process control were all outlined, as were measures to minimise the segregation of constituents.

Antoine Hoxha of Fertilizers Europe presented an overview of recent European regulatory developments. This covered the expected introduction of the new EU fertilizer regulation, as well as the circular economy and the EU emissions trading scheme (ETS). Antoine also demonstrated a new online carbon footprint calculator developed by the European industry. He also discussed new greenhouse gas (GHG) emission factors for fertilizer production. These are being used in the EU and other regions globally to evaluate the environmental impacts of fertilizers.

Food for thought

The presentations and discussions at this year's conference confirmed that considerable scope for innovation and process development continues to exist within the industry. Several papers suggested that industrial symbiosis will be a particularly fruitful and growing area in future. This will allow the by-products from other industrial processes to be re-used as raw materials in fertilizer production, and/or used to improve process efficiency.

It was also clear from this year's conference that – while the fertilizer industry faces a plethora of both threats and opportunities – there is still plenty of scope for innovative and agile companies to pull away and gain a competitive advantage. ■

Scrubbing technology round-up

We provide an update on the latest developments in high-efficiency scrubbing systems for urea plants from Kimre/UFT/tkIS, Stamicarbon/ECI and Toyo.

Toyo scrubbing technologies

Japan's Toyo Engineering Corporation is one of the world's leading urea technology licensors. Although typical emissions guidelines for urea plant finishing section are 50 mg/Nm³ for urea dust and 50 mg/Nm³ for ammonia, environmental guidelines and regulations are becoming ever more stringent. In response to this, Toyo has developed a range of systems for the effective abatement of urea dust and gaseous ammonia emissions, based on water and/or acid scrubbing. These technologies have been installed at numerous urea plants globally (Table 1).

Toyo water scrubbing system

Toyo offers a water scrubbing system for removing urea dust at the finishing stage in prilling and granulation plants. This proven and widely-deployed technology reduces the urea dust in exhaust air from urea finishing sections to less than 30 mg/Nm³. The system has been adopted at more than 40 prilling towers and granulation plants worldwide and has the following advantageous features:

- Low pressure drop of only 50-150 mm H_2O
- Efficient recovery of urea as a 45 wt-% solution
- Lower construction cost due to a simple structure and the low loading weight of the polypropylene packed bed

Exhaust air enters the bottom of the scrubber and rises upwards through a packed bed. Urea dust is removed when this exhaust gas comes into contact with a descending stream of circulation water moving downwards in counter-current. Clean air is finally vented to the atmosphere from the top of the scrubber after mist carry-over has been eliminated (Figure 1).

Toyo also offers three acid scrubbing options for the abatement of ammonia emissions (Table 1):

- A single-stage acid scrubbing system
- A double-stage acid scrubbing system
- An acid scrubbing system without by-product

Toyo single-stage acid scrubbing

This system has the same configuration as the water scrubbing system (Figure 1). However, by injecting acid into the circulation water, ammonia emissions in the exhaust air are reduced to below 20 mg/Nm³. At the same time – as with the water scrubbing system – urea dust emissions are also scrubbed to less than 30mg/Nm³.

The system removes and recovers ammonia gas as urea ammonium sulphate (UAS) or urea ammonium nitrate (UAN) solution, depending on the acid injected. With this system, it is not possible to return captured urea to the urea plant because it combines with ammonia in solution to form UAN or UAS.

Toyo double-stage acid scrubbing

This system combines two separate water scrubbing and acid scrubbing stages (Figure 2). Urea dust is captured by a packed bed in the (lower) water scrubbing first stage and recovered as 45 wt-% urea solution. Ammonia gas is subsequently absorbed by acid scrubbing in the packed bed of the

Table 1: **Toyo's scrubbing technologies**

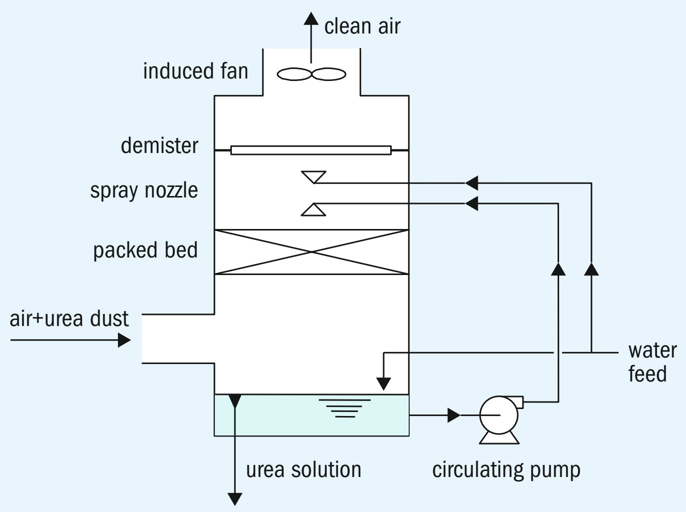
Scheme	Water scrubbing	Acid scrubbing		
		Option-1 Single stage acid scrubbing	**Option-2 Double stage acid scrubbing**	**Option-3 Acid scrubbing without by-product (ammonium salt)**
Toyo references	43 plants	3 plants	4 plants	1 plant
Required acid (98% H_2SO_4)	none	1 kg/t urea	1 kg/t urea	1 kg/t urea
By-Product	none	45% ammonium salt solution: 90 kg/t urea	40% ammonium salt solution: 5 kg/t urea	None
Urea product	urea	urea	urea	urea + AS (0.2 wt-%)
Recovery of urea dust	as urea product	as by-product	as urea product	as urea product
Recovery of ammonia	None	as by-product	as by-product	as urea product
Ammonia emission	ammonia in urea melt is emitted	< 20 mg/Nm³	< 20 mg/Nm³	< 20mg/Nm³

Source: Toyo


AM
MO
NIA
UR
EA
SYNGAS

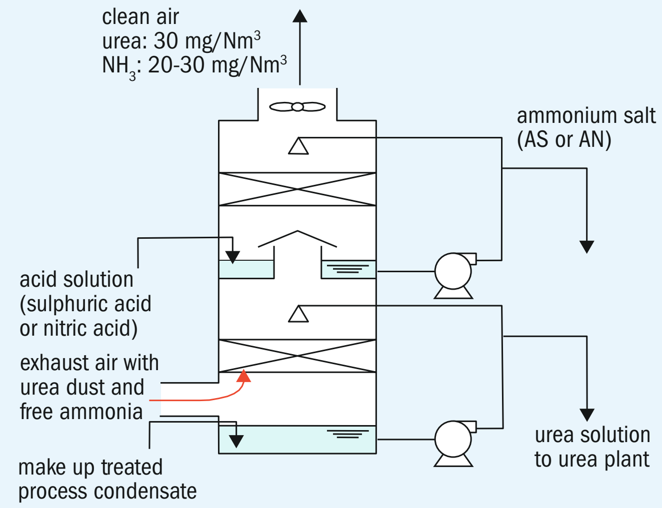
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

Fig. 1: **Dust scrubbing system**



Source: Toyo

Fig. 2: **Double stage acid scrubbing system**



Source: Toyo

(upper) second stage. This system option does allow urea to be recovered as a separate product. This scheme is suitable for plant which need to minimise by-product or configured to produce ammonium nitrate (AN) or ammonium sulphate (AS).

Toyo acid scrubbing without by-product

In this system option, ammonia present in exhaust air is absorbed by sulphuric acid in an acid scrubbing system and recovered in combination with urea as UAS. A small independent evaporator concentrates the recovered UAS solution. This is then sent to the urea finishing section where it is added to the urea feed.

This setup eliminates ammonium sulphate (AS) as a by-product by incorporating it within the urea production process. The final urea product obtained, which contains 0.2-0.3 wt-% AS, contains sulphur as an additional crop nutrient. This system option is suitable for plants producing urea for the agricultural market, particularly when there is no scope for producing by-products other than the main urea product.

Large-scale projects with dust scrubbing systems

Toyo has been awarded a number of major urea granulation plant contracts in recent years. Two notable examples that incorporated Toyo scrubbing systems are the large-scale Kaltim No 5 project (3,500 t/d) in Indonesia for PT Pupuk Kalimantan Timur (Kaltim), and another world-class project (4,000 t/d) in Nigeria for Indorama Eleme Fertilizer and Chemicals Limited (IEFCL).

Kaltim No 5 project, Indonesia

In 2011, Toyo was awarded a contract by Kaltim to construct a 2,500 t/d ammonia plant and 3,500 t/d urea plant. Kaltim is a subsidiary of the state-owned PT Pupuk Indonesia Holding Company. The urea plant was designed using Toyo's *ACES21*® urea process and spout-fluid bed granulation. It is the largest single-train ammonia/urea complex in Southeast Asia. A Toyo water-scrubbing system for urea dust was also installed.

Toyo provided engineering, procurement and construction (EPC) for the whole complex on a turn-key, lump-sum basis in collaboration with PT Inti Karya Persada Tehnik, a Toyo subsidiary company. Urea production at the plant began in early 2015. A performance test for the ammonia/urea complex was carried out in the same year with excellent results (Table 2).

Indorama project, Nigeria

A contract to build the world's largest single-train ammonia and urea complex in Nigeria was jointly awarded to Toyo and its consortium partner Daewoo Nigeria Limited by IEFCL. The complex, which has a design capacity of 2,300 t/d for ammonia and 4,000 t/d for granulated urea, became operative in mid-2016. It consumes locally-available natural gas as a feedstock and uses licensed KBR technology for its ammonia process and licensed Toyo technology for urea production.

Table 2: **Urea plant performance of Kaltim No 5 urea plant**

Production capacity, t/d	**3,545**
Product quality	
Total nitrogen content, wt-%	46.2
Biuret content, wt-%	0.9
Moisture content, wt-%	0.3
Granule size, wt-%	
2 to 4.76 mm	97.2
less than 1 mm	0
1 to 2 mm	3.0
above 4.76 mm	0
Urea dust emission, mg/Nm³	**21**

Source: Toyo

Table 3: **Urea plant performance of IEFCL urea plant**

Production capacity, t/d	**4,003**
Product quality	
Total nitrogen content, wt-%	46.4
Biuret content, wt-%	0.8
Moisture content, wt-%	0.3
between 2 to 4 mm	93
Urea dust emission, mg/Nm³	**7**

Source: Toyo

The urea finishing section incorporates a Toyo double-stage acid scrubbing system (Figure 2) to achieve urea dust emissions of less than 10 mg/Nm³ (Table 3).

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Kimre/UFT/tkIS horizontal cross flow scrubber

thyssenkrupp Industrial Solutions (tkIS) was awarded the contract for three new urea plants in the US, two located in Iowa and the other located in Louisiana. These three granulation plants have a capacity varying between 1,200 t/d and 3,500 t/d. All three plants use fluidised bed granulation technology licensed by Uhde Fertilizer Technology (UFT) and scrubbing technology developed by Kimre, tkIS and UFT.

At the same site, in addition to the new 3,500 t/d granulation plant completed and commissioned by tkIS, new scrubbers were retroffitted at two urea Spherodizer plants. These were required to reduce emissions and stack opacity and maintain overall site emission limits.

For the new plants, the dust emission limits required by the EPA were extremely challenging (Table 4) and well below previous requirements. For the first time, limits on stack plume visibility also had to be guaranteed. While the permits did not regulate the ammonia emissions from the urea granulation stacks, overall site ammonia limits did still need to be met. This necessitated limits on ammonia emissions from the fluidised bed granulation plants.

The operating permits for US plants require emission limits for dust down to 0.1 lb/st, corresponding to metric values of less than 9 mg/Nm³. Existing emissions reduction technologies are generally not able to meet such stringent requirements.

The visibility (opacity) of the stack plume generated by fluidised bed granulation is largely determined by two factors: the aerosols formed by urea isomers and the amount of fine particles below PM2.5 in the off-gas from the granulator. The latter, although only present in small quantities, have a large influence on the visibility of emissions due to their large surface area. The main challenge arising from the new emission limits is removing very small particles (PM2.5) and aerosols from the off gas.

The horizontal scrubbing system installed in the three new plants in the US were jointly developed by Kimre, tkIS and UFT. This consists of the following stages (Figure 3):

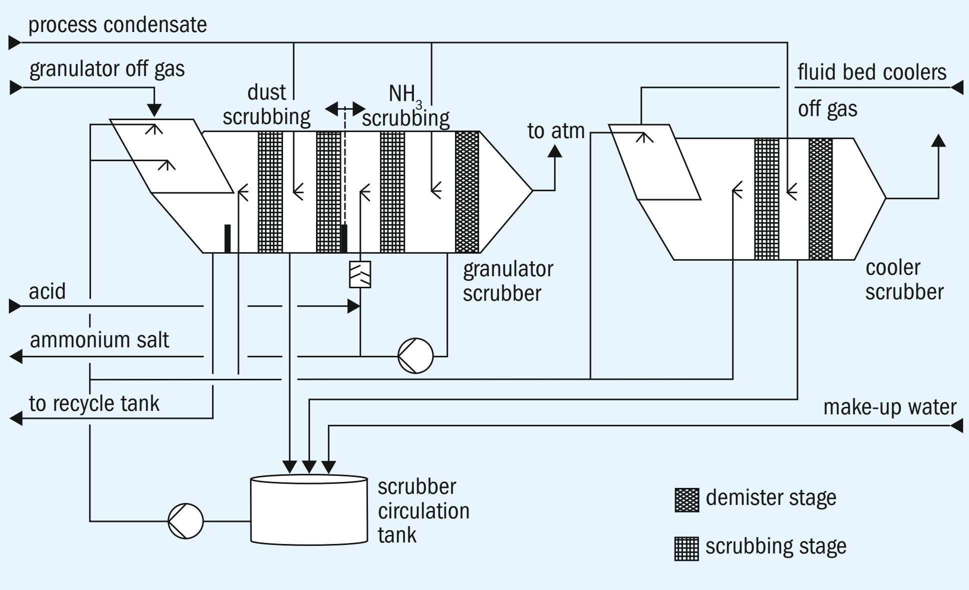
- Quench stage
- One to two dust stages, depending on emission limits
- Acidic NH_3 removal stage (optional)
- Separation stage

Table 4: **US emission limits**

Source	Urea dust	NH_3
US EPA (2014)	< 8.3 mg/Nm³ (< 0.11 lb/st prod)	< 30 mg/Nm³

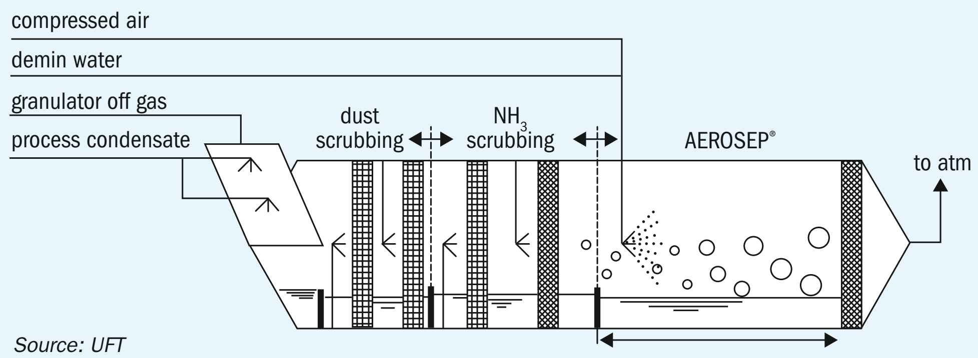
Source: UFT

Fig. 3: **UFT/Kimre advanced scrubbing system**



Source: tkIS/UFT

Fig. 4: **Horizontal cross-flow scrubber with added AEROSEP® stage**



Source: UFT

- *AEROSEP®* stage, if required to reduce plume visibility

The scrubber system shown in Figure 3 is for a large plant which requires separate granulator and cooler scrubbers. Smaller plants, can be designed with just one scrubber using the same simple process design.

Kimre's *AEROSEP®* system (Figure 4) can be incorporated to meet 'zero opacity' or 'no visible emissions' requirements. This system removes mist and particulates in a step-wise approach and is preferably installed between the acidic stage and the final demister. It is specifically designed to collect submicron particulates, or aerosols, using a combination of particle growth and particle removal. Used in combination with the horizontal cross-flow scrubbing system, the *AEROSEP®* stage allows compliance with all known requirements for dust, ammonia, PM2.5 and plume visibility.

CF Industries, Donaldsonville plant

tkIS and Kimre carried out pilot plant tests before finalising the detailed design of the granulator and cooling scrubber system for the new CF Industries, Donaldsonville plant site in Louisiana. These pilot plant tests were then scaled-up by about a factor 100 to for the commercial plant.

Table 5: CF Industries urea granulation installation air permit requirements and results

	Air permit requirements	Test results
Particulate matter (filterable), lb/h	29.67	1.63 (equiv. to 12.6 mg/Nm³ dry)
Opacity, %	< 20	3.8

Source: Kimre

The air flow of this large-scale granulation plant is about 800,000 cubic meters per hour and the inlet contamination is in the range of 90 kg/h for ammonia and more than 5 t/h for urea dust. The dimensions of the granulator scrubber are impressive: 11.3 x 6.8 x 16 m (H x W x L).

The three plants with installed Kimre horizontal scrubbers were completed during 2015 and 2016. Emissions tests (Table 5) were carried out for the EPA after start-up, once operations were stabilised. The particulate matter content of 1.63 lb/h – an average of three test runs of 1.45 lb/h, 1.71 lb/h, and 1.73 lb/h – is equivalent to 0.87 mg/Nm³. This is ten times lower than the most stringent emissions requirement to date, 10 mg/Nm³.

The total pressure drop over the granulator scrubber (including inlet and outlet) in the recently commissioned granulation plant is only 670 mm WC, a very low value when compared to other emission reduction systems. This is a remarkable achievement given the extremely low emission figures achieved and the granulator's huge air flow.

Two smaller urea Spherodizer plants are also located at the Donaldsonville site. The existing scrubbers for these plants were also replaced with Kimre horizontal scrubbers equipped with a dust stage and an *AEROSEP*® stage.

Stamicarbon scrubber technology

Stamicarbon, the innovation and license company of Maire Tecnimont Group, and EnviroCare International (ECI) have co-developed a multi-stage gas scrubber for granulators and prill towers. This innovative, high-performance scrubber is designed to remove urea particles and ammonia gas at extremely high efficiencies. It is capable of meeting most stringent emission levels, while minimising energy consumption by keeping pressure-drop low.

The submicron dust generated during granulation can cause unacceptably high emissions. While pre-existing technologies can easily scrub larger particles, a new approach was required to capture submicron dust – as well as remove ammonia efficiently via the injection of an acid solution.

The *EnviroCare MicroMist™ Venturi Scrubber* for granulation has been described previously (*Fertilizer International* 482, p23) and comprises of multiple stages that progressively treat and clean the off-gas (Figure 5):

1. Concentrated urea quench
2. Diluted urea quench
3. Conditioning trays (optional)
4. *MicroMist™ Venturi* (MMV) tubes
5. Acid treatment for NH_3 capture
6. High efficiency mist eliminator stage

The MMV granulation scrubber can easily achieve a dust removal efficiency in excess of 99.9 percent. Even lower emissions can be obtained, if desired, by the additional integration of a wet electrostatic precipitator (WESP).

Granulation installation experience

The MMV scrubber has been installed, in combination with Stamicarbon's urea melt and fluidised bed granulation technology, in multiple greenfield projects of which two are in operation. These latter two projects involved:

- A MMV scrubber and WESP at a urea granulator (Figure 6)
- A rectangular modular MMV scrubber at a 1,000 t/d urea granulator (Figure 7)

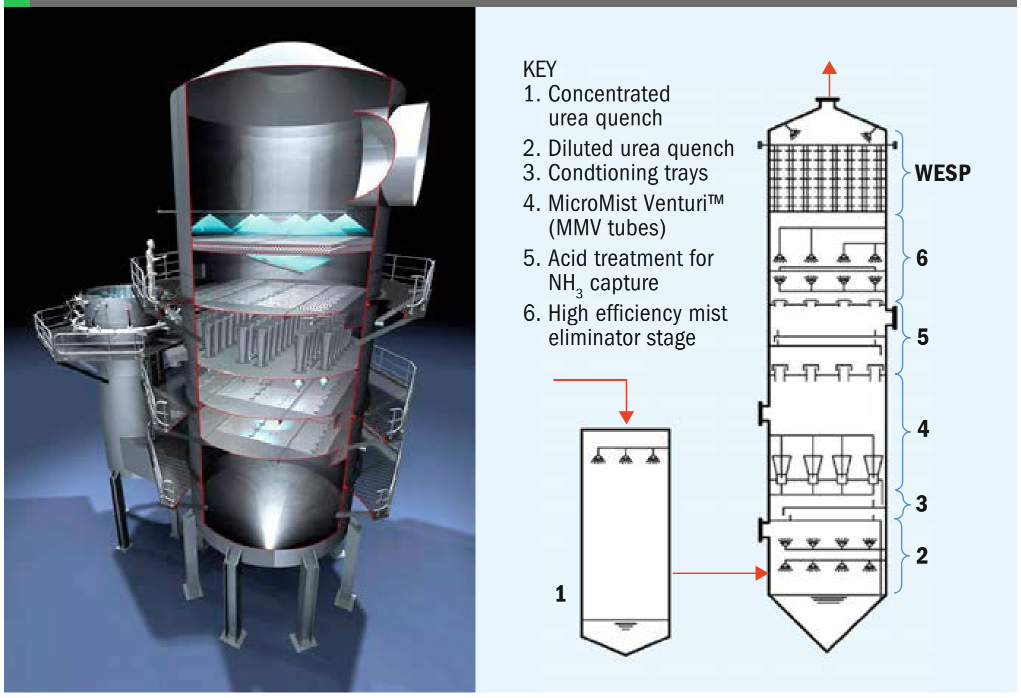
In both cases, MMV scrubber technology was selected because of very stringent emission requirements needed to obtain a new operating permit.

The same kind of scrubber technology can also be applied in retrofits, thereby replacing parts of previously-installed granulator scrubber and granulator cooler scrubber vessels fitted with multiple tray stages and mist eliminators.

Essentially, the base of the existing scrubber is left in place during a retrofit while the upper part is replaced by inserting a new modular MMV section. The spool scrubber shell (including design and engineering, venturi tubes, DOI trays, nozzles and mist eliminator) and the extra pumps, valves and instruments required can be provided by Stamicarbon. This scrubber dust revamp option, without any additional ammonia scrubbing stage, can achieve a dust removal efficiency in excess of 99.9 percent.

Integrating a large scrubbing system within a urea granulation plant is a highly complex undertaking that requires regular communication with the detailed engineering contractor. Having the correct technical specialists available for problem solving

Fig. 5: Representative scrubber 3D (left) and sectional views (right) with six stages schematically indicated



SOURCE: STAMICARBON

PHOTOS: STAMICARBON

Fig. 6: Construction phase of a MMV scrubber/WESP installation for a urea granulator.

Fig. 7: Construction phase of a rectangular modularized MMV scrubber installation for a 1,000 t/d urea granulator.

during all phases – conceptual design, detailed design, fabrication, shipping, erection and start-up – is also critical. All of the scrubber's internals can be pre-installed and trial fitted. This allows the total assembly to be inspected and tested by Stamicarbon and ECI before being shipped to site.

Stamicarbon jet venturi scrubber technology for prill towers

The off-gas discharged from prilling towers contains urea dust with an extremely large surface area. This creates a highly visible, persistent purple-white plume that does not mix well with the atmosphere nor dissipate easily. Because of this, environmental regulations for prill tower emissions are becoming stricter. Allowable emission levels are currently 50 mg/Nm^3 maximum for dust and 50 mg/Nm^3 maximum for ammonia within Europe, and are even more stringent in other regions. Exceeding these levels could result in a forced plant closure.

There is an economic preference when it comes to adapting Stamicarbon/ECI scrubber technology to prill towers: the scrubber should, if feasible, be placed on top of the prill tower. The option at ground level is expensive due to the additional ductwork required to bring the flue gas down to the ground. The fan, structural steel and the stack needed also add to the overall expense. Moreover, serious operational issues with clogging have been reported in the duct work. In contrast, installing Stamicarbon/ECI's newly-developed jet scrubber on the prill tower roof is a more reliable and less expensive option, as the technology is much lighter and does not require an additional fan.

In the Stamicarbon/ECI prill tower jet scrubber, off-gas is progressively treated and cleaned in three compact stages (Figure 8):

1. Concentrated urea quench and jet scrubber (bottom)
2. Lean urea jet scrubber (middle)
3. Acid treatment for NH_3 capture (top)

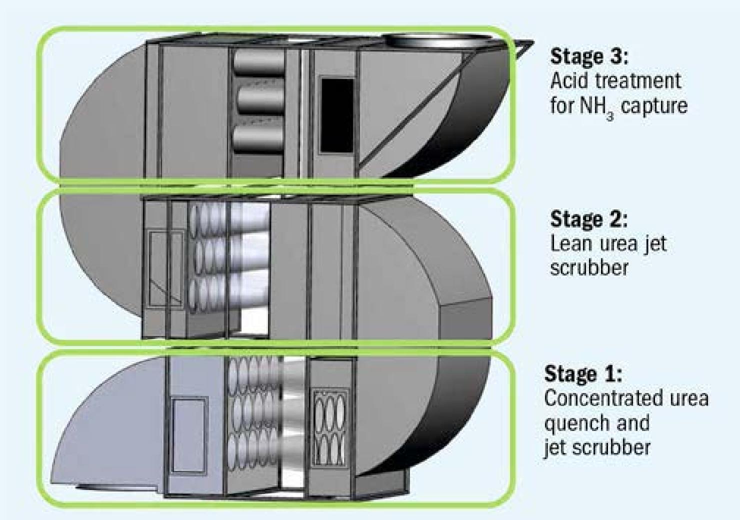
A high efficiency mist eliminator is placed between each stage.

Jet venturi scrubber experience on prill towers

An industrial pilot test was carried out on the roof of a urea prill tower using a single jet scrubber (Figure 9). The aim was to be in compliance with the current emission legislation. As a consequence, fumes in the waste gas would become invisible to the naked eye. To achieve this objective, the dust content needed be reduced to below 20 mg/Nm^3, requiring a dust collection efficiency of more than 85 percent. The pilot system included both dust capture stages (concentrated urea and dilute urea sections) but omitted the third ammonia capture stage, which is considered straightforward to achieve compared to dust emission.

The scrubber's jet effect cleaned the dust in the off-gases without pressure loss in the gas flow. This eliminated the mechanical ventilator usually needed to convey off-gases. The quenching effect at the entrance of the jet scrubber also cools down the off-gas. The lack of movable parts makes the jet scrubber very simple to operate. It is also very easy to clean, inspect and repair. The concentrated urea blow down solution can also be circulated for reuse, and returned to the urea manufacturing plant.

Fig. 8: **Scrubber cutaway view with three stages indicated**



Source: Stamicarbon

PHOTO: STAMICARBON

Fig. 9: Pilot Jet Scrubber located on top of prilling tower for emissions testing.

Potato crop nutrition

More than 350 million tonnes of potatoes are harvested each year for food processing or direct consumption. Potatoes have a particularly high potash requirement and are also a notably chloride-sensitive crop. We look at the nutrient needs of this globally-important dietary staple.

Production and consumption

The potato (*Solanum tuberosum*) is one of the world's most widely-cultivated dietary staples. Potato plants are herbaceous annuals which grow up to one metre (40 inches) in height and produce harvestable tubers – thickened stems – enriched in starch.

Grown in about 130 countries and consumed by more than one billion people, the potato is the third most important food crop after rice and wheat. When boiled, a single medium-sized potato provides about half an adult's daily vitamin C requirement along with significant amounts of vitamin B, iron, potassium and zinc.

The potato is also more agriculturally productive than most food staples, yielding 2-4 times the food value of grain crops per hectare. It is also surprisingly water-efficient, producing more food per unit of water than any other major crop.

World potato production has increased by almost 30 percent over the last decade, growing from 297 million tonnes in 2006 to 377 million tonnes in 2016 (Figure 1). Production is highly concentrated with the world's top 10 producers accounting for almost 70 percent of global production (Figure 2). China has emerged as the world's major producer in recent decades with production exceeding 99 million tonnes in 2016. That is equivalent to more than one-quarter of global production – and is more than double the production of India, the world's second largest potato grower.

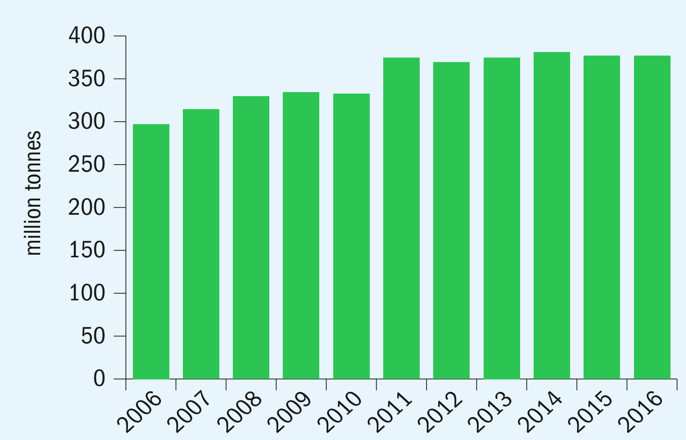
International trade in potatoes is relatively small compared to production, as the majority of the crop in large-producing nations is consumed domestically. The top 10 potato exporting countries placed 8.8 million tonnes on international markets in 2016, a volume equivalent to just two percent of world production. EU countries do, however, export a significant proportion of their production, with France, Germany, the Netherlands and Belgium collectively exporting 6.2 million tonnes in 2016.

Origin and types

Potato plants originated in the highlands of South America, a region that is now part of Peru and Bolivia. Although widely cultivated globally, commercial production is concentrated between latitudes 25° and 55° north and 5° and 40° south. Three main types of potato are grown, reflecting their different end uses:

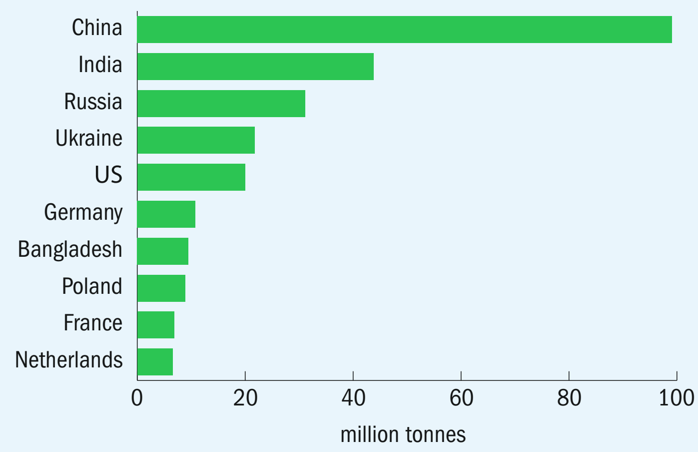
- **Seed potatoes** are tubers specifically grown for commercial planting and cultivation. They need to be disease-free and provide consistent and healthy plants.
- **Ware potatoes** are grown for human consumption and divide between two end markets: **fresh market potatoes** are sold for direct household consumption while **processing potatoes** are bought by food manufacturers to make chips, crisps, flakes and granules.
- **Industrial potatoes** are those grown for non-food uses such as starch production.

Fig. 1: **World potato production, 2006-2016**



Source: FAO

Fig. 2: **Top 10 world potato-producing countries, 2016**



Source: FAO

The quality characteristics required of potato crops depend on their intended end-use. Potatoes grown for processing, for example, are valued for yield, dry matter content, size and shape. Dry matter content is particularly important as it improves frying properties and flavour.

Growing conditions

Potatoes are ideally grown on well-drained, organic-rich, sandy soils or loams. Sowing is in the spring after the risk of frost has passed. Plants are grown in ridges and earthed-up (hilling) during the growing season to protect the crop from light. Planting density is typically 4,000-5,000 tubers/ha.

Water consumption over the entire growing season usually varies between 4,000-6,000 m³/ha. In rainfed cultivation, potatoes need 500-750 mm of rainfall supplemented by additional supply of irrigation water depending on weather conditions. The irrigation of potatoes in a temperate climate requires 1,000-2,000 m³/ha of water applied by centre pivot or boom sprinkler equipment. For potato growing in a Mediterranean climate, water is supplied by furrow, sprinkler or drip irrigation, depending on water availability. In arid regions, around 4,000 m³/ha of water needs to be supplied by drip irrigation.

Table 1: **Nutritional requirements of potato**

Expected yield (t/ha)	Tuber removal by yield (kg/ha)					Uptake by whole plant (kg/ha)				
	N	P_2O_5	K_2O	CaO	MgO	N	P_2O_5	K_2O	CaO	MgO
20	38	18	102	2	2	105	28	146	29	19
40	76	36	204	4	4	171	50	266	42	28
60	114	54	306	6	6	237	72	386	55	37
80	152	72	408	8	8	303	95	506	68	46
100	190	90	510	10	10	369	117	626	82	55
110	209	99	561	11	11	402	128	686	88	59

Source: Haifa

Nutrients: essential for yield and quality

Potassium is the nutrient removed in the greatest quantity by potato. The crop also requires large applications of nitrogen and appreciable calcium, phosphorus, magnesium and sulphur.

At harvest, a good crop of potato tubers removes around:

- 100 kg/ha of nitrogen (N)
- 50 kg/ha of phosphorus (P_2O_5)
- 300 kg/ha of potassium (K_2O)
- 20 kg/ha each for both calcium (CaO) and magnesium (MgO)

At very high yields (80 kg/ha), total plant uptake (tubers and haulm) of nitrogen and potassium can be more than 300 kg/ha and 500 kg/ha, respectively (Table 1). Maximum nitrogen and potassium uptake in potato usually occurs 95-120 days after planting. Studies suggest that nitrogen uptake is most rapid during tuber initiation and set (50-70 days after planting) and then falls back during tuber bulking (70-90 days after planting).

Nutrient availability influences potato yield and tuber size, as well as important commercial characteristics such as tuber quality, skin finish, storage life and cooking quality. Tuber quality includes properties such as dry matter content, starch content and cooking ability.

Potassium, calcium, magnesium and boron all have a positive effect on tuber

Chloride sensitivity

Potatoes are a notably chloride-sensitive crop. Large applications of MOP (potassium chloride, KCl) at planting can have harmful effects on crop emergence in dry soils. Signs of chloride damage to plants include scorched leaf tips and margins, and yellow, distorted leaves.

Chloride-free potassium fertilizers such as SOP (potassium sulphate, K_2SO_4) and NOP (potassium nitrate, KNO_3) are therefore often used in preference over MOP and are associated with increased yields and quality improvements. SOP, for example, is associated with increased tuber dry matter – a quality much valued by potato processors.

Although potato's chloride sensitivity is well known, some types are more affected than others. Processing potatoes and starchy types are classed as chloride-sensitive, for example, while seed potatoes and ware potatoes are more chloride tolerant.

SOP manufacturers such as Tessenderlo Kerley International (*GranuPotasse*, *SoluPotasse*, *K-Leaf*) and Compass Minerals (*Protassium+*) highlight the low-chloride benefits of SOP for potato and its ability to provide sulphur. Even K+S, a major MOP producer, concludes that: "The nutrient potassium (as potash) is best applied exclusively in the sulphate form since potatoes are susceptible to chloride toxicity." Similarly, NOP suppliers such as Haifa Group (*Multi-K*), SQM (*Qrop K*) and KEMAPCO promote the low-chloride benefits of NOP as well as the advantages of supplying nitrogen in nitrate form.

Most of the above companies have demonstrated these advantages through agronomic trials. The use of SOP is also recommended by the following agronomists and potato industry experts:

François Laurent, an agronomist at French plant research institute Arvalis: "For potatoes, there are two main reasons why the supply of potassium in the sulphate form is preferable. Its effect on the percentage of dry matter is undisputable and, in addition, it provides a readily available source of sulphur, an element that is becoming more and more limited."

Gérard Tropato, an agronomist for potato processing giant McCain: "For the production of chips, our key quality criteria are calibre, percentage of dry matter and level of reducing sugars. Sulphate of potash is the preferred form where levels of dry matter tend to be weak, such as in the northern part of France. It is also the recommended form if fertilizer is applied at planting or during the vegetative growth stage"

Rob Clayton, strategy director at the AHDB Potato Board, the successor to the UK Potato Council: "We have produced a handy reference guide which includes recommendations for potassium fertilization and is distributed to all registered potato growers in the UK. Numerous fertilizer trials funded by the Council over many years indicate that an application of potassium in the autumn, or using potassium sulphate rather than potassium chloride, are both likely to result in a higher dry matter content" storage and cooking quality by reducing tuber bruising, enzymatic blackening and discoloration. In general:

- Nitrogen encourages leaf and tuber growth and promotes starch production
- Phosphorus maintains leaf and tuber growth and influences starch quality and content
- Potassium promotes water uptake and dry matter production and helps reduce bruising
- Calcium reduces internal rust spot and black spot
- Magnesium enables photosynthesis and promotes good growth
- Boron helps reduce internal rust spot and blackening

Potato plants require a different mix of nutrients during their five growth stages (Figure 3):

- Sprout development
- Early vegetative growth
- Tuber initiation
- Tuber bulking
- Maturation

Adequate nutrient supply is particularly important during the critical tuber bulking stage. Tubers can grow by as much as 1,000-1,500 kg/ha each day over this period. To maintain growth at this rate, potato tubers require a daily N, P and K supply of up to 4.5 kg/ha, 0.3 kg/ha and 6.0 kg/ha, respectively, during bulking.

Both potassium and nitrogen are needed throughout vegetative growth, tuber initiation and bulking. Potassium requirements during the tuber bulking stage are especially high.

Overall, potato crops usually require 50 percent more potassium than nitrogen, and 4-5 times more potassium than phosphorus. Potatoes plants, for example, will typically remove 266 kg/ha of potassium, 171 kg/ha of nitrogen and 50 kg/ha of phosphorus, for a crop yield of 40 t/ha (Table 1).

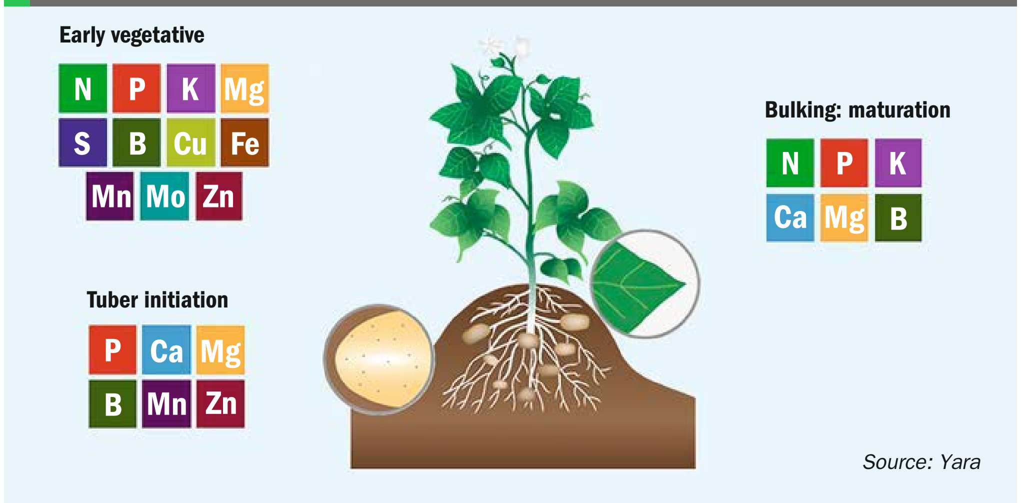
Nitrogen for growth

Ensuring a harvest of high-yielding and high-quality potatoes requires good nitrogen management, as application rates and timings have an important influence on potato yields, tuber size and quality characteristics. Trial results suggest that, on average, applying up to 100 kg/ha of nitrogen increases potato yields by around 20 percent.

Nitrogen is important for both leaf and tuber growth – and supports early vegetative growth in particular. Excess soil nitrogen later in the season can, however, suppress tuber initiation, reduce yields and reduce dry matter content. Too much nitrogen can also delay tuber maturity and result in poor skin set.

Nitrogen, by helping build and maintain a healthy leaf canopy, has a positive influence on tuber bulking rate and average tuber size. Importantly, it helps maintain size and uniformity, commercially-valuable characteristics in seed, ware and processing potatoes.

Fig. 3: **Nutrients required at each potato growth stage**



Phosphate for rooting and set

The phosphorus requirement of potatoes is frequently higher than that of many field crops due to their high nutrient demand and relatively shallow root system. Phosphorus is needed in relatively large quantities during early growth to encourage rooting and tuber set, and again later in the season for bulking. Yara reports that foliar treatments, applied after tuber initiation, increase tuber size and yields.

Potassium for high yields

Potato plants remove potassium in large quantities throughout the growing season and good availability is critical for high yields. A potato crop will remove around six kilos of potassium (K_2O) per tonne of tuber yield. The nutrient plays a key role in the movement of sugars from leaves to tubers and helps transform plant sugars into starch. Potassium has a positive effect on:

- Canopy health
- Efficiency of nitrogen fertilization
- Water balance of plants
- Tuber yield

Potassium also improves commercially-valuable quality characteristics by:

- Preventing discolorations such as internal blackening and blackspot
- Increasing citric acid content, vitamin C content and starch content of tubers
- Decreasing the sugar content of tubers – important for the processing industry
- Improving harvest and storage characteristics by reducing susceptibility to bruising

In contrast, potassium deficiency reduces the yield, size and quality of the potato crop. It also impairs resistance to disease and weakens tolerance to drought and frost. A lack of adequate potassium is also associated with low dry matter content in potatoes.

Calcium and sulphur for strong skin

Calcium affects tuber bulking rate and is essential during the rapid growth phase of tubers. Calcium, by strengthening tuber skins, also improves resistance to black scurf, silver scurf, powdery scab or common scab. Sulphur also reduces common scab and is taken up during all potato growth stages.

"Skin finish is becoming more important as consumers increasingly demand potatoes with clean, attractive skins, particularly when buying pre-packed or loose potatoes," comments Yara. "Tubers with surface diseases are not only less attractive, they are likely to have a reduced storage life."

Magnesium for size

Magnesium is needed during tuber bulking, and both tuber size and yield can be reduced if supply is restricted. Indeed, severe magnesium deficiency can reduce yields by as much as 15 percent. Together with manganese, magnesium also increases the concentration of valuable citric acid and vitamin C in tubers and improves resistance to discolouration during processing.

Vital micronutrients

Of all the micronutrients, potato plants require boron the most – due to its positive influence on root and shoot growth, plant development and pollination. It is generally required for good skin quality and tolerance to drought and heat, while a lack of boron can reduce both yield and quality.

Boron deficiencies in potato result in internal brown spots, black spots, brown centres and hollow hearts. Boron also enhances calcium uptake and mobilisation within plants, thereby helping to reduce levels of common scab and other tuber diseases.

Manganese and zinc also help maximise yields. Zinc plays a key role in nitrogen assimilation, plant metabolism and starch formation. It also helps minimise powdery scab. Supplying molybdenum can be important in acid soils.

Application methods

Fertilizers are frequently applied to potato crops using a combination of some or all of the following methods:

- **Side-dressing:** banded applications at or after planting.
- **Foliar application:** foliar sprays are not usually the primary way of providing crop nutrients, but are a useful way of correcting mid-season deficiencies. Micronutrients are also commonly applied by foliar treatment.
- **Fertigation:** this uses water-soluble fertilizers to efficiently and precisely supply nutrients (N, P, K, S and others) through drip irrigation systems. Nutrients are generally applied on the basis of plant tissue (petiole) test results.

Fertilizer recommendations

Nitrogen is normally applied to the seedbed at or prior to planting. Applications are generally split on sandy soils: part of the total nitrogen requirement is applied prior to planting with the remainder applied later in the season, either by side-dressing or fertigation. Splitting applications in this way helps reduce leaching losses and increase uptake and tuber yields.

Petiole analysis during the growing season helps growers to determine the nitrogen status of the crop and whether supplementary applications are necessary. Planting winter cover crops helps recover residual nitrogen during the winter.

Maintaining the correct ammonium/nitrate balance is important at planting time, according to Haifa. Too much nitrogen in ammonium form is disadvantageous, advises the company, because it promotes Rhizoctonia disease. The nitrate form of nitrogen, in contrast, enhances calcium, potassium and magnesium uptake, and can elevate dry matter content. Yara also recommends balancing the ammonium and nitrate forms of nitrogen at planting.

Broadcast application of **potassium** prior to planting is most commonly recommended. If band-applied, rates should be kept below 45 kg/ha to avoid salt injury to emerging plants. It is advisable to split dressings 6-8 weeks apart in temperate conditions where large amounts of potassium are applied (>400 kg/ha).

Phosphorus fertilization requirements are usually established by soil sampling prior to planting. Phosphorus is generally applied in spring. Pre-planting applications (broadcast or banded) are generally preferred. Placement needs to be within the root zone to provide the early-season growth required for high yields. If leaf analyses indicate deficiency, water-soluble phosphate (usually 10-34-0) can be applied via the irrigation system for a mid- to late-season boost.

Table 2: **Example fertilizer recommendations for seed, ware and industrial potatoes**

Netherlands, recommended nutrient rates			
Crop use	**N (kg/ha)**	**P_2O_5 (kg/ha)**	**K_2O (kg/ha)**
Seed	90-130	120-180	approx. 200
Ware	approx. 240	120-180	250-400
Industrial	approx. 240	120-180	100-200
France, recommended nutrient rates			
Maturity Group	**N (kg/ha)**	**P_2O_5 (kg/ha)**	**K_2O (kg/ha)**
Early	100-120	60-100	100-200
Second early	80-100	60-100	100-200
Maincrop	60-80	60-100	100-200
New	120-150	100-150	200-250
Storage	150-200	80-110	300-400
Industrial	150-200	80-120	250-300

Source: Tessenderlo

Fertilizer products

Germany's **K+S** markets a number of speciality fertilizer products for use on potato. The company's potato fertilization programme recommends *Patenkali*, (30% K_2O, 10 % MgO, 42.5% SO_3), a magnesium-containing SOP product, at an application rate of 600-1,200 kg/ha. The magnesium sulphate fertilizer *ESTA Kieserit* (25% MgO and 50% SO_3) is also recommended at a typical application rate of 170-200 kg/ha for a 40 t/ha yield.

K+S also recommends a 20-25 kg/ha foliar application of *EPSO Microtop* (15% MgO, 31% SO3, 0.9% B, 1% Mn), a water-soluble, micronutrient-enriched form of magnesium sulphate, during periods of high demand, and to correct or prevent magnesium, sulphur, boron and manganese deficiency in potato. Its ability to combat black spot has been confirmed in field trials.

Chile's **SQM** advises using the NOP product *Qrop* to provide potato with nitrogen in nitrate form. Its water-soluble *Ultrasol SOP*, *Ultrasol K* and *Ultrasol KS* fertigation products can also deliver potassium with sulphur and/or the nitrate form of nitrogen via drip irrigation. *Ultrasol micro Rexene ABC* also delivers chelated micronutrients (Fe, Mn, Cu, Zn, Co, Mg, B and Mo). Boron can also be provided to potato via foliar treatment with *Speedfol B SP*. Other products in SQM's *Speedfol* range can also be used for foliar application of phosphorus, calcium, magnesium and biostimulants.

The high-purity water-soluble MOP product *FERTI-K* (61% K_2O) from **Haifa Group** is used extensively in the fertigation of horticultural and field crops including potato. The company also reports that its NOP fertigation product *Multi-K* increases potato yield and dry matter content rela-

Fertilizing potatoes with *Polysulphate*

Polysulphate is a new multi-nutrient fertilizer mined in the UK. Its characteristics and mix of nutrients make *Polysulphate* especially suitable for potato crops, explains **Dr Patricia Imas**, chief agronomist at ICL Fertilizers.

Unique characteristics

Polysulphate is a natural mined mineral (polyhalite) with a low carbon footprint and is approved for organic agriculture. It is a unique fertilizer product thanks to its nutrient content. Four essential plant nutrients are present: sulphur, magnesium, potassium and calcium. Sulphur is the leading constituent (48% SO_3) together with potassium (14% K_2O), magnesium (6% MgO) and calcium (17% CaO), all in sulphate (SO_4) form.

The fertilizer readily dissolves in soil, making all four nutrients available for plant uptake throughout the growing season. Its prolonged nutrient release pattern also greatly reduces the risk of early season sulphate loss through leaching. *Polysulphate* is also notable for having a very low chloride content, very low salinity index, neutral pH and no liming effect.

The above unique characteristics make *Polysulphate* especially suitable for potato crops, as the product provides four essential nutrients in one single application.

Practical guidelines for potato fertilization

- *Polysulphate* is a low-chloride, sulphate-based source of water-soluble potassium, magnesium and calcium. It is capable of supplying all of the S, Mg and Ca needed by potato crops – and a significant proportion of the potassium removed at harvest – without adversely affecting soil pH.
- 400 kg/ha *Polysulphate* is generally a suitable dressing for potatoes.
- Incorporate straight *Polysulphate* into the seedbed before planting, or apply it as a constituent of a fertilizer blend at planting.
- The dissolution properties of *Polysulphate* means the Ca, K, Mg and S it contains are released gradually, providing the crop with a continual and fresh source of nutrients throughout the growing season.

Potatoes remove very large amounts of potassium at harvest. The proportion not supplied by *Polysulphate* can be applied as MOP (potassium chloride, KCl), ploughed or worked into the soil a month or two before planting. This allows rainfall to move unwanted chloride down through the soil and away from the roots of the potato plant.

Expected benefits

In our global trials, potato crops have shown a very good response to *Polysulphate*, in terms of yield and/or quality. Farmers are now regularly including *Polysulphate* in their fertilization schedules, following the positive results of trials in France, Germany, the Netherlands, Sweden, the UK, Israel, China, Perú and Brazil.

For example, a *Polysulphate* trial in China improved the proportion of large-sized potatoes and increased yield by 7.4 percent. It also raised the farmer's net income by RMB 4,860 per hectare. In a German trial, *Polysulphate* application increased the yield by 11 percent and starch content by four percent. It also reduced the bruising index after storage.

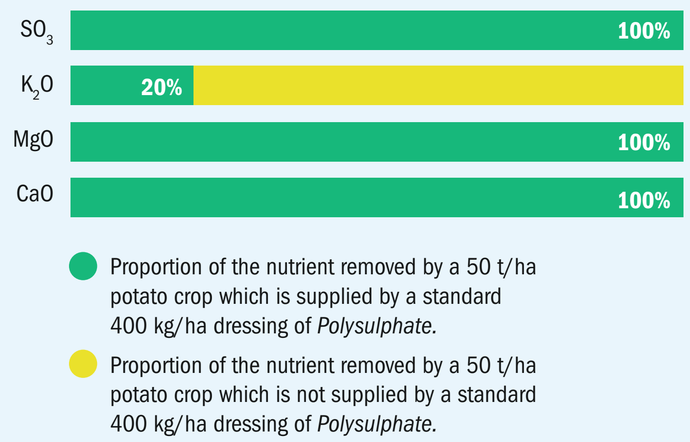
In a Swedish trial, *Polysulphate* increased the yields of all three cooking varieties by 6-11 percent, compared to an equal rate of potassium supplied by sulphate of potash (SOP). Leaf deficiency symptoms for potassium that appeared in the control plot were corrected in the *Polysulphate* plot, which showed green, healthy foliage (see photo).

In general, the application of *Polysulphate* to potato crops will result in:

- Higher yields
- Good skin finish
- Improved dry matter
- Increased nitrogen use efficiency

Swedish potato trial: control plot (left) and polysulphate plot (right).

Fig. 4: **Proportions of nutrients supplied to potato crop by Polysulphate fertilizer: 400 kg/ha application and 50 t/ha yield**



Source: ICL Fertilizers

tive to other sources of potassium. It also improves the shelf life of stored tubers. *Multi-K* can also be applied to the potato crop side-dressed in prilled form. *Haifa MAP* (12-61-0) and *Haifa Cal* (calcium nitrate) are also suitable for supplying calcium and phosphorus to potato as part of a fertigation programme

Controlled release fertilizers (CRFs) are recommend on light soils, where conventional fertilizers are easily leached. Haifa's CRF product *Multicote Agri* is recommended, at an N:P:K ratio of 2:1:3, for pre-plant application to potato. Granules of this polymer-coated NPK product are incorporated into the soil at a depth of 10 cm and at 10 cm distance from the planting row. A single application should supply nutrients throughout the entire growth season.

Potato trials carried out over three years on sandy soils in Quebec with *ESN*, the polymer-coated urea marketed by **Nutrien**, increased marketable tuber yield by 12 percent, compared with calcium ammonium nitrate. *YaraLiva TROPICOTE*, a calcium nitrate fertilizer with a biodegradable coating from **Yara**, can be applied at tuber initiation at a rate of 375-500 kg/ha.

Yara says its compound granular NPK fertiliser product, *YaraMila MAINCROP* (14-14-21), is ideal for potato crops where sulphur is not required. While the company's liquid NPK+S fertilizer (CHAFER 9.4-6.6-11.3 + 5% SO_3) is suitable for establishing potatoes in the spring.

Yara also offers *YaraVita CROPLIFT PRO* a foliar fertiliser containing a range of nutrients (20% N, 14% K_2O, 12.5% SO_3, 8% P_2O_5, 2% MgO) and micronutrients (Mn, Cu, Zn, B, Fe, Mo). This is applied to potato at a rate of 2.5-5 kg/ha at 10-14 day intervals. Yara also offers a wide range of *YaraVita* and *CHAFER* foliar products suitable for supplying nitrogen, potassium and phosphorus.

Tessenderlo Kerley International's *SoluPotasse*, a soluble SOP fertigation product, is widely used for potatoes grown under drip irrigation. The company also offers *K-Leaf*, a new high-quality grade of SOP designed specifically for foliar application. Tessenderlo recommends 2-3 applications of *K-Leaf* at a rate of 8-12 kg/ha starting at tuber initiation. Foliar application of SOP complements soil fertilization, improving both potato yield and quality. Yield and potato size improvements have been demonstrated by *K-Leaf* trials in Egypt, the Ukraine and Poland.

"Foliar spraying is thought to stimulate the plant's metabolism, also leading to a better absorption of nutrients via its roots," comments Tessenderlo. "The result is better nutrient uptake efficiency for all the fertilizers applied."

Compass Minerals is North America's only producer of SOP. Its premium *Protassium+* SOP product is marketed as a field-proven alternative source of potash to MOP – one that delivers potato yield and quality improvements. The company has conducted extensive trials to demonstrate the efficacy of *Protassium+* in potato growing. On average, applying SOP yields 5.1 more tons of potatoes per acre than equivalent MOP applications, according to the company. In a two-year trial in Othello, Washington, applying SOP also increased market value of the potatoes by $771/acre, in comparison to the equivalent MOP treatment.

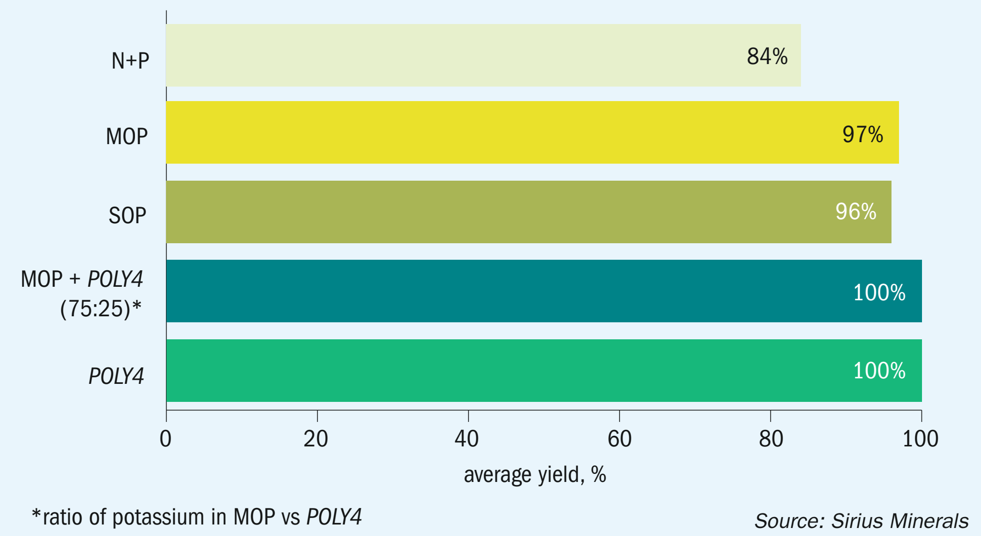
References

1. Mikkelsen, R., 2006. *Best Management Practices for Profitable Fertilization of Potatoes*. Newsletter, Potash & Phosphate Institute (PPI) and the Potash & Phosphate Institute of Canada (PPIC).

Transforming potato fertilizer plans

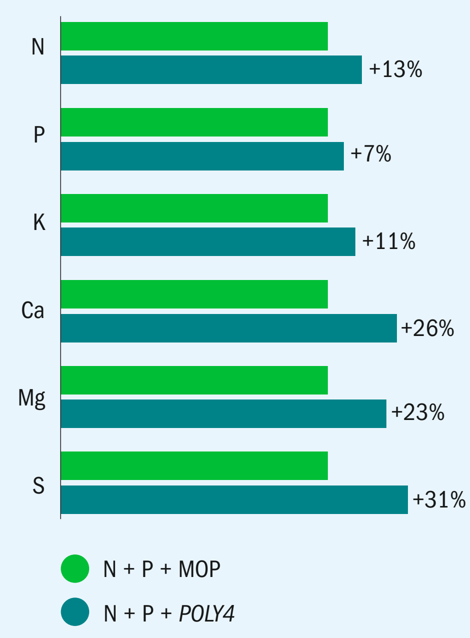
Sirius Minerals has carried out global trials on potato with its polyhalite product *POLY4*. These have been run in partnership with leading agricultural universities, research institutions and commercial partners. **Robert Meakin**, research & development director at Sirius Minerals, explains how *POLY4* can outperform traditional forms of potash in both blend and straight trials.

Fig. 1: **Average *POLY4* performance in potato trials versus other potassium sources**



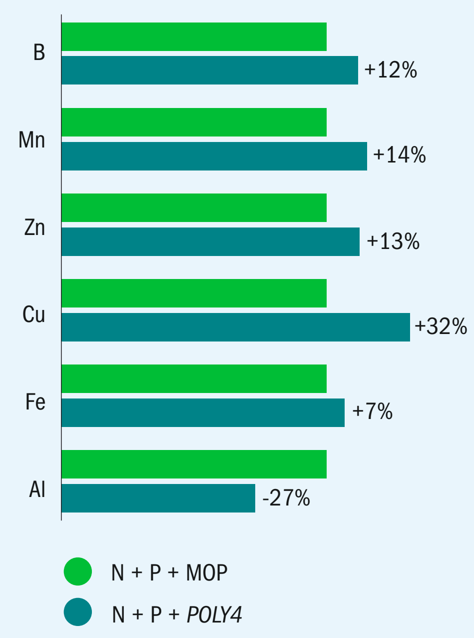
Source: Sirius Minerals

Fig. 2: **Macronutrient uptake with *POLY4* compared to MOP**



Source: Sirius Minerals

Fig. 3: **Micronutrient uptake with *POLY4* compared to MOP**



Source: Sirius Minerals

Sirius Minerals plans to invest up to $3.0 billion in the construction of the Woodsmith Mine, a large-scale, deep-shaft polyhalite mine in England's North Yorkshire region. The mine will eventually produce 10 million tonnes annually of the company's *POLY4* polyhalite product. The first production tonnages are due in 2021, under the current project timetable (*Fertilizer International* 481, p56).

A new option for potato growers

Potatoes are a chloride-sensitive crop. Currently, growers can opt to use potash in the form of either SOP, MOP or NOP to boost tuber quality such as dry matter content.

The arrival of *POLY4* on the market will offer growers a new low-chloride source of potassium. This polyhalite product can also satisfy the sulphur, calcium and magnesium needs of potato crop. In global trials, *POLY4* outperformed traditional forms of potash in both blend and straight applications (Figure 1).

Nutrient uptake

When applied on an equal nutrient basis, trials using *POLY4* as part of a fertilizer plan improved fertilizer use efficiency by increasing nutrient uptake over an extended period. The results presented here were conducted in China, the UK, France, Brazil and the US. They cover not only potato but other high-value and broad-acre crops such as tea, tobacco, soybean, wheat and corn. *POLY4* promoted nutrient release and supported the uptake of a broad spectrum of nutrients. This resulted in marked improvements in both crop yield and quality. Macronu-

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trient uptake improved by up to 31 percent (Figure 2), while micronutrient uptake improved by as much as 32 percent (Figure 3).

Improving potato quality

Inclusion of *POLY4* in fertilizer plans improved potato quality characteristics, including the dry matter content of tubers. This is an important characteristic that attracts a price premium in the potato frying industry. High dry matter content is associated with good fry colour as it influences the oil absorption rate.

Crop varietal selection, planting date, soil type and fertilizer choice all need to be taken into consideration when it comes to improving potato quality. The choice of potassium fertilizer (potash) is not only important for yield, it also has a significant effect on potato quality.

MOP (potassium chloride, KCl) is widely-used as a source of potassium. However, at high rates, it can decrease dry matter content. This effect is mainly due to the presence of the chloride anion. If potassium is instead applied as SOP (potassium sulphate, K_2SO_4) – which is low in chloride – dry matter levels can be increased considerably. Equally, increasing the proportion of potassium supplied by *POLY4* delivers the same improvement.

Furthermore, not only is *POLY4* a highly-effective potassium fertilizer, it also delivers and increases the uptake of sulphur, magnesium and calcium by the potato (Figure 4). This has the following benefits:

- Good sulphur availability ensures efficient use of nitrogen
- Calcium strengthens cell structure, which improves potato skin quality
- Increased magnesium uptake results in larger tubers with greater starch and protein contents

Global potato trials

Brazil: a *POLY4* trial by São Paulo University showed that replacing SSP with *POLY4* and DAP or MAP in a fertilizer plan improved yield. At the recommended rate of 220 kg K_2O per hectare, *POLY4* NPK + S achieved an 18 percent yield improvement over MOP NPK + S. Switching from SSP to *POLY4* for the supply of sulphur also delivered magnesium, further enhancing yield. Valuably, chloride content was lowered by substituting *POLY4* for MOP.

United States: The University of Minnesota assessed the effectiveness of *POLY4* as a fertilizer for potato production in the US. Trials showed that a 50 percent contribution to potassium supply from *POLY4* improved marketable yield by 15 percent over a combination of MOP + gypsum. Moreover, supplying 100 percent of potassium via *POLY4* resulted in a further yield improvement and an increase in the proportion of tubers of marketable size.

Scotland: SAC Consulting carried out *POLY4* potato trials. *POLY4* was used to deliver 25 percent of the potassium contribution to the crop. This increased leaf N, P, K and Ca contents and supplied all of the crop's recommended magnesium requirement. *POLY4* – because of its lower salt index and dissolution rate relative to MOP – increased seedling emergence, ground cover and crop uniformity. This provided better light interception and greater shading of weeds. Earlier establishment of ground cover naturally suppresses weeds which would otherwise compete for nutrients. Improving crop establishment and leaf area index earlier also raises the potential for higher yields.

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India: another potato trial was conducted with Sardar Vallabhbhai Patel University of Agriculture and Technology. The performance of *POLY4* was tested against typical MOP and elemental sulphur fertilizers at recommended local potassium and sulphur application rates. Replacing MOP + S with *POLY4* increased total and marketable potato yields by nine percent. The dry matter of potatoes fertilized with *POLY4* was also seven percent greater than with MOP + S, potentially offering an even greater economic return.

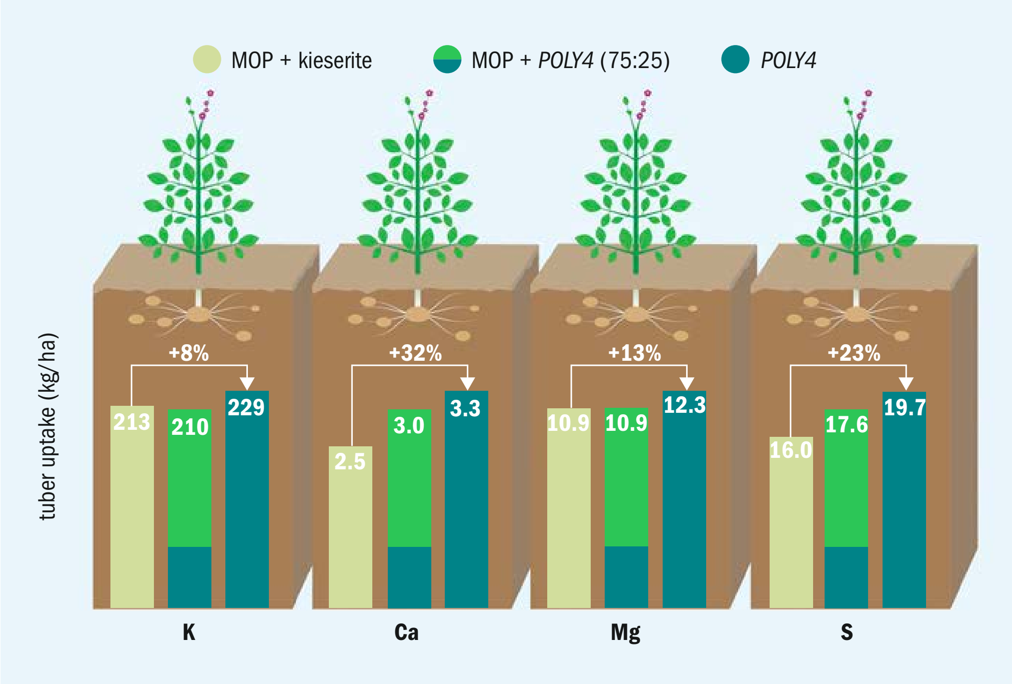
Transforming potato fertilizer plans

The above trials demonstrate that a *POLY4* fertilizer programme offers potato farmers more benefits than MOP-based fertilizer plans. Simply using an MOP and *POLY4* fertilizer plan, as opposed to a conventional MOP and kieserite treatment, supplies a better balance of nutrients (K, S, Mg and Ca) as well as a reduced chloride dose. *POLY4* offers increased flexibility for potato fertilizer programmes, and provides sustained nutrient delivery, reduced chloride application, and decreased fertilizer spreading and total plan cost (Figure 5).

POLY4 can also help resolve the well-known antagonism between soil potassium and magnesium that limits yields for potato growers. *POLY4* can do this thanks to two helpful characteristics: a lower dissolution rate, and its ability to supply magnesium alongside potassium. Most potato farmers will be applying potassium at 200-300 kg/ha (K_2O basis). However, the farmer should expect to supply 20 kg/ha of that 200 kg/ha value (about 10%) as MgO. This MgO application rate can be fulfilled by using *POLY4* to contribute 25 percent of the crop's potash requirement.

Further reading: For detailed references and notes please visit the Agronomy page on www.*poly4*.com

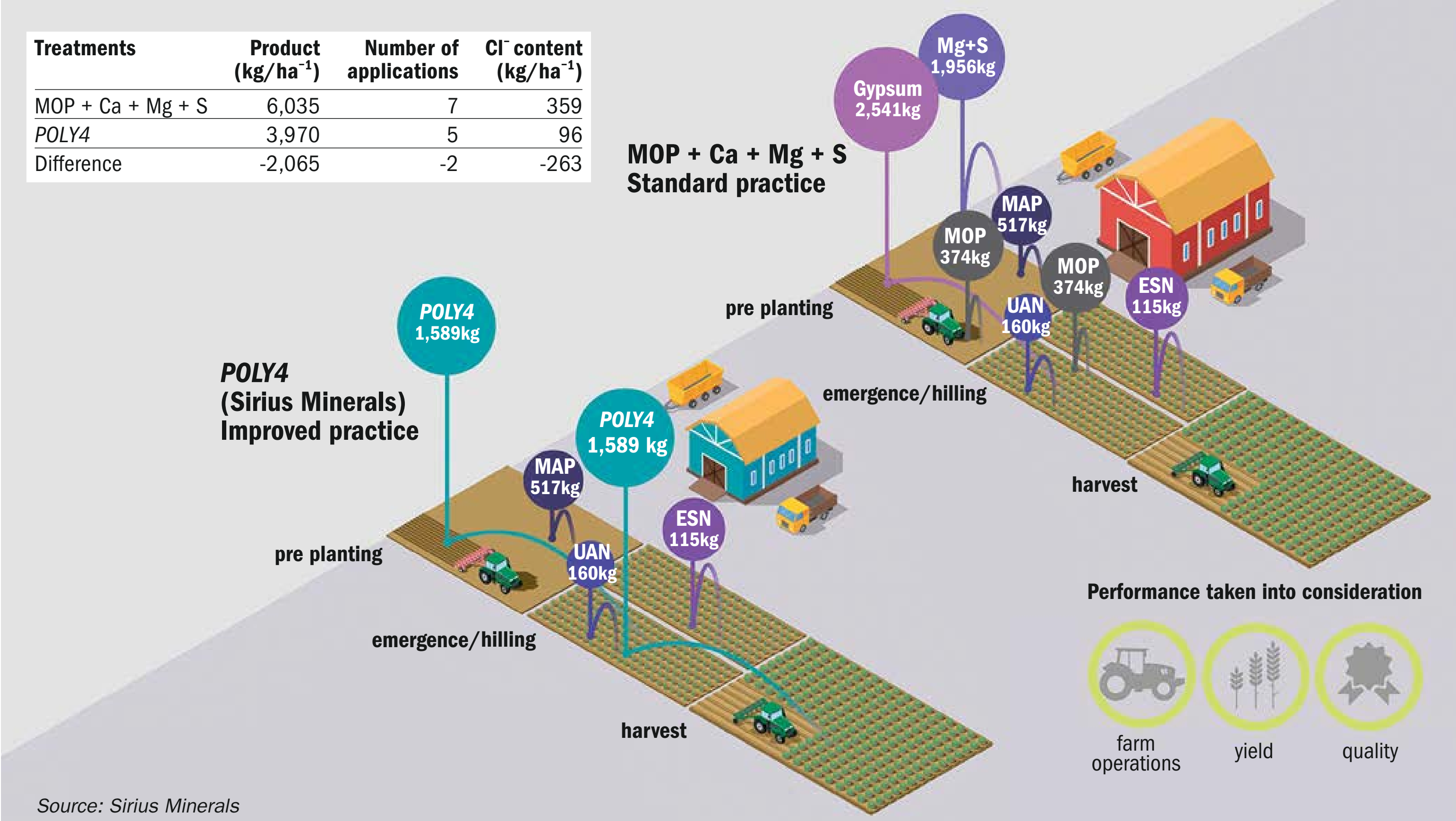
Fig. 4: **Tuber nutrient uptake**



Source: Sirius Minerals

Fig. 5: ***POLY4* potato fertilizer plan: summary of the benefits**

Treatments	Product (kg/ha^{-1})	Number of applications	Cl^- content (kg/ha^{-1})
MOP + Ca + Mg + S	6,035	7	359
POLY4	3,970	5	96
Difference	-2,065	-2	-263



Source: Sirius Minerals

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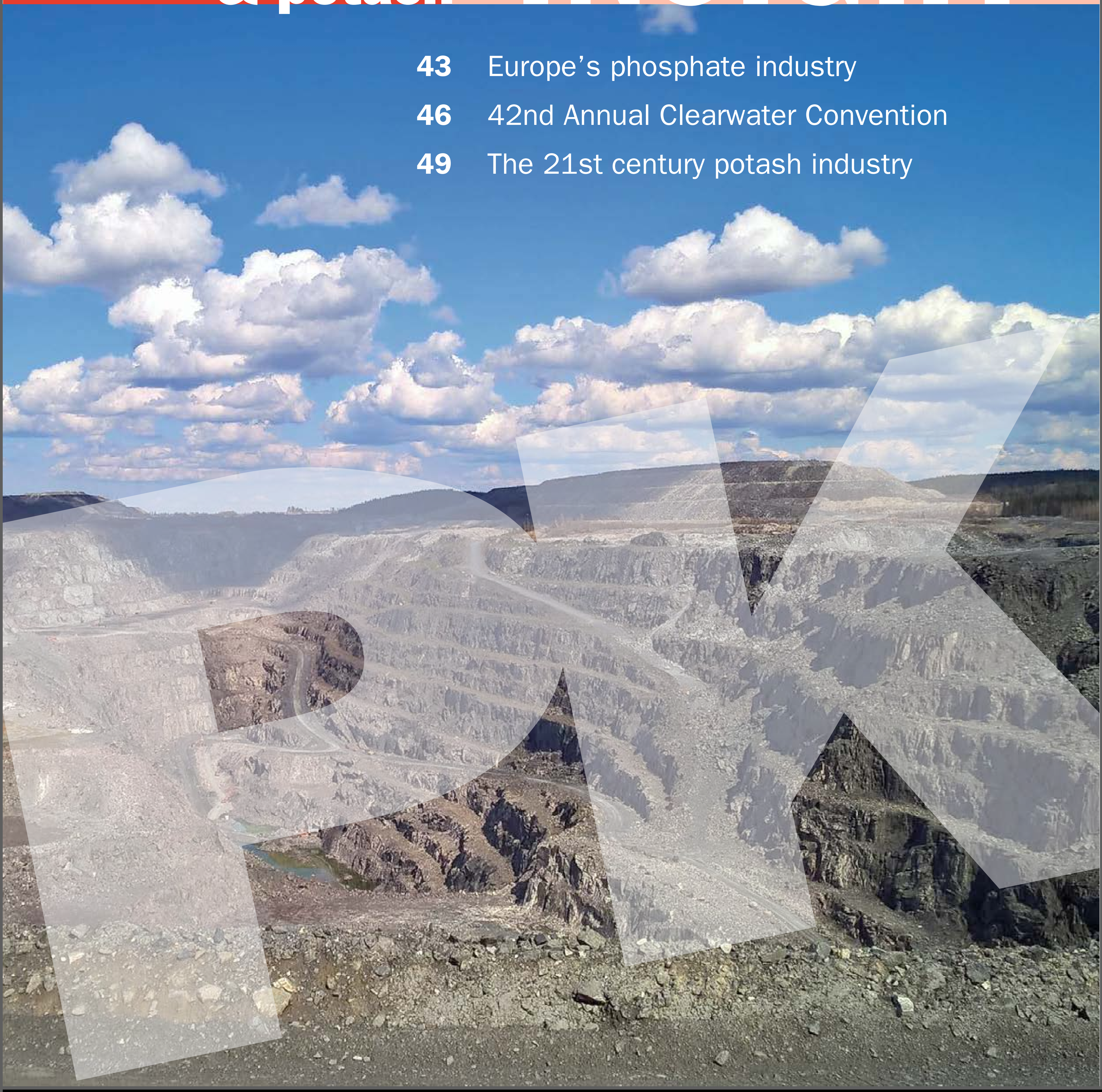

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Europe's phosphate industry

Leading European phosphate fertilizer producers are profiled, including EuroChem, Fertiberia, Grupa Azoty, Prayon and Yara.

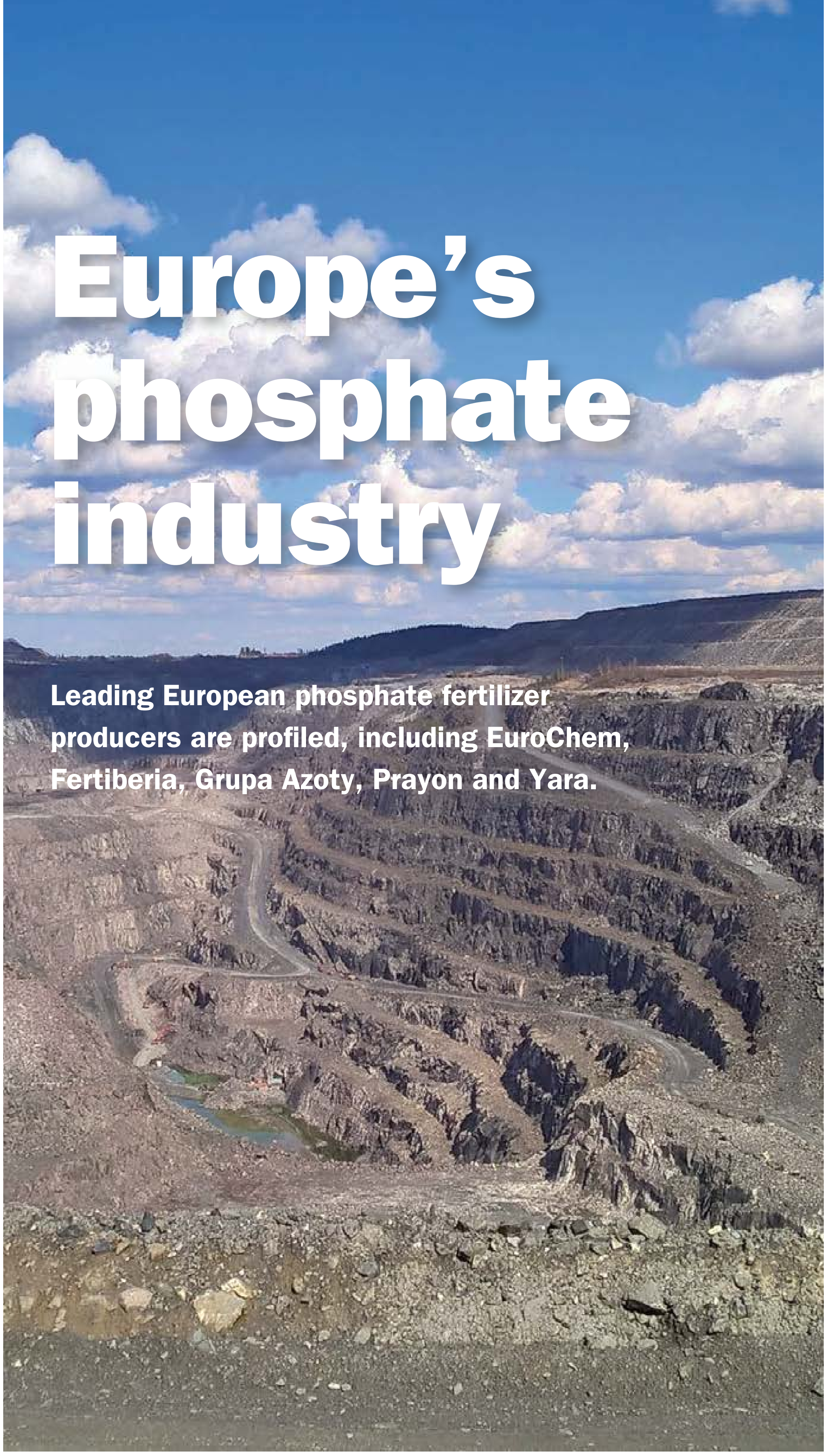

PHOTO: HANNA KAISA/SHUTTERSTOCK.COM

Yara International's Siilinjärvi mine in Finland is Europe's only phosphate mine.

Yara's production might

Yara International is Europe's leading phosphate rock and NPK producer. The company's Siilinjärvi mine in Finland – Western Europe's only phosphate mine – produces around one million tonnes of phosphate rock concentrate and 300,000 tonnes of phosphoric acid annually.

Yara's combined European operations provide 5.2 million tonnes of NPK production capacity (Table 1), more than 80 percent of the company's total global NPK capacity of 6.2 million tonnes. This is divided between six sites in four European countries: Siilinjärvi and Uusikaupunki in Finland, Glomfjord and Porsgrunn in Norway, Montoir in France and Ravenna in Italy.

Yara is a market-leading producer of NPKs, selling 5.3 million tonnes globally in 2017. That volume placed Yara well ahead of competing NPK producers such as Coromandel (3.3 million tonnes), Gresik (2.7 million tonnes), Iffco (2.7 million tonnes) and PhosAgro (1.9 million tonnes). The NPK market is a lucrative one for Yara. The company's compound NPK products sell at a premium of around $100/t relative to commodity blends. That translated into a total NPK product premium of $580 million in 2017, according to Yara calculations.

Premium products able to deliver high margins – including NPKs, fertigation products and calcium nitrate – feature strongly in Yara's fertilizer portfolio. These three product types make up around one-quarter of Yara's global sales volumes, while blended NPKs contribute a further one-fifth to sales volumes worldwide.

Increasing the capacity to produce and sell premium products is an integral part of Yara's future growth strategy, and will

Table 1: **Yara's European NPK production sites**

	Siilinjärvi, Finland	Uusikaupunki, Finland	Porsgrunn, Norway	Glomfjord, Norway	Montoir, France	Ravenna, Italy
Product	**Production capacity ('000 tonnes)**					
Ammonia			500			
Nitric acid	200	500	1,500	400	300	400
Phos acid	300					
Phos rock	1,000					
NPKs	500	1,200	2,200	600	300	400
Nitrates		200			400	400
CN			900	200		

Source: Yara

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be partly delivered by expanding European NPK output. An NPK expansion at the Uusikaupunki site in Finland came on-stream in the third quarter of 2016. Further NPK capacity additions in Norway – by 70,000 tonnes at Porsgrunn and 50,000 tonnes at Glomfjord – were also due to be completed in the first quarter of this year.

EuroChem: a focus on quality

EuroChem subsidiary Lifosa is one of the EU's leading phosphate fertilizer producers. Located in Kedainiai, Lithuania, the company, which dates from 1959, mainly produces diammonium phosphate (DAP), feed phosphates and aluminium fluoride.

Lifosa produced 805,000 tonnes of DAP and 165,000 tonnes of feed phosphates in 2017 and is recognised for its high-quality products. The company is strategically located for the export market, being relatively close to the ice-free port of Klaipeda, some 210 kilometres away on Lithuania's Baltic coast.

EuroChem Group acquired Lifosa in 2002. The purchase helped secure Lifosa's long-term future and competitiveness by providing access to a supply of high-purity, low-cost igneous phosphate rock from EuroChem's Kovdorskiy mine at Kovdor in Russia's Kola peninsular. In 2015, EuroChem announced plans to invest $104 million in expanding Kovdorskiy's production capacity by 948,000 t/a, raising total rock concentrate capacity to 3.4 million t/a by 2018.

Lifosa has been producing feed phosphates for nearly two decades. The company's original dicalcium phosphate (DCP) plant dates from 2001. This was followed by a monocalcium phosphate (MCP) unit in 2002 and a mono dicalcium phosphate (MDCP) unit in 2004.

EuroChem Group has channelled $210 million of capital expenditure into Lifosa over the last 10 years. One priority is the construction of a new 30,000 t/a capacity water-soluble monoammonium phosphate (MAP) production unit which began in 2016. Other development plans include the launch of urea-phosphate (UP) production unit, and the conversion of the current DAP line into a new NPK unit.

Prayon: water soluble phosphates

Belgium's Prayon Group's is an acknowledged leader in wet process phosphoric acid production technology. The company was founded in 1982, although its roots in Belgium's Liège region stretch back more than 100 years Currently, some 50 percent of phosphoric acid production sites globally use Prayon technology while 70 percent use Prayon equipment.

The Group brings together over 20 companies located in more than 10 countries, employing 1,450 people and generating a turnover of €500 million The company is jointly owned by OCP Group and Société Régionale d'Investissement de Wallonie (SRIW).

Prayon is also a world-leading producer of high-purity phosphate chemicals for the fertilizer, detergent, food additives and technical markets. The company's production arm manufactures purified phosphoric acid (PPA) using a proprietary solvent extraction process. This acid is available in different grades and concentrations for use in the production of a wide range of technical- and food-grade products.

Prayon's production sites in Engis and Puurs, Belgium, have the capacity to produce 250,000 tonnes of P_2O_5 per year. Emaphos, a joint venture between Prayon, OCP and Chemische Fabrik Budenheim (CFB) located at Jorf-Lasfar, Morocco, provides a further 150,000 tonnes of P_2O_5 capacity.

Prayon manufactures over 300,000 tonnes of phosphate salts each year from Engis and Puurs in Belgium, Les Roches de Condrieu in Lyon, France, and Augusta, Georgia in the US. Production output includes sodium, potassium, calcium, ammonium and aluminium phosphates. Many of these products are marketed under the *Europhos* brand name and targeted at food and technical/industrial markets.

Prayon has also been manufacturing horticultural phosphates in Europe for over 40 years, and markets a comprehensive range of water-soluble fertilizers. These were consolidated under the single *Hortipray®* brand in 2011. The *Hortipray®* range of fertilizer products is designed for application to fruits, vegetables, flowers and plants by fertigation, and are recognised for their purity and high solubility. They include:

- *micronutri Fe*
- MAP & MKP *anticalc*
- *Pbooster*
- Monoammonium phosphate (MAP)
- Monopotassium phosphate (MKP)
- Potassium nitrate (NOP)

Grupa Azoty targets Poland and Germany

Grupa Azoty Police, a subsidiary of Grupa Azoty, is Poland's largest manufacturer of phosphoric acid, phosphates and NPK fertilizers, as well as being a significant European producer. The company is based in Police in the country's southernmost Lesser Poland province. Its main commercial products include:

- MAP, DAP and NPK fertilizers, incorporating secondary nutrients (sulphur, magnesium) and micronutrients
- Granulated NS fertilizer comprised of ammonium sulphate, urea and magnesite
- Urea
- Liquid ammonia
- White titanium dioxide-based dyes

Grupa Azoty Police's fertilizer unit is the largest within the company, both in terms of production volumes and revenues. The unit produced 863,000 tonnes of NPKs in 2015 supplemented by 214,000 tonnes of MAP/DAP and 358,000 tonnes of phosphoric acid. Its NPK and DAP products – *POLIFOSKA®* and *POLIDAP®* – are market-leading brands in Poland. Its fertilizer products are also sold in Europe, South America and Africa.

The company is aiming to increase market penetration in Poland and Germany, its two primary markets, as part of a fertilizer market strategy. Liquid and specialty fertilizers are also being added to expand the product portfolio.

Grupa Azoty Police expects to complete a $18.5 million (PLN 67 million) upgrade project at its phosphoric acid unit this year. This involves replacing the existing DA-HF production process with new technology licensed by Prayon. The aim is to enhance production efficiency and improve output quality.

Grupa Azoty Police has mainly sourced its phosphate rock from Morocco, Algeria and Senegal in recent years, supplemented by supplies from Israel. AFRIG S.A., a 55 percent owned subsidiary company, has been supplying Senegalese-sourced phosphate at relatively low cost since 2013.

The company's part-ownership of AFRIG was designed to reduce dependence on external suppliers of phosphate rock and improve security of supply. Grupa Azoty said in 2016 that there was potential to ship one million tonnes of phosphate rock from Senegal to Poland annually. The company did, however, declare an impairment

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loss – an asset write-down – against AFRIG in August last year. This was after expenditure on mineral resource exploration and evaluation was found to have been largely worthless.

Grupa Azoty recently announced a new three-year phosphate rock supply agreement with Morocco's OCP in a deal thought to be worth around $103 million (PLN 350 million). OCP previously agreed to supply Grupa Azoty with one million tonnes of phosphate rock in 2017 in a similar but shorter-term $35 million (PLN 135 million) deal signed last May.

Polish phosphate rock imports have been on the rise in recent years. Trade statistics show the country imported 1.2 million tonnes in 2017, some 56 percent of this supplied by Morocco. Poland imported 674,835 tonnes of Moroccan phosphate rock in 2017, up from 541,279 tonnes in 2016.

Fertiberia adapts to market needs

Fertiberia produces eight million tonnes of fertilizers and intermediate products from 16 production centres located in four countries – ten in Spain, two in Algeria, three in Portugal and one in France. In 2016, the company produced:

- 950,000 tonnes of ammonium nitrate
- 650,000 tonnes of nitric acid
- 496,000 tonnes of ammonia
- 346,000 tonnes of urea
- 239,000 tonnes of nitrogen solutions
- 136,000 tonnes of NPKs

The Spanish company manufactures NPK fertilizers at the Huelva plant in Spain. Until five years ago it also used to manufacture phosphoric acid and finished phosphates at the site. Huelva originally had the capacity to produce:

- 290,000 t/a of complex NPK fertilizers
- 290,000 t/a of diammonium Phosphate (DAP)
- 150,000 of monoammonium Phosphate (MAP)

However, Fertiberia discontinued the DAP and MAP production lines and ceased manufacturing both products at Huelva in 2013 due to high production costs. This in turn was linked to the ending of phosphoric acid production at Huelva three years previously.

The move was also part of a wider restructuring plan to make Huelva a central hub for NPK production. However, Huelva produced 136,202 tonnes of NPKs in 2016, down almost 30 percent on production of levels of 188,462 tonnes in 2015 and 188,586 tonnes in 2014.

Lower production at Huelva in 2016 was linked to market conditions, according to the company. "NPK compound fertilizer production was substantially lower than estimated owing to the fall-off in demand," it said. More positively, Fertiberia launched a new line of NPK fertilizers in 2016 as part of the *Fertiberia Advance* product line.

The company announced in 2013 that in future it would be sourcing DAP from Morocco's OCP, and began discussing the supply of 250,000 t/a, priced on a quarterly basis. Phosphoric acid production at Huelva ended in 2010 due to environmental concerns. Since then, Fertiberia has sourced the phosphoric acid necessary for NPK production from international markets.

> **"Europe's major phosphate producers are increasingly focussed on higher-value segments such as compound NPKs, water-soluble fertilizers and feed phosphates.**

In addition to producing NPKs at Huelva in Spain, Fertiberia's Portugese subsidiary ADP Fertilizantes has the capacity to produce 400,000 t/a of NPKs and 170,000 t/a of superphosphates at its Setúbal plant.

2016 was a mixed year for Fertiberia. Total production that year "fell below estimates" with production sites "having to adapt to market needs", according to the company's latest annual report. Output at Setúbal fell by around 10 percent, for example, mainly due to lower production of superphosphates and packaged products. Fertiberia Andalucía bucked the downward trend, however, with DAP sales 30 percent higher than expected, allowing the company to increase its market share for this product in 2016.

Adapt to survive and thrive

The European phosphates industry has undergone further consolidation and market shifts since we last profiled the region's producers in 2011 (*Fertilizer International* 443, p45). At that time, the industry had been in steady retreat for several decades due to the combination of large-scale, low-cost global competition and the region's reliance on imported phosphate rock.

The trend for consolidation and closures in Europe has continued with Fertiberia notably ending DAP and MAP production at its Huelva plant five years ago.

The need to secure a competitively priced supply of phosphate rock also remains a challenge for non-integrated European producers. Grupa Azoty has, however, been able to address this by entering into a long-term supply agreement with OCP.

Looking ahead, the proposed introduction of stringent cadmium limits, as part of the new EU fertilizer regulation, has the potential to disrupt phosphate rock imports into Europe and increase costs, with low cadmium Russian rock most likely to gain at the expense of high cadmium rock from North and West Africa. The initial introduction of a higher cadmium limit (60 mg/kg P_2O_5) could be achieved without major disruptions to phosphate rock supply, according to the European Commission, although this is disputed by some suppliers.

Europe's major phosphate producers are increasingly focussed on higher-value segments such as compound NPKs, water-soluble fertilizers and feed phosphates. The shift to NPK production has been a particular popular and successful strategy for European phosphate producers, with EuroChem being the latest company planning to move away from DAP to NPK production at Lifosa.

The switchover from DAP/MAP to NPK production seen in Europe is part of much wider global trend, as margins for the former weaken and demand for the latter grows. Changing its product mix has provided Europe with a strong position in the growing and higher-margin NPK market. Indeed, EU phosphate producers currently account for some 47 percent of global NPK exports, most of this coming from Belgium, Norway and Finland. ■

Author's note: *The European phosphate and NPK fertilizer operations of ICL and Rosier are not covered by this article. These include ICL's 600,000 tonne capacity Amsterdam plant and 250,000 tonne capacity Ludwigshafen plant, and Rosier's two NPK plants at Moustier in Belgium and Sas Van Gent in the Netherlands. Fertilizer International hopes to profile these in a future edition of the magazine.*

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42nd Annual Clearwater Convention

The AIChE's 42nd International Phosphate Fertilizer & Sulfuric Acid Technology Conference was held at its usual venue, the Sheraton Sand Keys Resort, on Florida's Gulf coast on 8-9 June.

21st annual sulphuric acid workshop

Rick Davis of Davis & Associates and Jim Dougherty of MECS opened proceedings by organising and chairing the long-standing sulphuric acid workshop on Friday afternoon. The theme of this year's workshop was sulphuric acid plant steam systems, including fire tube boilers, waste heat boilers, superheaters, economizers and deaerators. The workshop covered the Boiler Code, process design, fabrication, quality control and water pre-treatment monitoring.

The Boiler Code

Rick Davis set the scene by explaining the objectives of the Boiler Code, as well as its limitations, in the workshop's opening presentation. The ASME Boiler & Pressure Vessel Code dates back to the early 1900s. It was part of a concerted move to improve steam engine safety prompted by the 1905 fire tube boiler explosion at the Grover shoe factory in Brockton, Massachusetts, a terrible industrial accident that left more than 50 dead and over a 100 injured.

While the first 1914 edition of the Code was a slim, single volume of just 114 pages, the latest 2011 version has 28 volumes and runs to 16,000 pages. Today, the Boiler Code is the cornerstone of operational safety, being part of the law in most US states and a standard insurance requirement. As well as making safety paramount, the Code helps set operational objectives for process temperature control and energy recovery, and also has a zero tolerance of leaks.

Two particular sections of the code were highlighted by Davis. Firstly, the rules for the construction of pressure vessels covered by Section VII, Division 1. This lists minimum requirements for materials, design, fabrication, inspection and testing of boilers. Secondly, Davis drew attention to Section VIII of the Code which deals with the operational care of power boilers – including commissioning, steam sampling and boiler chemistry.

Davis outlined the range of process specifications that engineers need to consider together with other specifications for equipment design and repair work.

He was keen to stress that the stipulations of the Boiler Code are minimum requirements. He also pointed out that the Code has limits in terms of what it does and does not cover. The welding design of the boiler internals and gas inlets and outlets fall outside the Code, for example, as does any equipment external to the boiler and steam drum.

The minimum requirements set out by the Boiler Code are good ones, concluded Davis, but are not completely comprehensive in scope. "The Code is good but has it limits," summed up Davis. "The rest is up to you and your contractor/engineer to specify requirements."

Steam system process design

The process design of steam systems was covered in more detail in a comprehensive and thorough presentation by Noram's **Andrés Mahecha-Botero**. He posed two 'big picture' questions: why do we need steam systems and what specifications should we use?

The basic components of a steam system are the deaerator, economizer, waste heat boiler, superheater, steam turbine and condenser. Steam system process design has four main parts:

- Gas-side (step 1)
- Acid-side (step 2)
- Steam-side
- Cooling water-side

As the primary design consideration, the gas-side is generally the 'master' to the 'slave' steam-side, suggested Mahecha-Botero.

Sulphuric acid plants are highly exothermic. How to capture and use surplus heat is therefore a critical consideration – by using turbo generators/power turbines to drive blowers and pumps, for example. Safety is also paramount as high-temperature water and steam are both hazardous.

It is necessary to design steam systems for a worst-case scenario for temperature and pressure, advised Mahecha-Botero. This can be achieved by ensuring process design parameters have built-in margins.

Steam system quality control

For steam systems, the aim of quality control (QC) is to prevent defects before they occur or, if they do occur, find them during the fabrication process, explained MECS' **Ed Doe**. The most common boiler failures are due to bad welds between tubes and tubesheets. These result from:

- Bad welds caused by base metal preparation
- Bad root pass welds
- Welders not using a weld procedure
- 'Bad welders' – welders making mistakes and having 'bad days'
- Improper use of welder filler material
- Improper non-destructive examinations

Choosing a competent, capable boiler fabrication company with a culture of quality is particularly important. There also needs to be evidence that the chosen fabrication company is putting QC into practice. "First impressions are often correct, so go with your gut. Go out on the shop floor – is it tidy and organised? Also check to see if QC is in place and being used," advised Doe.

Preventing defects – especially those resulting from human error – is a particular challenge given that boiler welding is a repetitive task that can involve 4,500 individual tube-to-tubesheet welds. However, defects can be prevented by having an inspection and test plan (ITP) in place during fabrication. "The best ITP is the one that's being used. Many ITPs end up being placed in the project file. It should be out on the shop floor and a dirty, dog-eared document," Doe said.

Non-destructive examination (NDE) of welds during boiler fabrication, typically by radiography, is mandatory as part of the Boiler Code. NDEs help prevent defects by “keeping welders honest”, suggested Doe, as “people always do things better when they're being watched”. He advised that NDE is best done by radiography of randomly-selected welds. These need to be selected after they have been made as it is important for the welder not to know which have been chosen in advance.

Fabrication

Mike McGuire of Optimus described the practicalities of boiler fabrication and the design process behind this. Optimus first began fabricating speciality boilers, economizers and fin tubes in the early 1990s. The company sold its first waste heat boilers (WHBs) and economizers for the sulphuric acid market in 1996. The company also supplies a range of superheater designs including pendant and cylindrical types. Notable references include:

- MECS waste heat boiler and MECS sulphuric acid economizer for Mosaic’s New Wales complex
- Large economizer for the PCS Aurora plant
- Morses Mill, New Jersey sulphuric acid superheater

Boiler design initially involves the preparation of design drawings incorporating engineering data. These are then submitted for customer review, prior to the drafting of detailed fabrication drawings. Design pressure and temperature requirements are set out in the following sections of the ASME Boiler Code:

- Shell-side: boiler construction rules in Section 1 (WHB) and recommended guidelines in Section VII (Economizer/Superheater)
- Tube/gas-side: pressure vessel construction rules Section VIII, Division 1

The Code also contains calculations for determining the thickness of components such as shells, tubesheets, vestibules, stand-off rings and saddles. Structural design (WHB saddles, gas nozzles, piping, foundation loads etc.) is another important part of the design process.

Deaerator and steam/condensate system monitoring

Edward Sylvester of Chemtreat ended the workshop with a lively presentation on the objectives of pre-treatment monitoring. Diligent monitoring is necessary to ensure:

- High quality water
- Pre-treatment equipment is operating at peak performance
- Immediate isolation and correction of any ingress

As a first step, pre-treatment plants and reverse osmosis (RO)/ demineralisation plants are used to supply high-quality make-up water to the deaerator. Subsequent monitoring at every stage of the steam/condensate system also helps guarantee:

- High-quality feedwater for the steam generator
- High-quality steam for the plant process turbine
- High-quality condensate

The ASME provides guidelines on water chemistry and treatment. These set out the quality requirements for make-up water, feedwater, steam and condensate. “Steam/condensate system quality should be very good,” advised Sylvester. The only allowable chemicals are neutralizer amines, volatile O_2 scavenger, and sodium and silica at parts per billion level. “On the water-side, our objective is to protect your investment,” summed up Sylvester.

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

The fifth fuel

Eric Coffin of Green Energy Engineering described energy efficiency as “the 5th fuel”. He presented an analysis of the potential energy savings for a typical process plant pumping system. In an idealised and 100 percent efficient system, you would expect the required flow (1,500 gpm) for a given head (100 feet) to be delivered by hydraulic horsepower (35 hp) with no efficiency losses.

But in practice, a string of pump and electric motor inefficiencies (75% efficient pump, 90% efficient motor and an 85% power factor) means the system actually requires 66 hp of hydraulic horsepower to operate. In other words, in a real-world scenario some 43 percent of the purchased power is lost.

However, if overall pump system efficiency was improved using the best available equipment (85% efficient pump, 95% efficient motor and a 95% power factor) the purchased horsepower could be reduced to 49 hp. For this single example, the annual electricity saving for switching to a 50 hp motor would be $9,300, suggested Goffin. Applied to pumps across the process plant the savings are potentially huge in his view.

Sinkhole remediation

Mosaic's **David Jefferson** described the large-scale remediation project needed to seal the sinkhole that opened up beneath a gypsum stack at the company's New Wales site in 2016. Some 80 people have been working on the project six days a week for the past 18 months. However, Jefferson was able to tell conference delegates that the remediation project was successfully completed in early June.

The water loss incident at the stack first began in mid-September 2016, although it took some 11-12 days for the pond to empty and the sinkhole to become visible. The remediation project sealed the sinkhole by injecting cement into a geological confining layer (the Hawthorne Limestone) at its base. This high-pressure grouting operation began in the spring of 2017. It required repeated angled drilling around the circular perimeter of the sinkhole at a rate of up to three boreholes every week. Backfill was also added above the confining layer to increase the grouting rate.

Phos acid corrosion resistance

Wayne Moroz of Mersen Corrosion reviewed the corrosion-resistant process equipment used in hot phosphoric acid processes – with a particular focus on the different options for construction materials. It can be a major challenge to design and manufacture heat exchangers, columns and vessels capable of withstanding highly-corrosive and concentrated phosphoric acid at a temperature of more than 100°C.

Moroz recommended using the 'corrosion resistance pyramid' when selecting metallic and thermoplastic materials for hot acid process equipment. 'Top of the pyramid' materials such as glass, glass-lined steel, silicon carbide and impregnated graphite should also be considered.

The presence of impurities can affect corrosion resistance, although silicon carbide and impregnated graphite are less affected by this. These two materials – as well as Teflon-based thermoplastics used as liners or coatings – are considered to have zero corrosion.

Cadmium and arsenic removal

An innovative new solution for removing arsenic and cadmium from phosphoric acid was introduced by **Rajesh Raitani** of Solvay. The company's new *ACCO-PHOS* series reagent can be added at the reactor/digester stage where it forms an insoluble complex with heavy metals. This is taken-up by the phosphogypsum present and therefore easily removed during subsequent filtration.

ACCO-PHOS reagents are stable, highly-selective for cadmium and arsenic, and a 'bolt-on' technology that requires minimal capital outlay. In a recent industrial phosphoric acid trial in Europe (Egyptian/Algerian ore, 5 kg/t P_2O_5 reagent dose), Solvay's *ACCO-PHOS 810* reagent reduced cadmium concentration in filtered acid from 10 ppm to 0.1 ppm after 90 minutes. Arsenic was also reduced from 5 ppm to 0.01 ppm under the same conditions.

Engineer of the Year

Neil Greenwood of KEMworks Technology was named this year's Hero of the Industry while **Justin Graff** of The Mosaic Company was announced as Young Engineer of the Year. The accolade Engineer of the Year this year went to **Paul Kucera**, also of Mosaic. Delegates will convene again in Florida for the 43rd Annual Clearwater Convention on 7-8 June next year.

Scale inhibitor trials

Nalco Global Mining's **Paul Wiatr** gave an update on three recent plant trial results for scale inhibitors. One trial (Trial 1) was at a plant with a shell-and-tube heat exchanger. The other two trials (Trials 2 and 3) were at a plant with two identical graphite block heat exchangers.

In Trial 1, the production campaign was extended by 65 percent and acid production increased by 9 tons to 29 tons per day P_2O_5. The number of times feedline scale cleaning was necessary fell by one-third. Tube cleaning efficiency also increased with more tubes cleaned in less time. Steam utilisation by the heat exchanger also improved.

The campaign length in Trial 2 was also extended by more than 30 percent. Concentrated acid production increased in both Trial 2 and Trial 3, by 43 tons and 91 tons per day, respectively.

Agitator design and slurry behaviour

Richard Grenville of Philadelphia Mixing Solutions explained how to get the best performance from agitated slurry tanks. Agitator design, installation and operation has a number of aspects. Firstly, the physical properties of the liquid and particles need to be defined, as does the degree of suspension or distribution. Key properties include: the density of particles and the liquid, particle size and distribution, and solids concentration.

Importantly, it is these properties which in turn control slurry viscosity. If viscosity is high enough – and the slurry slow-settling – then the agitator design can assume that the slurry will behave as a single-phase, viscous, non-Newtonian fluid. Viscosity must, however, be measured over a range of different impeller speeds to determine the degree of non-Newtonian behaviour.

Agitators can be accurately sized and delivered on time, as long as the above factors are properly considered and taken into account, advised Grenville. If not, inaccurate assumptions by the vendor may end up delaying the project and plant start-up.

Stack emissions case study

Dave Ivell of Jacobs presented an update on the revamp of a DAP/NPK plant operated by Zuari Agro Chemicals in Goa, India. The aim of the revamp was to reduce ammonia stack emissions to 35 mg/Nm³, down from losses as high as 500 mg/Nm³. To achieve this, the plant's existing fume scrubber was reconfigured as a pre-scrubber. A new venturi/cyclonic scrubber and tail gas scrubber with floating ball packing were also installed, as was a new dryer fan.

Project objective were achieved, confirmed Ivell, with stack emissions well below target levels, while production output is consistently at or above levels prior to the revamp. The novel use of floating ball packing was a particular success. There has been no requirement for regular cleaning and a steady pressure drop has kept airflows and production rates at design levels.

Electrokinetic dewatering

Mark Orazem of the University of Florida outlined new findings on the potential of electro kinetic dewatering (EKD) for treating phosphatic clay. He presented trial results from a new continuous EKD prototype tested at the university's chemical engineering department. This yielded a cake with a solids content of 37 weight percent and produced solids at an average rate of 5.9 kg/h m². Economic analysis suggests this prototype design could dewater a 10 weight percent phosphatic clay feed to produce a 35 weight percent cake at a cost of $11-12 per ton of dry clay.

The Potash Industry in the 21st Century

The potash industry has undergone technological transformation throughout its long 150-year history. That is true of extraction methods as well as mineral processing/beneficiation techniques. Engineering firms will continue to play an important role in developing state-of-the-art production technology, as **Dr Henry Rauche**, managing director of ERCOSPLAN, explains.

Economics: the driving force

Production economics have always been the key driving force behind innovation and change in the potash industry: higher recovery rates and better utilisation of deposits – resource efficiency and sustainable resource use in today's terminology – have been the main imperatives.

In the industry's early years, on average, about 65 percent of the potassium chloride (KCl) present in mined ore worldwide found its way into the final product. Recovery later improved to about 75 percent between the World Wars. Nowadays, for advanced producers, it is more than 87 percent. This impressive improvement in recovery shows the potash industry's progress, decade by decade, towards more sustainable resource utilisation.

Reducing primary energy demand has been another imperative, one that has placed energy reduction measures firmly on the agenda since the industry's earliest years. Hot leaching – a process exclusively relied upon in Germany until the 1950s – was targeted in particular, due to its large contribution to operating costs. Here, the main energy reduction measure involved reducing water use. This cut primary energy use by decreasing the total amount of circulating brine that required heating.

Similarly, economic reasons were behind the improvements in Sylvite flotation performance achieved in North America. The same is true of the groundbreaking development of the dry electrostatic separation process (ESTA) in Germany in the 1960s and 1970s.

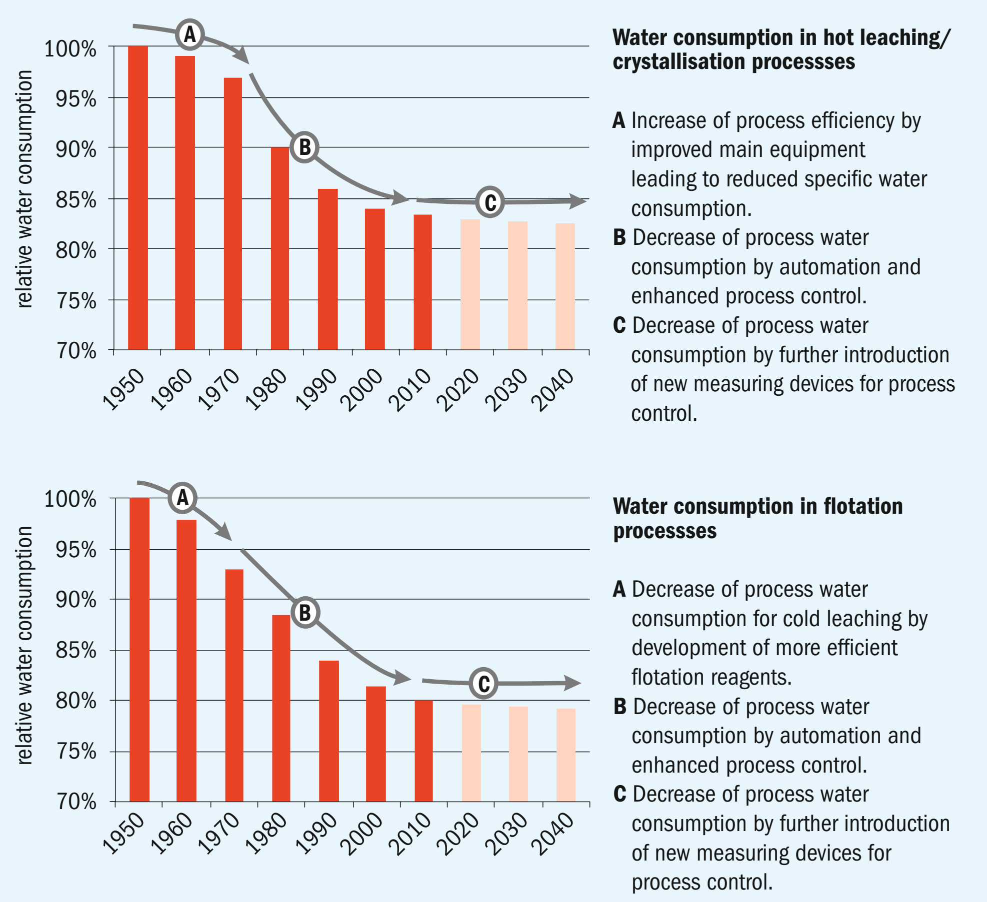
Although energy savings and advances in fertilizer production have been the primary motivation behind many decades of industry R&D and innovation, almost all of the resulting technological improvements have helped to significantly lower the industry's overall environmental impact. This has been achieved either by decreasing the quantity of processing residues, or by drastically reducing water consumption. Collectively, these changes have markedly improved the overall ecological footprint of potash fertilizer production.

Today, water consumption in potash processing has been cut to the minimum, due to the large reductions achieved previously (Figure 1). Enormous R&D efforts will therefore be required to deliver any further improvements.

21st Century challenges

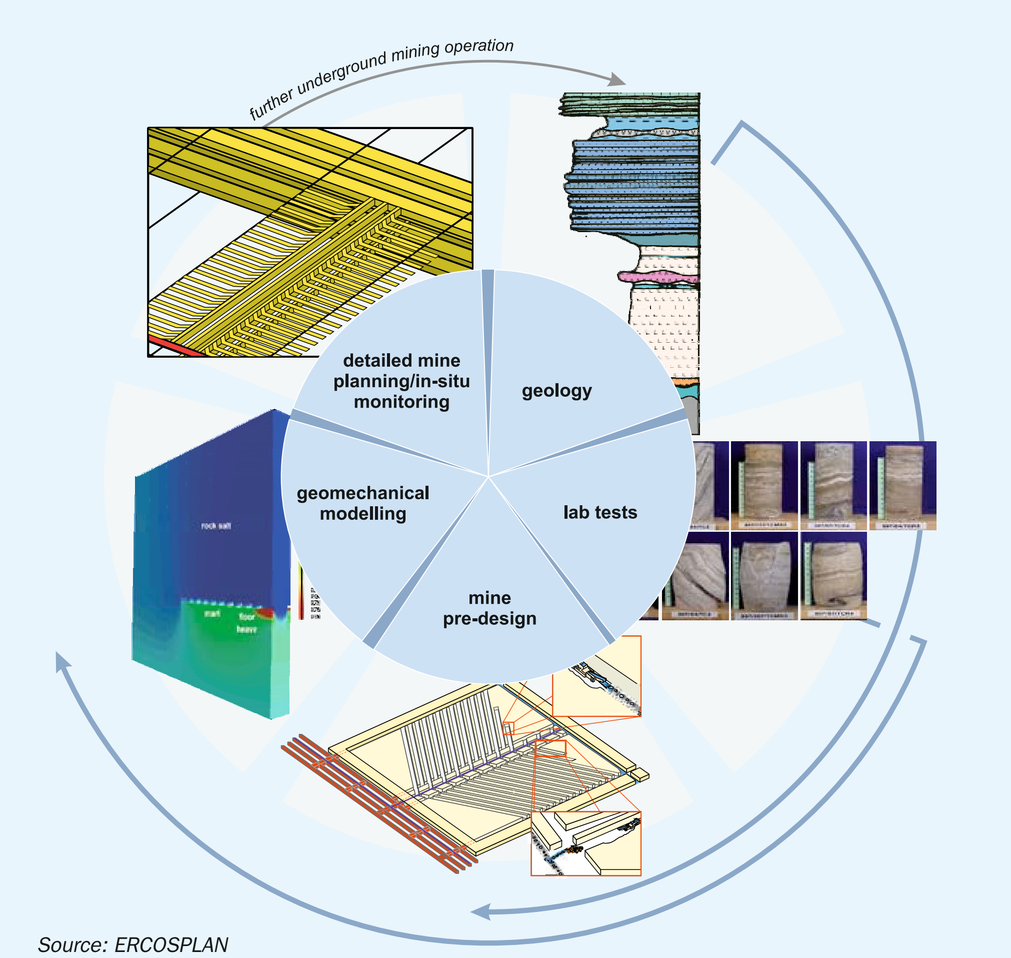
As in the past, efficient resource use and the reduction of environmental impacts remain the main twin challenges for the potash industry in the 21st century. There is one crucial difference, however: addressing these two challenges has become an ever more difficult task because the most simple and low-cost solutions – the low

Fig. 1: **Decrease in potash process water consumption relative to 1950 (100%): hot leaching/crystallisation processes (top) and flotation processes (bottom)**



Source: ERCOSPLAN

Fig. 2: **Iterative mine planning considers geological and rock mechanical modelling, as well as monitoring and test work**



Source: ERCOSPLAN

hanging fruit – have already been found and were applied long ago.

This situation means today's potash industry is faced with formidable tasks and tough challenges. This is true for potash producers, as well as for international engineering and consulting firms such as the ERCOSPLAN Group of Companies which has been providing 'Potash Engineering Made in Erfurt' for over 65 years. Indeed, ERCOSPLAN has helped potash producers worldwide overcome many challenges using the following motto:

"All from one source: starting from the exploration of mineral salts taking into account all environmental issues during mining and processing of potash ore, up to the decommissioning of production plants and site restoration of industrial properties."

Practical engineering solutions

For the potash industry, there is always a need to balance economics and ecology, even during times when market conditions are difficult. The following paragraphs highlight a range of solutions showing how this can be done. These practical solutions are designed to ensure that potash production is sustainable and its

Fig. 3: **Planned extraction of additional rooms in the existing pillars of a potash mine, based on rock mechanical modelling**

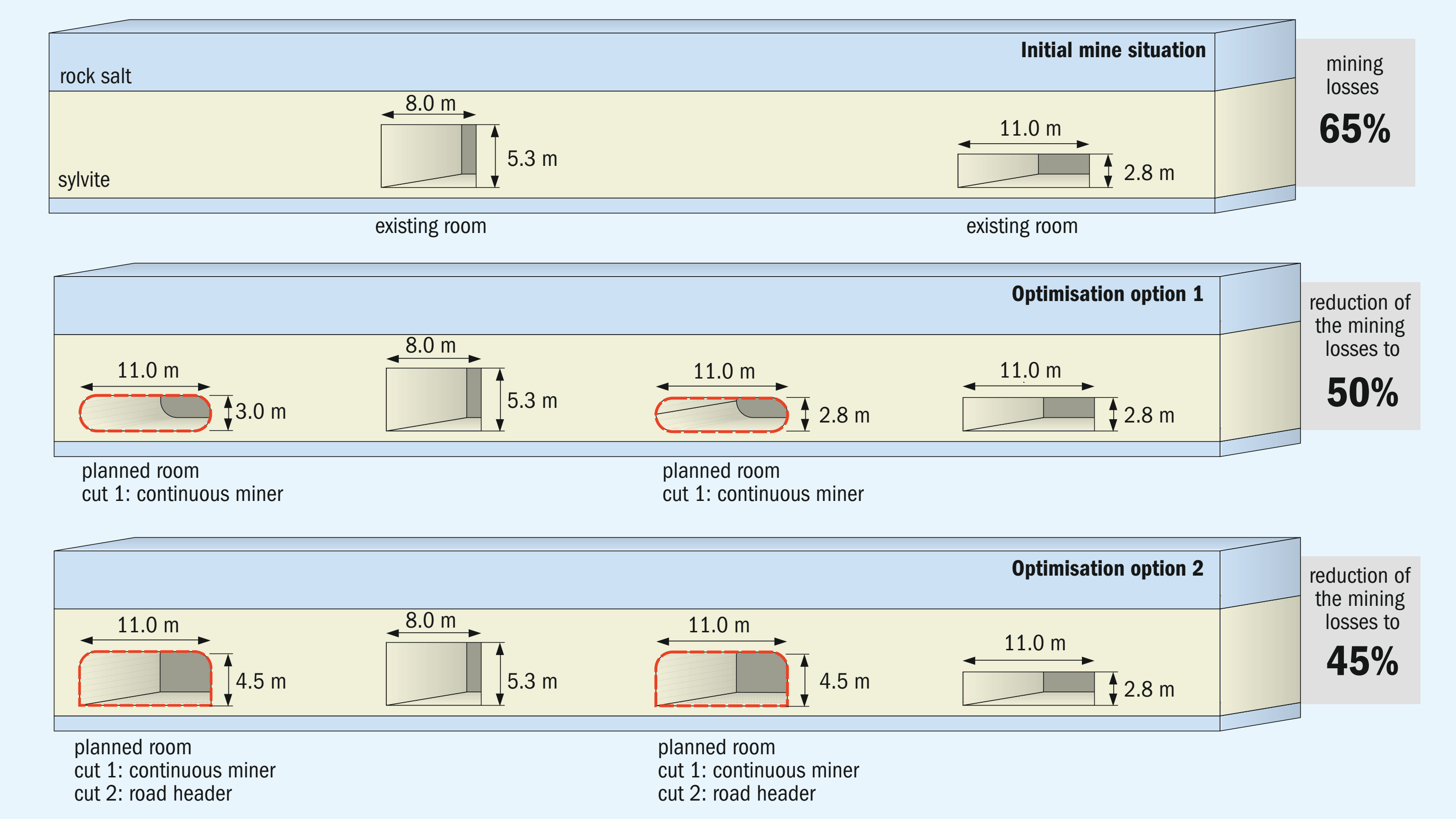


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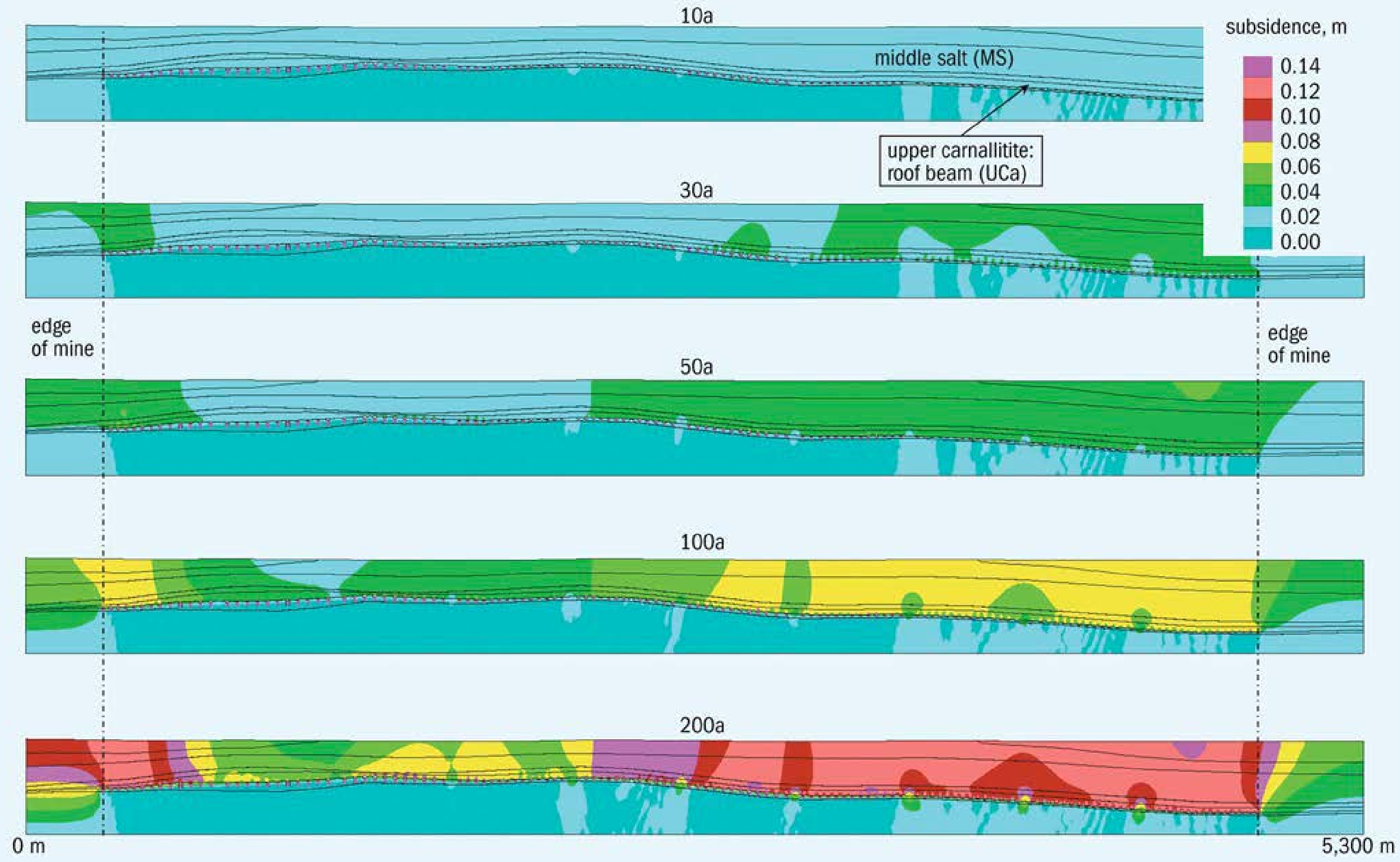
Fig. 4: **Analysis of subsidence development above a planned mining area over time**



Source: ERCOSPLAN

environmental impacts are reduced. All of the following solutions have been applied by ERCOSPLAN in the planning of future potash projects.

Advances in 3D models

Increasing the effectiveness of potash production begins with planning the mining of potash ore. Geographically-based 3D modelling tools are particularly useful in this respect. They enable more sustainable use of resources by optimising mine development and mine dimensioning. They include geological models (GoCAD, ArcGIS) of evaporite deposits and rock mechanical modelling (3DFLAC, 3DEC). By providing greater knowledge about the deposit, these models help to improve the extraction ratio and reduce resource loss. This is especially true if the models continue to be used frequently during mine operations, after modelling parameters have been verified by in-situ exploration and monitoring (Figure 2).

Geological and rock mechanical modelling can be applied to existing mines as well as new ones. Rock mechanical modelling has been used to reconfigure and improve mine planning in an operational sylvinite mine, for example (Figure 3). This model revealed that new rooms can be extracted within the existing pillars, leading to a potential mine life extension of around three years.

Backfilling on the agenda

The potential to reduce mining losses is most frequently found in those mines which employ backfilling, or where this can be potentially introduced. Backfilling has not, however, become widely adopted during the past 50 years. In operating mines, this has primarily been because existing mine layouts are not suitable for backfilling, or because geological conditions do not permit it. The additional operating costs involved have also prevented backfilling from becoming a viable option in both operating and the few newly-developed mines.

However, backfilling is now always considered as an option in current planning for new mines. This takes into account the resulting reduction in the costs of waste disposal to tailings piles – and includes this in the cost-benefit calculation. The slurry backfilling method is particularly efficient. The method is not new, having first been introduced in the Germany's South Harz Potash District in 1916. Such new/old solutions can be applied to liquid as well as solid wastes. Innovative methods for the disposal of liquid processing residues in the extracted mining chambers need to be considered, for example.

For mining projects to gain acceptance, a strategy to reduce environmental impacts needs to be pursued from the start of engineering. As well as decreasing the amount of solid and liquid residues to be disposed of, as mentioned above, backfilling also helps to minimise surface subsidence. By increasing the extraction ratio of the deposit, it can extend the life of a mine too.

How subsidence will develop over time for a planned potash mine in Southeast Asia is shown in Figure 4. Adoption of backfilling for this project means mine safety can be ensured and subsidence limited to a set amount.

Fig. 5: **Schematic diagram of a pneumatic flotation cell**

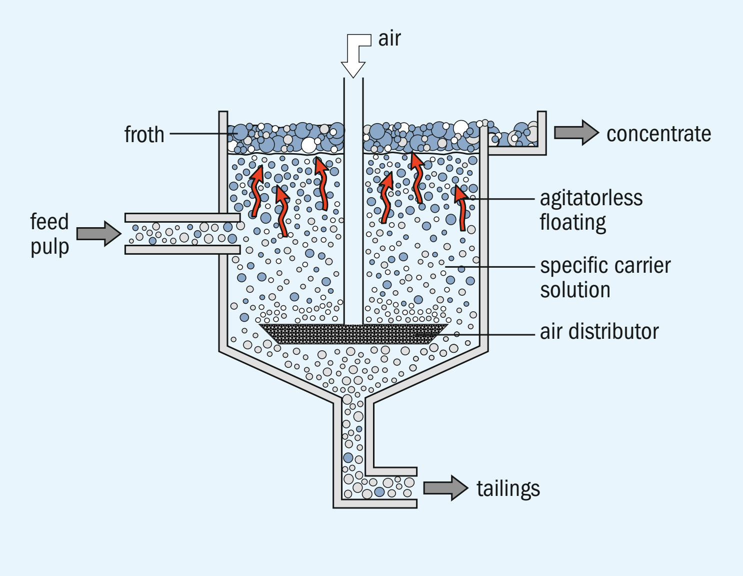


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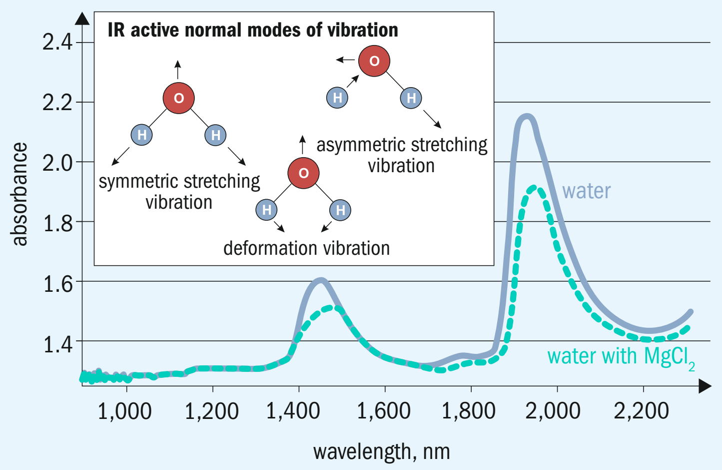
Fig. 6: **Comparison of the NIR spectra of water and aqueous $MgCl_2$ solution**



Source: ERCOSPLAN

Effective ore mining and transport

Planning and designing efficient technical solutions for new projects has many aspects. Lowering costs is of key importance. The exploitation of the deposit also needs to be maximised. That requires highly-efficient mining operations and ore transport, both underground and on the surface, and related auxiliary processes such as ventilation. Deposit-specific conditions and country-specific mining and environmental laws also need to be taken into account at the project planning stage.

Efficient ore processing & beneficiation

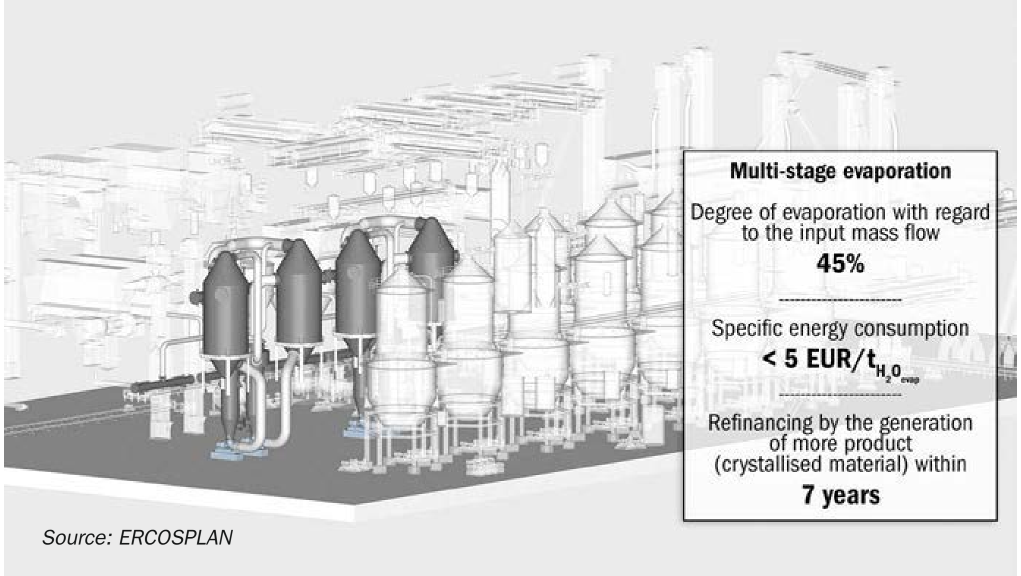
As well as mining potash ore in the most effective way, highly-efficient ore processing and beneficiation is necessary if sustainable resource use is to reach new levels. The efficiency of potash processing has been continually improved over the decades. There have been significant developments in water-based processing methods – flotation and hot leaching/crystallisation, for example. Dry processing by electrostatic separation has also been introduced. At the same time, environmental impacts have been reduced as a consequence of the decreases in water and primary energy consumption associated with these process improvements.

Selecting equipment that incorporates better quality and high-performance materials is becoming increasingly important too. The advantages of this include:

- Equipment that is more durable and requires less maintenance and less frequent replacement
- Equipment that has improved functionality, e.g. lower energy and water consumption
- Equipment that has been modernised and enhanced for standard applications, e.g. pneumatic flotation cells, hydrocyclones
- An overall increase in the efficiency of potash processing

One example of equipment innovation is the relatively recent adoption of pneumatic flotation by the potash industry to improve the set-up of flotation cells – even though its operating principles have been well-known since the early days of flotation. The use of a pneumatic flotation cell (Figure 5) can markedly improve the efficiency of the flotation of fine-grained particles compared to a standard mechanical flotation cell. For example, upstream pneumatic flotation of sludge can increase process recovery for ores containing large amounts of fine-grained insoluble material. Furthermore, the recovery of fine KCl particles that often occur during the flotation process can also be increased using pneumatic flotation. Presently, pneumatic flotation is in use at the main potash production centres in Canada and at new production sites in Russia.

Fig. 7: **Model of an additional evaporation section within a potash processing plant**



Source: ERCOSPLAN

Monitoring, control and automation

Significant advances in process monitoring, control and automation have also helped reduce potash production's environmental footprint. Improvements in measurement and control technology ensure accurate and timely data collection. This is essential when determining the amounts of consumables (water, reagents and energy) required for the process. New measuring devices include:

- Radar level instruments
- Coriolis flow meters
- Belt-scale radiometric equipment
- Radiometric density measurement
- Humidity measurement via microwave or near-infrared (NIR)

Radiometric K_2O measurement has only been used in potash processing in recent decades, making it a relatively recent innovation in comparison to the operational life of most current potash plants. The introduction of NIR for measuring ion concentrations in brines, and mineral phases in solids, is another example of modern potash processing monitoring and control (Figure 6). Such NIR measurements allow process control to react immediately to fluctuations in mass flow compositions, an advantage because it eliminates the need to wait for laboratory test results.

Improving waste recovery

The production of potash is accompanied by the generation of solid salt tailings and liquid brine wastes, both of which may have negative environmental effects. In practice, effective waste management and disposal methods are therefore essential for limiting the environmental impacts of potash production.

Additional processing of liquid residues is one option that can increase the recovery of potash and decrease environmental impact. However, the large amount of thermal energy required needs to be properly evaluated, as it may negatively affect overall ecological efficiency. In reality, it is a question of balancing the additional potash output achieved with any increase in primary energy consumption, and determining the breakeven point, both in ecological and economic terms. A case study for an additional evaporation section within a potash processing plant is shown in Figure 7. The merits and demerits of adding an extra evaporation step need to be investigated in detail on a case-by-case basis.

Process selection and costs

Ultimately, it is process selection and/or improvements that will play a significant role in overall progress towards an eco-friendly potash industry. The more efficient the production process is, the less product loss takes place. This in turn results in economic advantages by increasing product quantities, minimising residues and reducing waste management and disposal requirements.

However, general improvements in efficiency – and the solutions necessary to achieve these, as described above – carry a price tag and are often associated with substantial amounts of CAPEX and/or OPEX. Any potential rise in capital and operating costs is a significant challenge for potash producers, given the potash market's current low price environment.

Nevertheless, ERCOSPLAN is working closely with its clients to successfully engineer cost-effective and tailor-made solutions. These consider unique factors – always important for each individual potash project – to achieve the right balance between economics and ecology. Striking the right balance will continue to be a major 21st Century challenge for the potash industry, as it has been since its birth more than 150 years ago. ■

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Editor:
SIMON INGLETHORPE
simon.inglethorpe@bcinsight.com
Contributor:
OLIVER HATFIELD
publications@integer-research.com
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TINA FIRMAN
tina.firman@bcinsight.com
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