Aqua Strategy review: Process progress with sewage phosphate recovery

Cover story

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Momentum is growing around the recovery of phosphates from municipal wastewater. In this and the following article, **Keith Hayward** reviews some of the notable project and process developments in Europe and North America this year with commercially-available and emerging technologies.

Phosphate fertiliser. Fertilisers are one of the main product options for recycled sewage phosphate. © shutterstock / Fablok

Nutrients represent one of the main pollutants of the aquatic environment, especially due to fertiliser washed from agricultural land or inputs from livestock manure or human sewage. At the same time, phosphates in particular are increasingly seen as a concern given that the rising global population

depends on a finite supply of this essential resource. It is against this backdrop that initiatives are progressing on both sides of the Atlantic in order to promote nutrient recycling.

In the US, the Environmental Protection Agency is leading the Nutrient Recycling Challenge, aimed at promoting nutrient recycling using livestock manure. Earlier this year the EPA announced the first phase winners. A total of 34 entries were then selected to continue to the second phase of the challenge, running from October to March 2017. In this non-competitive part of the challenge, the entrants are being called on to develop technology designs based on their initial concept proposals. The third phase anticipated for next year will see prototyping and proof of concept, with a fourth phase involving demonstration units on farms.

The initiative therefore recognises that technology has a part to play in developing alternative approaches, and the first phase winners included the AnSBEAR process, which features two-step electrocoagulation of anaerobic digestion supernatant, the AirPrex process, and systems from Paulee Cleantech Ltd and Bravespec Systems.

In Europe, the interest in nutrient recycling will gain in the long term from the wider commitment to building a circular economy. Last December, the European Commission launched a new circular economy initiative. Europe's long term goal is to achieve a vision by 2050 of 'living well within the limits of the planet'.

The European Environment Agency is supporting this policy shift, and has launched a series of reports with this in mind. At the same time, the agency, noting that phosphates are among the list of critical raw materials, issued a report this year revealing that no countries had reported having targets to reduce the use of primary materials or specific materials, including those on the EU list of critical raw materials.

Alongside this, one of the most important developments of the year as far as nutrient recycling is concerned has been the release by the European Commission of proposed changes to the EU Fertiliser Regulation. The changes aim to put organic and waste material sources used in fertiliser production on an equal footing with inorganic fertilisers. Inclusion of these sources under these regulations would allow Europe-wide certification of products based on them, with the intention of encouraging market uptake across the continent. The proposed changes also aim to drive down the cadmium content of fertilisers over time. This move is intended to help prevent accumulation in the soil of this metal and is one of the measures to attract the most criticism from the fertiliser industry.

With phosphate classed as a critical raw material, in introducing the proposed changes, the European Commission noted that 90% of the phosphate used in the EU is imported, mainly from Morocco, Tunisia and Russia. It believes that 20-30% of the EU's demands for phosphate fertilisers could potentially be met by undertaking recycling in line with a circular economy approach. The

Commission also noted that 'domestic waste (in particular sewage sludge) contains large amounts of phosphorus'. Sewage sludge has however been excluded from the proposed changes, due to concerns over the contaminants that can be present.

Project and process progress

A comprehensive sewage treatment plant assessment currently underway in the UK includes a £50 million investigation into phosphates. Early results revealed this year have shown that there is a risk of failure to meet water quality objectives for soluble reactive phosphorus at 90% of the sites being assessed. The work confirms the presence of phosphate in the sewage plant discharges, meaning it is likely that additional treatment will be needed, but it also points to a contribution from other sources.

More generally, many sewage plants do nonetheless already remove phosphate from water, transferring it to the sewage sludge. This sludge, processed as biosolids, is in many locations already recycled to agricultural land or for similar uses. Another option important in some locations is thermal processing or incineration, processed either in sludge-only installations or with other materials in co-incineration or cement production, for example.

The evolving range of technologies and processes for phosphate recovery fits into this wider picture. Current full scale use is focused mainly on recovery of phosphate in the form of struvite, or magnesium ammonium phosphate. This is recovered from digested sludge or from the centrate from dewatering this sludge. In the middle of this year, the Struvite Recovery & Recycling Learning Alliance was launched in Europe to bring together the fragmented experience of working with such technology.

Much phosphate removal is achieving using chemical precipitation, but the struvite recovery processes are focused on treatment plants with biological phosphorus removal. Other technologies, such as the ExtraPhos process described in the following article, are able to recover phosphate where chemical precipitation has been applied. Other options include recovering phosphate from the thermally processed or incinerated sludge.

The world's largest nutrient recycling facility

One of the highlights over the last year has certainly been the opening of what is heralded as the world's largest nutrient recycling facility, at the Stickney Water Reclamation Plant of the Metropolitan Water Reclamation District of Greater Chicago. This features the Pearl process of Ostara Nutrient Recovery Technologies Inc. This produces the struvite-based Crystal Green refined fertiliser product.

The project puts nutrient recycling from sewage on a new scale. The Stickney plant serves 2.2 million people and a population equivalent of 4.5 million people, treating up to 1.44 billion gallons of wastewater a day.

Three Pearl 10K units have been installed in a standalone facility at Stickney WRP, each able to produce 10 tons per day. Together they will recover up to 85% of the phosphorus and 15% of the nitrogen from the wastewater flow. The utility receives a revenue stream from the sale by Ostara of the Crystal Green product, as well as benefitting from operational improvements associated with the reduction of struvite formation, and with the new process helping the utility exceed its 1.0mg/l effluent total phosphorus limit. The nutrient recovery plant handles four million gallons of flow a day, producing 9-10,000 tons of Crystal Green a year. MWRD has said that it also intends to add Ostara's Wasstrip process after start-up to further enhance performance of the facility.

MWRD selected Ostara along with consultants Black & Veatch for the design and build of the nutrient recovery facility, with the project team including Dr James L Barnard, Black & Veatch's Water Global Practice and Technology Leader.

Ostara's European success

Ostara has scored a double success this year in that its Pearl process also features in an innovative project officially inaugurated in June at the Amersfoort sewage treatment plant in the Netherlands. The company had at that time a pilot installation with Thames Water in the UK, but the Amersfoort project represented its first full scale plant in mainland Europe.

The company's Pearl and Wasstrip processes have been incorporated in the Omzet project at the Amersfoort plant of the Vallei en Veluwe Regional Water Authority. This project builds on the Dutch 'Energy Factory' concept and is transforming the plant into one that produces energy and recovers raw materials, with the intention of demonstrating an economically viable process that can be replicated elsewhere in Europe.

Amersfoort treats flow from a population equivalent of around 315,000. It is expected that the plant will produce a 30% electricity surplus of 2 million kWh/year and an estimated 900 tonnes of Crystal Green fertiliser.

NuReSys

Belgian company NuReSys has also seen success with the use of its technology in nutrient recovery over the last year or so. During last year an installation was commissioned at the Apeldoorn

wastewater treatment plant in the Netherlands, and the company also recently announced a contract award for a struvite recovery plant for the municipality of Braunschweig in Germany.

The NuReSys technology uses a two-stage process, which can be applied to digested sludge and to the centrate from sludge dewatering. In the first stage, air injection is used to strip out carbon dioxide and so increase the pH in the reactor. In the second stage, magnesium chloride is dosed, leading to the controlled precipitation of a struvite product, Bio-Stru.

The Braunschweig contract was awarded to NuReSys along with Bremer Pro-Aqua. According to NuReSys, the challenging tender required a versatile and flexible solution able to cope with flow varying from 8 to 25 m^3/h and phosphate phosphorus levels of between 300 and 800 ppm.

The Apeldoorn installation, for which NuReSys was a sub-supplier, is designed to produce 1500 kg of struvite a day. The previous municipal installations for the company are at Land van Cuijck in the Netherlands, a 400 kg struvite / day plant installed alongside a Demon system and commissioned early in 2015, and a 55 kg/day pilot plant installed in 2013 for Belgian water utility Aquafin. NuReSys also has four earlier industrial installations to its name.

For the North American market, NuReSys is now in partnership with Schwing Bioset.

Colsen

Another Dutch municipal nutrient recovery installation is getting underway for the town of 's-Hertogenbosch, where Colsen is to install its ANPHOS phosphate recovery system. Construction commenced following the issuing of the required permit by the Province of Noord-Brabant in January, with completion due at the end of 2018.

The installation forms part of a larger project which will see the Treurenburg wastewater treatment plant converted to become an energy neutral plant with nutrient production. Thermophilic digestion of the plant's sludge along with biological sludge from other plants will produce biogas. The gas will be desulphurised using Colsen's BIDOX system and then used by the local Heineken brewery and for fuel by an adjacent waste collection service.

Colsen was awarded the contract by Besix-Hegeman, covering design and implementation for the thermophilic sludge digester, the struvite-based ANPHOS phosphate recovery, the BIDOX biogas system, and permit work.

Veolia

Veolia Water Technologies has also seen success recently for its Struvia process. This is being installed at the 72,000 population equivalent Helsingør wastewater treatment plant in Denmark.

This plant has been designed to handle a flow of 60m^3/day and 250mg/l phosphorus. Achieving a phosphorus recovery of more than 90%, the plant is to produce 110 kg/day of struvite product.

Struvia treats sludge digester centrate in a stirred reactor containing the company's Turbomix mixer and a Turboflo lamella separator. A prototype of the technology was run at the Brussels-North wastewater treatment plant in 2013 and 2014 within the EU P-Rex programme. It achieved above 85% removal of phosphate phosphorus. Testing has also been carried out at the Braunschweig wastewater plant in Germany.

Phosphorus recovery from thermal processing / incineration

Given the substantial use of thermal processing / incineration for sewage sludge in Germany, and the country's desire to promote phosphate recovery (see following article), process options are being developed there in particular to recover phosphorus from the residues or ash of these sludge processing routes.

Mephrec process

In July this year, following a year of planning and six months of construction, a major new test project moved forward when a large scale pilot installation of the MEPHREC process began operating at Nuremberg Wastewater Treatment Plant 1 in anticipation of the construction of a full-scale plant.

The process mixes dried sludge with lime and foundry coke. This is heated at 2000 deg. C, giving a phosphorus product for fertiliser use and a metal product. Not only are any heavy metals in the sludge contained in the metal product, the process destroys any organic contaminants present.

The project partners have invested €5.2 million in the construction of the facility, while operating costs of the experiment to the end October 2017 are put at approximately €2.4 million. The testing will assess both the economic and operating parameters of the process. The intention is that the findings will support a full-scale project for the Nuremburg sewage sludge processing plant, providing sustainable phosphorus production for the project partner cities of Erlangen, Fürth, Schwabach and Nuremberg.

The test facility is using dried and granulated sludge from the Nuremberg plant combined with ash from the Lünen sludge incinerator. This mixture is formed into brick shapes in a 360 kg/hour press. These are mixed with limestone (34kg/hour) and foundry coke (60kg/hour) and fed into the smelter. The output design of the facility is 180 kg/hour of granulated phosphorus, which is to be used in fertiliser trials, and 10-30 kg/hour of iron alloy bars.

The intention is that the full-scale plant will produce syngas to be used in a cogeneration plant for heat and electricity production for the wastewater treatment plant.

Outotec

There is also German input to the ongoing development of another option applied to the sludge incineration route. The technology, trademark and patent rights to the AshDec ash decontamination process were acquired by Finnish company Outotec in 2011 from Austrian company Ash Dec Umwelt AG. This process extracts recycled phosphorus fertiliser from the ash produced during incineration of biomass or sludge. Outotec continues to work on improvements with the Federal Institute for Materials Research and Testing in Berlin.

In the process, ash, alkaline salts and a reducing agent are combined in a rotary kiln and thermally treated at 900 deg. C. Volatile heavy metals including arsenic, cadmium and lead evaporate. A filter then captures these as dust. Small granules of phosphate are continuously discharged from the reactor, and the company adds that any organic contaminants that are not destroyed during combustion are removed during this thermal treatment.

The end product is a calcined phosphate fertiliser. The product contains 16-20% P_2O_5 and 3-20% K_2O, depending on the feedstock and any additives. A pilot plant was operated in 2014, following initial work between 2008 and 2010. According to Outotec, the main objective of ongoing work is to increase the acceptability of the products under the prevailing market conditions by increasing the overall nutrient concentrations in the product and by eliminating potential fluctuations with regard to the nutrient plant availability.

According to the company: ‘The AshDec team and plant nutrition and soil scientists from various universities closely cooperate to figure out the potential of calcined phosphates which goes beyond the benefits of recycling: increased efficiency, no acidification, no accumulation of pollutants and – possibly – better pest resilience of crops.’

Phosphate recovery prospects

These developments suggest there is a promising future for such phosphate recovery technologies. However, progress will be shaped by some important factors, and water utilities will need to be able balance these factors as they make their investment decisions for the future.

One factor, for example, is move towards water utility energy neutrality or even creating wastewater plants that are energy positive. The Omzet project at Amersfoort combines such a switch with nutrient recovery. However, other plants are putting more of an emphasis on energy neutrality, given the pressures to reduce carbon emissions. For example, Aarhus Water in Denmark has postponed phosphorus recovery until it has shown its new process can meet ambitious energy targets, as Aqua Strategy reported in June.

Linked to this, such plans can include fundamental changes in the core wastewater treatment technology, impacting investment scheduling. For example, the Aarhus Water project incorporates secondary treatment using EssDe (cold) anaerobic anammox process. Similarly, Dutch company Paques points to the reduced energy requirements of its Anammox process, which can be combined with its Phospaq process to remove phosphate and ammonia, with Phospaq recovering phosphate as struvite. This year has seen the company sign a licensing agreement for deployment of Anammox in North America with Ovivo Inc.

Then there are the growing concerns around the pollutants that can be found in sewage sludge and biosolids, with attention increasingly turning to pharmaceuticals. In the US, for example, a two-year project was announced at the start of the year to collect data on polybrominated diphenyl ethers, azithromycin and ciprofloxacin in wastewater biosolids. Phosphate can be recovered from the sludge stream, but the remaining sludge still needs to dealt with and any shift away from agricultural use, for example, may force a rethink on the overall sludge strategy. Similarly, one of the sewage treatment options starting to be used in Switzerland to tackle pharmaceuticals is powdered activated carbon. On its own, this is a non-destructive process, but it fits in Switzerland where the carbon-containing sludge is incinerated rather than applied to land.

Clearly policy shifts, such as that being seen in Germany (see following article), can drive the uptake of phosphate recovery. In the meantime, the biggest driver is likely to be the very real operational and maintenance costs that water utilities can face as a result of inadvertent struvite production in their wastewater process streams, especially with growing use of anaerobic digestion for biogas production. Some of the phosphate recycling technologies are said to offer removal rates of over 80%. Also, Ostara, for example, offers utilities an income from the fertiliser product produced at their treatment plants. Speaking with Aqua Strategy earlier this year, the company's Chairman and CEO, Phillip Abrary, highlighted operational savings just as much as the income in the overall hard economic appeal of the technology for utilities, saying that payback can be around five years.

Outotec's fertiliser quest

The ongoing work of Finnish company Outotec on its AshDec process illustrates how the move towards the recovery of phosphate from sewage needs to link up with the needs of end users such as the agricultural users of fertilisers.

Outotec's research and test work this year has focused on achieving a higher nutrient concentration and production of complex (PK+S) fertilizers, the company told *Aqua Strategy*. Full replacement of sodium sulphate by potassium sulphate as an additive and reaction partner for phosphorus did not lead to satisfying results but a mixture of both compounds worked well. The advantage according to the company is that by adding potassium as an additive, a second macronutrient is present in the product alongside phosphorus. In addition, it says that concerns about long-term accumulation of sodium salts in the soil, even if only marginally supported by scientific evidence, are cleared out.

The company says that the improved process produces a PK+S 16-7+4 fertilizer increasing the total nutrient concentration to above 25% and reduces non-functional compounds in the product. The ash-based product also contains relevant silicate concentrations in the order of >10%. Sodium silicate is produced during the thermal treatment, and the company says that such plant available silicates can contribute to the crop resilience against pests by strengthening the cell walls and skin. If this hypothesis holds true, the company says the AshDec fertilizer would provide additional value to farmers.

The company also says that its process and product development does not depart from the core product philosophy of producing a non-water soluble, non-acidic, calcined phosphate. It points out that in a report published this year the Expert Group for Technical Advice for Organic Production (EGTOP) came to the conclusion to recommend calcined phosphates and struvite for organic production. It says also that the NextGen Fertilizer initiative of Professor Susanne Schmidt leading a team of Australian researchers, mostly based at The University of Queensland (UQ), aims at producing fertilizers with nutrient release and plant nutrient uptake curves synchronized. It argues therefore that since the efficiency of conventional mineral fertilizers leaves a lot to be desired, there is room for improvement.

Keywords:
resource recovery, phosphates, nutrients, Ostara, NuReSys, Colsen, Veolia, Outotec, Paques, Ovivo, Black & Veatch

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