SCOPE NEWSLETTER

European Sustainable Phosphorus Platform

Nutrient recovery & sustainability conferences

Contents

PERM: 4th Phosphorus in Europe Research Meeting

2nd June 2021 online - ESPP – Biorefine – ETA
www.phosphorusplatform.eu/PERM4

With over 370 participants this 4th PERM event follows a first workshop co-organised by ESPP and the European Commission DG RTD in Berlin 4th March 2015 (conclusions published by the European Commission), the second in Basel, 19th October 2017 (with InterReg Phos4You, see www.phosphorusplatform.eu/Scope126) and the third in Rimini 8-9 November 2018 (with Smart-Plant, www.phosphorusplatform.eu/eNews028). The 2021 PERM4 meeting was part of the **EU Green Week 2021** and was co-organised with the BioRefine Cluster Europe and ETA Renewable Energies Florence.

Ludwig Hermann, ESPP President, opening the meeting, indicated the aims of showing policy makers and companies what R&D is underway into nutrients in Europe, and of enabling exchange of experience between R&D projects.

The online event is accompanied by a full update of ESPP's inventory of nutrient-related R&D projects here www.phosphorusplatform.eu/R&D

EU nutrient R&D perspectives and project networks

Federico De Filippi, European Commission (CINEA European Climate, Infrastructure and Environment Executive Agency) outlined opportunities for testing innovative actions on nutrients under the LIFE Programme 2021-2027 (c. 5.4 billion € EU funding), in particular in the sub-programme "Circular Economy and Quality of Life". LIFE is now integrated into the EU funding and tender portal, the same application tool as Horizon Europe. For LIFE Standard Action Projects, the approach is mainly bottom-up, and content comes from the project proposer in the framework of the objectives defined in the call documents. The next call for proposals is expected in July 2021 here.

Under the 2014-2019 LIFE programme, 36 out of 99 water-related projects concern resource recovery from wastewater. These include ULISES (includes biogas, energy optimisation, solar disinfection for irrigation, bio-fertiliser by enzyme hydrolysis and struvite production, El Bobar, Almería, Spain), EasyMining Re-Fertilize, Newbies (ammonium sulphate recovery from digestate, human urine and landfill leachate).

Katja Klasinc, European Commission DG RTD, outlined perspectives for nutrient R&I activities under Horizon Europe. This will follow from the strong action in Horizon 2020.

Projects on nutrient recovery funded under Horizon 2020 include (non-exhaustive list, this classification is a simplification as many projects cover several areas):

- from wastewaters: INCOVER, SMART-PLANT, POWERSTEP, REWAISE, WATER-MINING, WIDER-UPTAKE, B-WATERSMART, ULTIMATE, RUN4LIFE, NEXTGEN, HYDROUSA, WALNUT, OPTAIN, SABANA, WATERAGRI, ZERO-BRINE
- from organic wastes or manure: SYSTEMIC, SCALIBUR, RUSTICA, SEA2LAND, CIRC4LIFE, LEX4BIO, WATER2RETURN, FERTIMANURE, NOMAD
- nutrient efficiency, nutrient use, other: CIRCULAR AGRONOMICS, NUTRI2CYCLE, GO-GRASS, SolAce, ECOBREED, TomRes, NUTRIMAN, NUTRISHIELD, SEA2LAND, BlueBio.

In particular, Horizon 2020 has funded a number of large demonstration projects, with full scale or demonstration installations and replication sites across Europe, for example SYSTEMIC, nextGen, Hydrousa.

A **SWOT analysis for nutrient recovery and recycling** is published in the conclusions of the workshop organised by SMARTPlant, nextGen, Hydrousa, Project-O and the European Commission (EASME) at IWARR Venice, 2019 (see SCOPE Newsletter n°132 and ESPP eNews n°41):

STRENGTHS:

- Positive image for wastewater operators and local politicians.
- Availability of technologies and recycling routes.
- EU and national Circular Economy policies and political recognition of importance of nutrients (phosphorus on EU Critical Raw Materials List, nitrogen driven by Nitrates Directive and National Emissions Ceilings Directive)

WEAKNESS:

- Lack of coherent support by administration and incoherent legislation among countries.
- Widespread production of small quantities = need for new logistic and market models.
- Lack of operating data of larger-scale facilities, over time, in real wastewater industry conditions.

OPPORTUNITIES:

- Implementation of the current tested nutrient recovery technologies.
- New collaborations and networking knowledge.
- Implementation of new EU Fertilising Products Regulation and anticipated addition of STRUBIAS products
- Phosphorus recycling obligations in Germany (in place) and possibly in the future in other Member States.
- Possibility to make more coherent End-of-Waste status in different Member States (if action is engaged)

THREATS:

- Public acceptance of recycled nutrient products

Key target areas for **nutrient R&I in Horizon Europe** will be nitrogen and phosphorus environmental thresholds (in coherence with Planetary Boundaries), regional N and P targets and regional transition towards these, identifying and optimising regional N and P budgets, uptake of nutrient recovery technologies and societal acceptance, environmental impacts of recovered nutrients, governance for nutrient management. Nutrient calls are published under Cluster 6 "Food, Bioeconomy, Natural Resources, Agriculture and Environment", in the section on Clean Environment and Zero Pollution.

Nutrient R&D networks

Ana Robles Aguilar, Gent University, outlined several **R&D networks** coordinated by Gent. RE-Source is a network of 23 international academic collaborations within Gent University focused on resource recovery from agro-food wastes and by-products. Gent also coordinates a network of PhDs and post-docs (25 at present in 10 universities across Europe) working on nutrient recovery. Gent University is also involved in two Marie-Curie Innovative Training Networks (ITN), AgRefine and Ferticycle, and in the IMETE Erasmus Mundus programme.

Erik Meers, Gent University, summarised the Nutriman project (R&D thematic network), which has developed a catalogue of nutrient recycling technologies and projects with links to technology suppliers and pilot or demonstration projects.

Soil Health and Food

Alfred Grand, member of the EU Horizon Europe Mission Board "Soil Health and Food" and organic farmer and composter in Austria, indicated that the Mission has the objective to achieve 75% of EU soils either healthy or showing improving health by 2030 (compared to over 60% unhealthy today). Currently, over 65% of EU agricultural soil is at risk of eutrophication-causing nutrient losses to surface waters. Soil degradation is costing the EU some 50 billion €/year in lost productivity and environmental and other damage. The Mission also aims to ensure that the EU does not "export" soil deterioration through imported food products or animal feeds.

Soil health indicators are taken as soil organic carbon, contaminants, excess nutrients, soil nutrient levels and pH

The mission aims to develop research and innovation projects, including one hundred "living labs" and regional "lighthouse" demonstration projects, soil health monitoring and communications to farmers and citizens.

Parallel sessions

Five parallel sessions enabled outline presentations of over 60 different R&D projects into nutrient management and recycling. Rapporteurs presented the following conclusions in plenary:

Manure nutrient recycling

Rapporteur Marina Ettl, Yara International ASA, and moderator Laia Llenas Argelaguet, Fertimanure and Universitat de Vic - Universitat Central de Catalunya.

There is a diversity of projects addressing manure recycling, with different processes, and combination with various other input materials, all with an overall objective of balancing farm nutrient management, and so reducing nutrient losses and emissions. Phosphorus and nitrogen are key targets, but sulphur and carbon are also potentially interesting.

Regulatory inadequacies were underlined, in particular the fact that the Nitrates Directive does not require limitation of phosphorus use, whereas reducing phosphorus losses is often essential if Water Framework Directive water quality objectives are to be achieved.

Projects should include user acceptance as a key objective, by involving operators in the field (e.g. nearly 30 "follower" digestor plants for SYSTEMIC). Higher value products should be prioritised, such as customised fertiliser blends. "Tailor Made Fertilisers" can be designed for a specific crop, soil and climate, combining organic and mineral fertilisers as required.

Open questions include investment and operating costs for recycling, logistics and transport, market acceptance of recycled materials, and whether or not the EU's Farm-to Fork will provide supporting tools.

Nutrient recovery from sewage & wastewaters

Rapporteur Bertrand Vallet, Eureau, and moderator Christian Kabbe, EasyMining.

The session showed a very active and varied range of R&D ongoing into P-recovery from wastewaters, recovering nutrient in different forms and in different configurations: from sewage sludge incineration ash, struvite, vivianite ammonium nitrate from offgas stripping, algae.

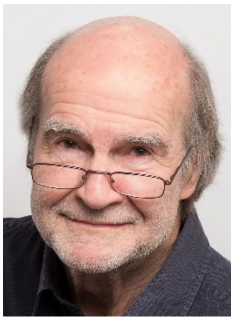
Pilot and large scale plants show that today P-recovery is possible.

As well as technologies, projects are looking at value chain integration (from sewage works to fertiliser market) and at support through data (mass flows), stakeholder training, networking.

Session discussions noted the need to verify that products fit farmers' needs before developing technologies. The active engagement today of the fertiliser industry can facilitate this. Legislation is seen as important to "push" P-recycling, with participants suggesting for example to include a % recovery obligation in the Urban Waste Water Treatment Directive update.

The need to assess climate impacts of phosphorus recovery approaches was underlined.

Contaminants, safety, Life Cycle Analysis (LCA)



Rapporteur Aurore Assaker, Ghent University & Biorefine Cluster Europe, and moderator Ludwig Hermann, ESPP President and Proman.

Proman and Lex4Bio have collected over 120 LCAs in which biobased fertilisers are analysed, showing that over half include field application as a life-cycle stage but often not taking into account emissions and losses in the field. Two thirds compare biobased fertilisers to mineral P fertiliser use, but often with inadequately supported substitution hypotheses.

From the different session presentations, copper and zinc are identified by LCA as important challenges for biobased fertilisers, as is the ratio of heavy metals / phosphorus.

There are many discrepancies between LCA methods and study boundaries, making it difficult to draw overall conclusions. Work needs to be engaged to agree common methodologies, for example application to defined sewage works configurations, units for expressing crop phosphorus availability.

Fertiliser properties and user uptake

Rapporteur Ana Robles Aguilar, Ghent University, and moderator Kari Ylivainio, Natural Resources Institute Finland (LUKE) and Lex4Bio.

New technologies are continuing to be developed to produce fertilisers from biowastes, and also to produce bio-stimulants.

Also, new secondary nutrient sources are being explored, such as fish processing wastes, or residues from ethanol production from urban biowaste.

New Marie Curie networks are starting on P-removal and recycling.

Use of algae to treat waste streams, then process in biorefineries, is now operational full scale.

Another route under development is use of secondary phosphorus to feed insect larvae production, for use as animal feed protein.

Several projects are studying the fertiliser effectiveness of recycled phosphorus materials, and will provide increasingly reliable data to farmers and regulators.

Fertiliser companies in Europe are confirming their interest in using secondary nutrients, as a complement to ongoing need for mineral P fertilisers.

Nutrient stewardship

Rapporteur Kimo Van Dijk, Wageningen University & Research, and moderator Chris Thornton, ESPP.

This session showed nutrient research projects covering nutrient thresholds in the environment, nutrients in food systems and resilience, nutrients in organic farming, mapping nutrient flows and innovative phosphorus technologies.

The session was opened by Sandra Poikane, European Commission JRC, who presented JRC and ECOSTAT ongoing work on nutrient targets for Good Ecological Status (Water Framework Directive, see here) and on setting nutrient thresholds and boundaries (see here).

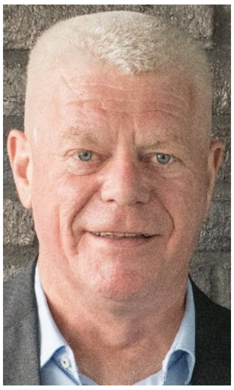
Discussions of research needs on nutrients underlined the need for strong interaction between policy and research. Research at different levels is needed, from catchment level to food systems, including different sectors and stakeholders.

Research should demonstrate the effects of measures, such as impacts of changes in fertilisation practice on water quality.

Transfer of research results to farmers is important but difficult. Farmers associations and advisory bodies can be relays.

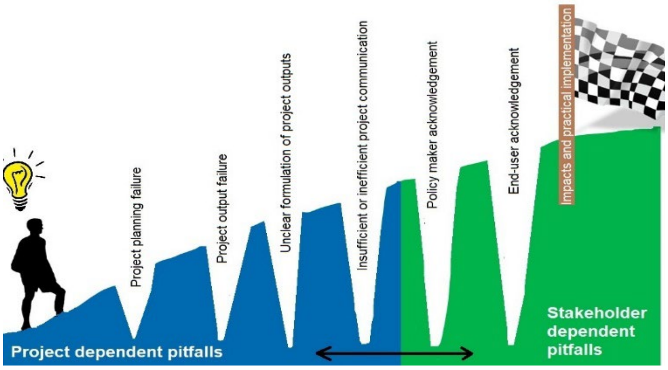
Concerning recycled nutrient materials, consumer and food industry acceptance are critical and research such as risk assessment and sociological interpretation is needed. Long-term field trials of today's recycled nutrient products need to be launched to provide data to support science, environmental assessment and farmer communication.

From R&D to implementation



Henning Lyngsø Foged, Organe, presented conclusions of the **SuMaNu** project Gap Analysis report 2021 (ESPP eNews n°52). This assessed to what extent seven R&D projects on manure management led to implementation by user uptake in the field or by policy changes. Different pitfalls between R&D project objectives and stakeholder uptake are identified: project planning, project output, formulation of outputs, project communication policy maker acknowledgement, end-user acknowledgement.

The projects analysed showed to be generally very good at delivering results, but performed poorly in policy integration and end-user acceptance. Conclusions are that projects should specifically include development of policy proposals in their work programme and should involve end-users and policy makers.



SuMaNu: Typical pitfalls that causes gaps between envisaged project goals and realised impacts, evidenced as practical implementation among end-users.

Comments from participants confirmed the importance of policy impact and end-user uptake of projects, and that more emphasis should be given to these difficult matters already from project design and composition of the consortium. Participants suggested that although influencing policy is difficult, projects can however make timely contributions to the iterative processes of policy proposal, development and implementation.

Conclusions

The final panel, with **Dries Huyguens, European Commission JRC, Francesco Fatone, Università Politecnica delle Marche, Ancona, Italy, Antoine Hoxha, Fertilizers Europe and Oscar Schoumans, Wageningen University and Research,** drew the following conclusions:

- wide and active range of R&D projects working on nutrient environmental impacts, the nutrient – food system, nutrient management, nutrient recycling, with a large number of scientific publications
- need to improve coordination between EU, national and regional nutrient R&D and actions (in that nutrient management is highly variable between regions), and to assess impacts of projects after their completion
- need to develop coordinated data bases and methodologies, e.g. on nutrient flows, LCAs, fertiliser tests of bio-based fertilisers …
- challenge of transferring R&D knowledge to policy makers, farmers, water industry
- research is needed on links between nutrient recycling and climate, including soil carbon
- need for EU support (e. g. Horizon Europe) to scale up nutrient recycling from R&D to market
- importance of R&D into social aspects (user acceptance), fiscal support policies, regulatory obstacles

PERM: 4th Phosphorus in Europe Research Meeting, 2nd June 2021 online, organised by ESPP, Biorefine Cluster Europe and ETA Renewable Energies Florence: PERM4 web page: www.phosphorus-platform.eu/PERM4

ESPP's inventory of nutrient-related R&D projects here www.phosphorusplatform.eu/R&D

PERM5 will take place in Vienna, Austria, with the 4th European Sustainable Phosphorus Conference, 20-22 June 2022 https://phosphorusplatform.eu/espc4

FAV WWT online 2021

Faversham House online event, 7th July 2021. Full conference videos can be purchased online https://event.wwtonline.co.uk/phosphorus/

ESPP slides here www.slideshare.net/NutrientPlatform

The Faversham House 2021 WWT online event brought together over 100 participants looking at perspectives for phosphorus removal requirements and technologies in the UK and in Europe, with technology showcases.

The event was introduced and chaired by **Karyn Georges, Isle Utilities**, who emphasised that phosphorus removal is a major challenge facing the water industry, with tighter discharge limits necessary to achieve good water quality status, whilst at the same time reducing sewage treatment carbon emissions. New P-removal technologies are coming onto the market. Circular Economy objectives are opening opportunities to recover and recycle phosphorus and perhaps in the future other nutrients.

Chris Thornton, ESPP, presented EU policy developments which are driving action on P-removal and P-recovery, in particular the Green Deal target of a -50% nutrient loss reduction by 2030, ongoing revision of the Urban Waste Water Treatment and Sludge Directives, the new Chemicals Policy which should reduce some contaminants in sewage sludge (PFAS/PFOS ban) and the Circular Economy Action Plant.

Ludwig Hermann, ESPP President, took part in the final panel discussion on future approaches to P-removal in sewage works, with the other speakers. This concluded the need to look at new and innovative solutions, beyond existing technologies, to enable P-recovery as well as recycling. This requires cooperation and knowledge exchange between different sectors and approaches. Tenders should be performance based, and not limit to certain technologies.

Challenges for P-removal from wastewater

Narinder Sunner, Stantec, outlined the operational challenges of lower P discharge limits, whilst also achieving carbon emission objectives. Lower P discharge limits require more complex operation, such as ferric dosing at multiple points. Very low P discharge limits are often achieved by added performance tertiary treatment, comparable to drinking water treatment processes. This requires considerably higher skill levels onsite to manage such processes.

Another key question is to reduce costs by taking a holistic approach to P-removal across the whole water use cycle, not just as an add-on in sewage works, and by addressing drivers such as P, N and climate together.

Helen Wakeham, England and Wales Environment Agency, indicated that although major investments had been made in phosphorus removal in the UK, and considerable progress made, further action and costs will be needed. P discharges from sewage works will be -83% lower than in 2027 compared to 1995. Nonetheless, nutrient levels in surface waters, causing quality failures, are now limiting economic development in some water basins. 2 billion UK£ has been invested by the UK water industry in P-removal, and a further 1.6 billion will be invested in the coming seven years. Developments in coming years will include implementation of a discharge limit of 0.25 mgP/l for some works, an increasing number of works with discharge limits, and catchment permitting, which has been demonstrated to be effective in achieving water quality objectives at lower costs. Today around 70% of P in UK surface waters comes from sewage works and 30% from agriculture. At the end of the current investment phase, sewage works contribution will be less than 50%

New-build biological P-removal (EBPR) capacity at Severn Trent's Minworth wwtp (near Birmingham), today treating c. 1.8 million p.e. with EBPR.

Rosemary Barker, Severn Trent Water, UK, outlined the challenges of more demanding P-removal and the approach Severn Trent is taking. The next investment cycle (AMP) will mean many more works will have P discharge permits, and tighter P- discharge limits for existing works. Severn Trent aims to develop biological P-removal where possible, and already has more than twenty works operating EBPR (Enhanced Biological P-removal). EBPR reduces dependency on chemical coagulants (which are by-products, so with availability questions) and offers lower CO_2 emissions. However, EBPR cannot reliably achieve <0.5 mgP/l without some chemical dosing. Sludge fermenters and dosing of trade wastes are being tested to increase available carbon and so improve EBPR performance. Achieving P-discharge below 0.5 mgP/l often necessitates a tertiary solids removal step, and to get down to <0.3 mgP/l requires tertiary chemical dosing followed by solids removal. Severn Trent has developed a matrix of solutions for tertiary solid removal (different filter systems, ballasted coagulation …), depending on works parameters, with no one solution fitting all.

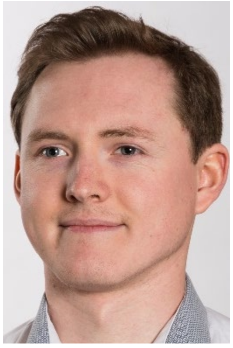
Innovative P-removal technologies

Russel Bright, Thea Elkins-Coward and Andrew Best, Industrial Phycology (I-PHYC), presented the company's phosphorus removal technology, which uses banks of closed-tank algae photoreactors with controlled conditions and specifically conditioned algal cultures for tertiary P-removal (that is, with input of outflow from standard biological treatment), down to 0.1 mgP/l. Ammonia is also removed to low levels and there is some removal of pharmaceuticals and other chemicals. The sewage residence time is 6-8 hours and the algae are recycled between tanks. The conditioning of the algae culture ensures rapid P-uptake independent of algal growth. The system has the advantage of avoiding the need for iron dosing, which poses questions of ferric salts supply and cost (with increasing demand resulting from tighter and more widespread P discharge limits) and of iron discharge limits to surface waters. Also, the algae system fixes around 23 $tCO_{2\text{-equ}}$ per year per 1000 p.e. capacity (assuming that the carbon is retained, e.g. by using the algae as a filler for resigs and foams). Alternatively, the algae can be used as a P-rich biofertiliser.

Photo: Broadwindsor Wastewater Treatment Plant, South West Water, UK. - The black tanks are the I-PHYC algae system, the concrete ponds are sludge holding tanks (not related to the algae process).

Barry Oliver, Royal Haskoning, presented the **Nereda** granular sludge process (see SCOPE Newsletter n°133). This is a sewage works solution where cycling and biopolymer dosing are used to select and develop sludge granules which settle easily, so ensuring solids removal. Biological phosphorus removal down to 1 mgP/l is achieved, with ammonia also < 1 mg/l. There are 40 Nereda plants operating worldwide today, serving over 10 million connected population, with a further 50 projects under construction.

Ana Soares, Cranfield University, UK, outlined different technologies available for P-removal: chemical flocculant dosing, biological phosphorus removal (EBPR), algae processes. Biological nitrogen removal and improvements in biological P-removal were outlined. She presented ion exchange processes, currently at TRL 7-8, which can both remove and recover phosphorus (e.g. to iron nanoparticles) and nitrogen (ammonia removal on zeolite ion exchange media), including a LCA comparing ion exchange for P removal to 0.5 mgP/l EBPR plus tertiary iron dosing plus sand filter. Combining new technologies such as anaerobic membrane bio-reactor (AnMBR) with ion exchange offers interesting potential.



Ben Hazard and Mike Froom, Te-Tech presented the [te-cyc](te-cyc) process for sewage works holistic upgrading, to achieve 1 mgP/l P-discharge with high-rate biological P-removal, or < 0.3 mgP/l with chemical dosing. The system is based on a sequencing batch reactor, with simple operation and reduced technical installations (valves, pumps, control systems). Operating conditions ensure stable selection for phosphorus accumulating organisms (PAO) which form large, easily settled flocs because of EPS production (extracellular polymer substances). Over 90% nitrogen removal is also achieved and discharge suspended solids are typically < 5 mg/l (average). Some 500 plants are operating today worldwide, mainly large plants, e.g. up to 1.2 million p.e. Te-Tech has today developed a small-scale, modular, drop-in solution, which can provide sewage treatment for small settlements (300 – 3 000 p.e.), with capacity for modular extension in the future. Ferric and alkali dosing are considerably lower than adding ferric into an existing sewage works system or two stage dosing with tertiary solids removal.

Photo: modular te-cycTM developed by Te-Tech Process Solutions .

Arthur Umble, Stantec, summarised installation of **MagPrex (CNP)** at Metro Water Recovery, Denver Colorado, USA, in a plant treating sewage for around 2 million p.e.. The P discharge consent will be reduced from 1 mgP/l to 0.1 mgP/l by 2037. The plant moved to EBPR in 2011, leading to a 4% deterioration in dewaterability of sludge, which significantly impacts costs because land spreading is some 250 km round-trip truck distance from the site, and also resulting in significant struvite deposition upstream of and in anaerobic digesters. Struvite is precipitated in the post-digestor sludge, upstream of dewatering. The struvite is at present sequestered into the sewage sludge going to land use. A 60 000 litres/day pilot reactor has shown 90% conversion of orthophosphate to struvite (at Mg:P dosing ratio 0.7:1 – 1.7:1) resulting in a 4 - 6 % improvement in sludge dewatering. Metro have now commissioned the full-scale MagPrex installation in 2019.

Simon Radford, Evoqua, presented the **CoMag** technology, which uses a magnetite ballast and low polymer dosing to flocculate solids and improve settlement (by a factor of c. 10 x), so improving P-removal and outflow water clarity (see also Jim Goodwin in SCOPE Newsletter n°125). The magnetite is then separated from the sludge using a magnet, and reused in the process. Advantages are low footprint and so the possibility to install into existing sewage works tanks. The process can in some cases largely achieve 0.2 mgP/l discharge with many full-scale plants operating at 0.1 mgP_{-total}/l. (see UKWIR UK national trials summarised in SCOPE Newsletter n°129).

Photo: Underwater camera within a CoMag vessel showing the settling and clarified water leaving the top.

EWWM 2021: European Waste Water Management

The 14th annual Aqua Enviro European Waste Water Management (EWWM) took place in Birmingham, UK, and online, 28-29 September 2021, and featured a full day on phosphorus removal and recycling.

Perspectives for iron salts and P-removal

Nardiner Sunner, Stantec, underlined the importance of "ferric" (iron coagulant salts) as the main technology for sewage phosphorus removal, with low Capex and no N_2O generation in the wastewater treatment plant, whereas possible greenhouse gas emissions in biological P removal remain to be investigated. However, a major challenge lies in future availability, with current UK ferric use in wastewater estimated at c. 450 kt/y, production c. 550 kt/y but future needs estimated at 750 kt/y (UK) for 2023-2024.

A wide range of technologies are being promoted for "tertiary" P-removal, to achieve discharge limits < 1mgP/l: cloth or sand filters, Nereda (granulated sludge), CoMag, reed beds … However, in some works 0.3 mgP/l can be achieved with dosing of ferric into the secondary treatment and effective solids settling/removal.

Further work is needed to optimise ferric P-removal, in particular improved mixing and dosing control. Other technologies are needed for small wwtps where ferric logistics are difficult (no permanent operator onsite), such as electrocoagulation, algae treatment, microvi fixed bacteria …

Julie Jeavons, Stantec and Martin Jolly, Yorkshire Water, summarised the company's challenges for phosphorus removal. Yorkshire Water has some 70+ wwtps needing to either add P-removal or reduce P-discharge to achieve tightened consents in the next 5-7 years. The company studied these sites with the aim of identify those where biological P-removal (EBPR) would be viable, given the long term lower operating costs, reduced chemical dependence and denitrification benefits of EBPR. Nine of Yorkshire Water's largest waste water treatment works have been identified as appropriate for EBPR. These sewage works will be converted to EBPR using existing ASP tanks with supplementary chemical and tertiary treatment (pile cloth media filters and ballasted coagulation CoMAG) for polishing down to low levels of phosphorus required in the final effluent.

Thomas O'Shea, Severn Trent Water, UK, *[text not validated by speaker]* outlined the challenges posed in AMPs 6 and 7 (UK water industry regulatory Asset Management Plans, 2015 to 2025). A total of 300 wwtps have new or tighter P-discharge permits, with 80 wwtps < 0.5 mgP/ and some down to 0.2 mgP/l. Iron discharge is generally limited to 4 mgFe/l, but in some cases to 2.5 mgFe/l. Discharge consents of 0.4 mgP/l can usually be achieved without TSR (tertiary solids removal), but increased ferric dosing leads to require increased caustic dosing, and consequently problems with denitrification. TSR implies increased costs, both Capex and Opex, and can also lead to problems from backwash returning to the wwtp. Also, operators have in the past usually aimed to achieve 50% of P-discharge consent, considered to provide adequate safety margin, but with very low consents (0.2 mgP/l), operators are now aiming at 80% of this limit, so requiring closer monitoring and rapid alarm systems.

Rowan Luck, Severn Trent Water, UK, presented experience at three wwtps which were modified and upgraded under AMP6 to achieve lower P discharge levels of 0.2 or 0.25 mgP/l, including TSR (tertiary solids removal) systems: Broughton 14 000 p.e., Dinnington 28 000 p.e., Harby 33 000 p.e. The sites were also subject to tighter ammonia, BOD and/or iron discharge limits. In all cases, modification of the ferric dosing systems (and in some cases, related caustic dosing) was required to achieve the new, low P discharge limits. A significant challenge was the time taken to achieve new discharge limits, because of necessitated modifications to the wwtp configuration.

Andrew Baird, WCS, *[text not validated by speaker]* noted that under AMP7 (UK water industry regulatory Asset Management Plan 2020 to 2025) over 780 UK wwtps will have tighter or new phosphorus discharge consents, of which 150 will be < 0.3 mgP/l. Some 30 000 private water treatment installations will also be concerned (this does not include single-home septic tanks). Various technologies are available for P-removal in these small installations, for which handling of chemicals (such as ferric) is problematic, including P-adsorbing materials (in sand filter, flotation or disk filter systems), algae systems.

Technologies for P-removal

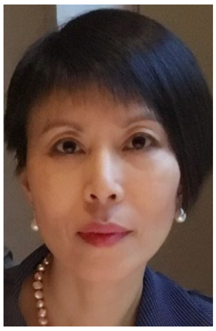
Several innovative technologies for phosphorus removal were presented:

Peter Eddowes, ARVIA Technology, presented a process combining destruction of micropollutants using Arvia's **NYEX** system and phosphate removal and recovery by electrocoagulation. In the NYEX process, a specific conductive adsorbent attracts organics. When electric current is applied, the organics are destroyed, and the acidified stream is acidified. A separate alkali stream is also generated. The acidified stream moves to a second reactor where dissolution of iron occurs using sacrificial iron electrodes, however, there is no precipitation or fouling of electrodes. The stream then moves to a settlement tank, where the pH is adjusted to neutral using the NYEX alkali stream, iron phosphate precipitates and the stream is discharged. A 50 litre batch test unit has been laboratory trialled on United Utilities Longton wwtp final effluent (c. 8 mgP/l). After settling, 0.02 mgP/l phosphate and 0.02 mgFe/l was achieved.

Ben Hazard, Te-Tech, presented **te-cyc**: summarised above, FAV WWT conference.

Hans Wouters, Brightwork BV, and **Gareth Medley, Dwr Cymru Welsh Water**, covered the **Sand Cycle** system for optimising tertiary continuous sand filters, installed full scale, treating 100% of discharge at Whitchurch (11 000 p.e.) and Llanberis (2 300 p.e.) waste water treatment works, Wales. Probably over 100,000 continuous filters are currently in use worldwide, applying different designs and manufacturers. Sand is continuously circulated and washed using an internal airlift and washer assembly, allowing the filter to operate without interruptions and making the system simple to operate. The Sand Cycle system uses microchips in the sand to remotely monitor sand movement during operation. It enables online operational control and optimisation of operating parameters. As a result, filter performance is improved. At Whitchurch the filter capacity increased from 14 l/s to 25 l/s, in alignment with 2040 growth horizon strategy without need for newbuild. At Llanberis the total ferric dosing could be reduced from 8 l/h down to 3 – 4 l/h by inline dosing into the feed to the filters. As a consequence, a simultaneous reduction of the caustic consumption from 7 l/h down to 5 l/h is reached. Consistent low P and residual Fe levels are reported of less than 0.3 mgP/l and 1.0 mgFe/l respectively. Sludge production is also reduced. Sand Cycle is applicable both in existing assets and newbuilt plants.

P-removal tertiary filters at Llanberis Welsh Water waste water treatment works (Brightwork, Sand Cycle).


Caroline Huo, BlueWater Bio, Wendy Rostron, Mott MacDonald Bentley, and Adam Guest, United Utilities, updated on performance of tertiary P removal using **FilterClear** at Barton wwtp (8 200 p.e.), treating the totality of the plant discharge. The plant today has discharge consents of 0.5 mgP_{-total}/l (spot and rolling average), 4 gmFe/l for iron and 3 mgN_{-NH3}/l for ammonium. The FilterClear installation at Barton was commissioned in March 2020, combined with two-point ferric dosing. FilterClear is a depth filtration process (with four layers of media: anthracite, silica, alumina and magnetite) which can achieve effective P removal at high filtration rates of 25 to 35 m/h. More details of FilterClear in ESPP SCOPE Newsletter n°125).

The Barton FilterClear installation was initially achieving TP < 0.2 and iron 1-2 mg/l, but significant caustic dosing was required to balance the ferric dosing and top up alkalinity for nitrification. This led to scaling problems for downstream pumps and pipework. These problems were resolved by reducing and moving from 2 to 1-point ferric dosing dosing, and also changing the caustic dosing point. The plant is now reliably achieving the discharge consent of 0.5 mgP_{-total}/l with the added benefit of reduced ferric and caustic consumption.

Suzie Vale, Severn Trent Water, UK, *[text not validated by speaker]* summarised experience with **CoMag** as tertiary phosphorus removal at Finham wwtp (500 000 p.e.). CoMag uses iron salt dosing, then magnetite (Fe_3O_4) and polymer to increase floc density and so improve solids settling. Magnetite is then separated in a shear mixer and recycled back to the process. A number of CoMag installations are operating worldwide, and Finham is the largest capacity to date. An initial issue with magnetite loss has been resolved by changing the polymer used and correcting clarifier baffle design. The installation is achieving c. 0.1 mgP/l and 1 mgFe/l discharge (significantly below revised consents of 0.2 mgP/l and 4 mgFe/l).

CoMag at Lletty Brongu (above) and Ruthin (below) waste water treatment plants.

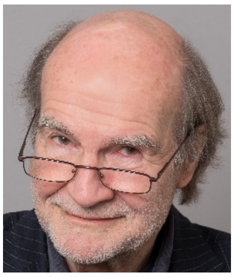
Harrison Brown, Evoqua, and Victoria Wilson, Dwr Cymru Welsh Water, summarised experience with **CoMag** at Lletty Brongu Waste Water Treatment Works (21 300 p.e.) and Ruthin Waste Water Treatment Works (6 400 p.e.). In both cases CoMag is installed for P-removal after existing trickling filter systems and uses the existing humus tanks, refurbished as CoMag clarifiers. CoMag is well suited to being retrofitted into existing trickling filter plants due to its ability to treat a wide range of influent conditions, including the high solid loads commonly experienced on trickling filter sites. Upgrading also included new ferric, caustic and polymer dosing systems, and training of operators. After initial commissioning, both sites are now achieving on average < 0.3 mgP_{total}/l. and average 1 $mgFe_{total}$/l in discharge.

IWA RR 2021

International Water Association
Resource Recovery Conference

The 4th IWA Resource Recovery Conference took place online from Istanbul, 5-8 September 2021, with over 200 participants, included two sessions on phosphorus recovery, with some 30 participants. Other sessions covered recovery of water, energy, carbon, VFA and organics.

Photo: conference organiser: Gökşen Çapar, Ankara University, Turkey.



Ludwig Hermann, Proman and **ESPP President,** outlined EU policy developments towards nutrient recycling and resource recovery, and indicated some possible routes for enabling economic business models: carbon credits for displaced energy consumption for recovery of nitrogen, phosphorus recycling obligations (examples of Germany, Switzerland), recycling targets and incentives, pricing of fertilisers by nutrient use efficiency rather than by volume …

P-recovery by adsorption and ion exchange

Dari Frascari, University of Bologna, Italy, presented trials of ion exchange systems for phosphorus recovery and recycling. Layne^{RT}, a commercial hybrid anion exchanger (HAIX) resin combining quaternary ammonium and iron nanoparticles has been tested for 2 ½ years in a 10 m^3/day pilot using real wastewater plant effluent at Cranfield University UK (see summaries of published papers below by **Pinelli, Guida, Soares et al.**). Phosphorus is selectively adsorbed to the iron sites and other anions to the resin matrix. Sodium hydroxide is used to regenerate the iron sites, and brine (sodium chloride) the resin. Results show that acid is not necessary for the resin restoration, with water rinsing being sufficient. Bed regeneration can be automated. Phosphorus removal down to 0.1 – 0.3 mgP/l (95% soluble P removal) was shown. After 2 ½ years deterioration of resin P-removal effectiveness was not significant and selectivity for phosphorus, versus e.g. sulphate, was maintained (with inflow P 10 mgP/l). Initial tests (three regenerations) using calcined pyroaurite for ion-exchange were also presented (a magnesium – iron LDH layered double hydroxide), showing high selectivity for phosphorus.


Xavier Foster and Céline Vaneeckhaute, University of Laval, Quebec, also presented tests using HAIX resin in synthetic ion solutions. Results suggest that using a weak anionic base resin enables very dilute sodium hydroxide solution to be used for regeneration with increasing P-adsorption capacity over six regeneration cycles. This could potentially enable regeneration cost reduction.


Ru Liu and Oded Nir, Ben-Gurion University of the Negev, Israel, presented lab tests of a process for phosphorus removal and recovery by adsorption of P onto granular-ferric-hydroxide, desorption (regeneration) using potassium hydroxide, then recovery of potassium phosphate and potassium hydroxide solution by electrodialysis with bipolar membranes (EDBM). The process was tested at the laboratory scale (2 litres) using pure chemical solutions (not real wastewater). Acid cleaning of the adsorbent beds (HCl) was also necessary. The chemical solution inflow to the P-adsorption beds was 10 mgP/l, reduced to 1 mgP/l in outflow. The desorption liquor was c. 3 500 mgP/l and the recovered potassium phosphate solution was 0.1M.

Büşra Kara, Marmara University, Turkey, presented experimentation of a process to recover phosphorus using activated carbon combined with magnetite (a magnetic iron oxide). The batch lab trials used pure chemical solutions (not real wastewater). The composite material was produced by functionalising activated carbon with hydrochloric acid, then reacting in an iron salt solution, then adding sodium hydroxide to precipitate, and finally drying. After 24-hours reaction time, then magnetic separation, the magnetite composite material showed an adsorption capacity of 26.5 mg P/g at pH 10. Some ammonia was also removed to the composites. Regeneration with hydrochloric acid recovered < 50% of adsorbed phosphorus, and around 10% of nitrogen. Regeneration with sodium hydroxide recovered around 75% of adsorbed P, but very little N.

Cranfield UK: Successful pilot operation of ion-exchange for P-removal and recovery

Two new papers present 2 ½ years operation of HAIX LayneRT® ion-exchange to remove and recover phosphorus from real wastewater in a 10 m³/day demonstration plant, with performance maintained after 60 regeneration cycles (see also above D. Frascari presentation at IWA RR 2021).

The LayneRT hybrid ion exchanger (HAIX) consists of hydrated ferric nanoparticles in a strong base anion (quaternary ammonium) resin. This exchanger is selective for phosphate: some other mineral ions (silicate, sulphate, ammonia ...) and some organics were also adsorbed but this did not significantly impact the process effectiveness or durability over time.

The papers present tests to optimise operation, characterise and model the physicochemical process and comparisons of different regeneration solutions (NaOH sodium hydroxide, NaCl salt brine), and then 2 ½ years continuous operation in real wastewater. The NaOH principally regenerates the iron-based P-adsorption sites, whereas the NaCl regenerates the resin matrix.

The demonstration system was a 58 l column (total height 1.6m) operating at 10 m³/h with secondary treated wastewater from Cranfield municipal sewage works, UK. Regeneration was first by backwash in water, then 2% w/w sodium hydroxide (without use of NaCl), reused multiple times. Phosphorus was precipitated from the regeneration liquor as calcium phosphate.

***P-removal**: with inflow c. 7 mgP_{-total}/l (of with around 90% as soluble orthophosphate), the system reduced orthophosphate concentration to below 0.1 mgP_{-PO4}/l even after 60 cycles (90 – 85% removal of orthophosphate).*

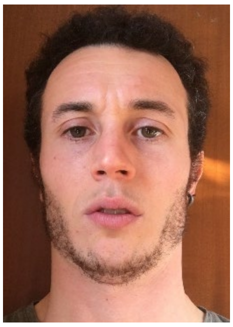
***P-recovery**: the recycled regenerant NaOH solution was considered saturated in phosphate when "breakthrough" occurred in the resin bed, that is output orthophosphate levels rose above the target concentration (decided by the operator: 0.1 mgP_{-PO4}/l but could be set higher). Calcium hydroxide (lime) was then added to precipitate calcium phosphate so renewing the regeneration solution.*

Conclusions are that the LayneRT HAIX resin is an effective selective medium for removing and recovering phosphorus as a tertiary treatment, showing reliable and durable performance in real wastewater (secondary effluent), enabling phosphorus recovery. Further work is needed: verify levels of contaminants in the recovered calcium phosphate (expected to be very low because of the resin adsorption selectivity) and use of the calcium phosphate as a fertiliser or for input to fertiliser production; possible recovery of organics from the regeneration liquor; possible occasional NaCl regeneration of the resin base; overall economics, which will depend on regeneration or disposal of the spent NaOH regeneration liquor and of the end-of-life HAIX resin; demonstration in other sewage works.

"Demonstration of ion exchange technology for phosphorus removal and recovery from municipal wastewater", S. Guida, A. Soares et al., Chemical Engineering Journal 420 (2021) 12991, https://doi.org/10.1016/j.cej.2021.129913 .

"Regeneration and modelling of a phosphorous removal and recovery hybrid ion exchange resin after long term operation with municipal wastewater", D. Pinelli, D. Frascari et al., Chemosphere 286 (2022) 13158, https://doi.org/10.1016/j.chemosphere.2021.131581 .

Acid leaching



Andrea Tasca, University of Pisa, Italy, presented lab. scale tests of acid leaching of HTC (hydrothermal carbonisation) char from Ingelia's 14 000 t/y sewage sludge treatment installation at Naquera sewage works, Valencia, Spain (see ESPP eNews n°27 and SCOPE Newsletter n°132). Leaching with sulphuric acid at pH1 (solid/liquid ratio of wt5%, four hours) recovered >70% of the total phosphorus from the HTC char. The acid leaching reduced organic carbon content of the char by up to c. 20% and increased ammonium content from near zero to c. 20%. A previous paper (Tasca et al. 2020) presented leaching of the HTC char with nitric acid, achieving c. 60% P extraction at pH 1, 2 ¼ hours. Work is in progress to investigate the quality of the recovered phosphoric acid which would presumably require purification to remove organic carbon and possible contaminants, as well as on the possible uses of the P-depleted but probably now acidic char.

Gaia Boniardi, Politecnico di Milano, Italy, presented lab. scale tests of acid leaching of sewage sludge incineration ash (bottom ash, fly ash) using 0.2M sulphuric acid. The ash was from a pilot-scale experimental pilot grate furnace (100 kg pelletised sludge per hour) at San Giuliano Ovest wwtp (PerFORM WATER 2030 project), and had phosphorus content of 7 – 9 %P and metals higher than fertiliser limits (nickel, chromium, arsenic, copper, zinc). 70 – 85 % of P was leached from the ash, but also metals. Precipitation by neutralising to pH 3.5 – 5 resulted in a mixed phosphate salt (17% P) with low metal levels, mainly consisting of iron and aluminium phosphates. Nonetheless, purification of the leachate would be necessary to reduce contaminants. Use of different neutralising agents did not significantly modify the phosphate precipitation. Poorly combusted ashes (significant LOI) showed lower P-recovery levels, showing the significant influence of combustion conditions on P-recovery.

A 2021 paper (below) presents further laboratory tests of acid leaching from five different sewage sludge incineration ashes, all from sewage works using some iron salts for P-removal, using sulphuric and hydrochloric acids. P content of the ashes ranged from 7.6% to 9.6%, in line with typical values from literature. Copper, zinc and heavy metals in the ash were also analysed. P extraction showed to be related to the acid (liquid) / ash (solid) ratio, probably because this increased contact efficiency. Leaching was similar for the two acids, at comparable strengths, with sulphuric acid releasing 5 – 10% more phosphorus. Optimal leaching was achieved at pH 2, L/S radio 20:1 and contact time 2 hours. P-leaching under these conditions varied from 54% to 92%.

See also "Assessment of a simple and replicable procedure for selective phosphorus recovery from sewage sludge ashes by wet chemical extraction and precipitation", G. Boniardi et al., Chemosphere 285 (2021) 131476, https://doi.org/10.1016/j.chemosphere.2021.131476 .

Water operators and circularity

Kees Roest, KWR Water Research Institute, Nieuwegein, The Netherlands, presented conceptualisation of a fully circular water industry in The Netherlands, developed jointly with the country's water companies. This considers water, energy and all materials required as inputs and generated as outputs by the water industry, and also social values such as public health and safety. The aim is to define objectives for 2050 then identify actions and define pathways to achieve these.

Dines Thornberg, Biofos, Denmark, updated on the VARGA project, a Denmark national 'lighthouse' project to reduce environmental impacts and implement resource recovery at the Avedøre municipal wastewater treatment plant (350 000 p.e.). A pre-filter on inflowing wastewater (currently under testing for part of the plant: 80 000 p.e.) aims to remove up to 55% of COD, then going directly to anaerobic digestion, to increase methane production and reduce secondary treatment energy requirements. Modification of the dissolved oxygen set point and carbon dosing has shown potential to significantly reduce N_2O climate emissions. Separately collected municipal organic waste is being anaerobically digested, and the digestate has been successfully demonstrated as an organic fertiliser. In a further project, FUBAF, single cell protein production from methane is being tested. Phosphorus recovery from sewage sludge incineration ash by electrolysis is being tested

Following positive lab trials (see SCOPE Newsletter n°138), a first pilot was developed, but proved unsuccessful because of challenges with abrasion by ash, membranes, electrodes, collection of released hydrogen gas and filling and emptying with new ash. A second pilot electrolysis plant is now being developed.

ESPP & nutrient platforms members' webinar

The members' webinar on 31st August 2021, brought together 80 ESPP and nutrient platform members, presenting updates on platforms in Europe and Canada, and progress in implementing German and Swiss P-recovery regulations.

The webinar was opened by **Ludwig Hermann, ESPP President** (Proman), **Simone Apitz, DPP President** (Hessen Ministry for Environment, Climate, Agriculture and Consumer Protection) and **Renske Verhulst, Netherlands Nutrient Platform**.

Developments in Sweden, Canada, Baltic

Kaj Granholm, Baltic Sea Action Group (BSAG), outlined developments in the Baltic. HELCOM is expected to adopt new and lower nutrient emission targets and a nutrient recycling strategy in October 2021. Much further action is needed to reduce phosphorus inputs to the Baltic, to reduce eutrophication, in particular from agriculture. Support for use and production of recycled phosphorus products is necessary.

Klara Westling, Svenskvatten (Swedish Water and Wastewater Association), updated on Sweden. Currently around one third of sewage sludge is applied to land. The Enquiry on 'Sustainable Sludge Use', requested by the Government in 2018, despite a mandate suggesting to ban sludge application to land, concluded in 2020 (see ESPP eNews n°40) that recycling by agricultural use should continue subject to quality standards. The Enquiry recommended a recycling target of 60% of P for sewage works > 20 000 p.e. With various delays and government changes there are no further developments, and the Swedish EPA has not yet not yet reported concerning definition of sludge quality criteria.

Céline Vaneeckhaute, University of Laval, Canada, updated on implementation of the Quebec Province organic waste management policy which bans landfilling and incineration of sewage sludge, food waste and other organics by 2022. Consequently, new composting and methanisation installations are under development. However, in places fields do not need phosphorus application, so processing of digestate is needed.

P-recovery legislation implementation: Germany, Switzerland

Andrea Roskosch, German Federal Environment Agency (UBA), outlined Germany's regulatory P-recovery obligation, adopted in 2017 (see SCOPE Newsletter n°129) which fixes deadlines of 2023 for reporting (for all sewage works) and 2029 / 2032 (depending on sewage works size) for implementation of technical P-recovery. After 2029/2032, agricultural application of sewage biosolids will only be possible for sewage works < 100 000 / 50 000 p.e. (with conditions). For larger sewage works, after 2029 or 2032, technical P-recovery will be obligatory wherever the P content of sludge is > 2% and must achieve one of the following: recovery of > 50% of P in sludge, P-recovery in the wastewater treatment such that sludge P is reduced to < 2%, or mono-incineration and recovery of > 80% of P in ash. If smaller sewage works do not valorise sludge to farmland, then they must also implement technical P-recovery.

Overall current status in Germany is that a dozen struvite precipitation installations are operational (P-recovery from liquors in the sewage works or sludge treatment) but that these are often not reducing to < 2% P in sludge. Work is underway to establish whether processes to release more P in a soluble form, so enabling higher rates of P-recovery by struvite precipitation.

Currently around 75% of German sewage sludge is incinerated (40% co-incineration, 35% mono-incineration). Significant mono-incineration capacity is under construction or planned, so that in 2032 sufficient mono-incineration capacity is expected to be in place.

Several processes to recover P from sewage sludge mono-incineration ash will soon be operating.

Perspectives for the future include further mono-incineration development, need for support for P-recovery implementation, challenges for uptake of recovered P, harmonisation of waste and water legislation and consideration of a possible total ban on land application of sewage sludge.

ESPP table summarising the German P-recovery regulation obligations

Larger sewage works (100 000 p.e. from 2029 and 50 000 p.e. from 2032)		**Smaller sewage works**
If P in sludge **<2%P**	If P in sludge **>2%P**	
No P-recovery obligation (other than the general recycling clause) unless sludge is incinerated	Three options: • recover 50% of P from sludge • recover P from sludge sufficiently to reduce below 2%P • incinerate sludge and recover > 80% of P in the ash	Sludge can still be used "in or on" soil. If sludge is incinerated and P>2%, then obligation to recover 80% of P in the ash *
All sewage works must prepare a phosphorus recovery plan by end 2023		
In all cases, the general requirement to recycle phosphorus as far as is "technically feasible and economically viable" applies		

Sibylla Hardmeier, Swiss Federal Department of the Environment, Transport, Energy and Communications, outlined Switzerland's regulatory P-recovery obligations, adopted in 2015 and 2018 (waste and fertilisers regulations, see SCOPE Newsletter n°129), requires P-recovery from both municipal sewage and meat and bone meal ash (MBA), by 2026, under specified conditions.

An "Enforcement Guide" published in 2020 (Module BAFU/ OFEV UV-1826 "Wastes rich in phosphorus", in French and in German) fixes **P-recovery targets of 50% (75% is also being discussed)** from phosphorus rich waste by 2026. Each Swiss canton (26) must define a P-recovery plan. This is expected to lead to construction of 5-10 new regional (inter-cantonal) P-recovery plants and also sludge mono-incineration, because although all sewage sludge in Switzerland is already incinerated today, some 20% currently goes to co-incineration where the phosphorus is 'lost' (e.g. in cement works).

The SwissPhosphor network has published two reports comparing P-recovery technologies (in German 2017 summarised in ESPP eNews n°12, 2019, 2021 update underway) and is working on a funding model , considering e.g. possible import taxes on fertilisers, consumer fees on wastewater, tax on MBA disposal …

Lessons to date are the need for communication and cooperation with stakeholders, definition of clear roles for different actors in regulation and in wastewater management, and the importance of a market for the recovered phosphorus products.

Swiss Government document on implementation of P-recovery published

The Swiss Federal Office of the Environment (OFEV / BAFU) has published an enforcement aid document clarifying the Swiss legal P-recovery obligation (from sewage sludge and from MBA: meat and bone meal) and describing the state of the art, suggesting a 50% P-recovery rate. The document states that as much P should be recovered as is possible with state-of-the-art technology, and that the long-term objective is P self-sufficiency, that is to recover at least as much P as is currently imported into Switzerland in mineral fertilisers and chemicals. The Switzerland phosphorus flows diagram included in the document indicates that imports of mineral fertilisers and chemicals = 4 590 tP/y, represent around 51% of the 6460 tP/y in sewage sludge and plus 3650 tP/y in animal by-products (other than manure). The 50% can be achieved as 50% of sewage works P inflow (P-recovery in the sewage works) or 50% of P in ash (P-recovery from ash). ESPP notes that, defined thus, the self-sufficiency objective does not take into account the 4 060 tP/ imported in animal feed and other products: taking these into account would mean a P-recovery rate of 86%). The document further reminds that the legislation requires contaminants to be eliminated according to state-of-the-art if the product is a fertiliser: this is considered achieved if the requirements of the Swiss Chemical Risk Reduction Ordinance (ORRChem RS / USG SR814.81) for recycled fertilisers. The document indicates that sewage works < 1 000 p.e. are generally exonerated from the P-recovery obligation. The document confirms that implementation of the P-recovery obligation is the responsibility of the Swiss cantons, which have legal responsibility for planning and management of waste.

"Phosphorreiche Abfälle. Ein Modul der Vollzugshilfe zur Verordnung über die Vermeidung und die Entsorgung von Abfällen (Abfallverordnung, VVEA)", BAFU 2020 www.bafu.admin.ch/uv-1826-d

"Déchets riches en phosphore. Un module de l'aide à l'exécution relative à l'ordonnance sur la limitation et l'élimination des déchets (ordonnance sur les déchets, OLED) », OFEV 2020 www.bafu.admin.ch/uv1826-f

Nutrient platforms updates

Presentations from ESPP (European Sustainable Phosphorus Platform), the German Phosphorus Platform and the Netherlands Nutrient Platform, outlined the actions and projects of the three nutrient platforms operational in Europe today.

ESPP (established 2014) has today 49 paying members, the Netherland Platform (2011) has 30 and the German Platform (2015) nearly 70. All three platforms are funded totally or mainly by members' fees.

ESPP's activities currently address EU policies (in particular Green Deal nutrient loss reduction target, the EU Fertilising Produces Regulation, water policy revisions, Horizon Europe …), "Legacy Phosphorus" in agriculture, climate change – nutrients and eutrophication, the Nutrient Recycling Technology Catalogue and ESPC4 (4th European Sustainable Phosphorus Conference, Vienna 20-22 June 2022). Projects include reinforcing ESPP's secretariat and maybe developing an Industry Advisory Group (to be defined). Participants requested action on economic policies to incentivise nutrient recycling and on the struvite REACH dossier.

The Netherlands Nutrient Platform acts on removing regulatory barriers to recycling and stimulating circular economy policy, raising awareness and promoting success stories and facilitating projects and business cases. Projects and actions underway include work on End-of-Waste status for struvite (upstream of possible EU fertiliser status), EU Fertilising Products Regulation implementation and manure treatment, with a specific 3-year project on micronutrients, struvite in manure, nitrogen recycling in wastewater treatment works, new fertiliser products.

The German Phosphorus Platform (DPP) works with federal and state authorities on roll-out the German P-recovery legislation and support for R&D and large scale implementation (e.g. RePhoR, see ESPP eNews n°48). provides networking, information on P-recovery technologies, and compatibility of fertiliser regulation with recycling. DPP's "Policy Memorandum" (October 2020, see ESPP eNews n°49) outlines proposals covering support for implementation of P-recycling, regulatory approval of P-recyclates, demonstration of plant availability, fertiliser regulation, and German strategies for other nutrients.

Status and operational projects developed by national nutrient or phosphorus **platforms under development in Ireland, Sweden, Italy and Canada** were also outlined.

Phos4You final project outcomes

Phos4You is an Interreg project, 2016-2021,
6.5 million € EU funding,
12 partners in the North West Europe region, led by Lippeverband

https://www.nweurope.eu/projects/project-search/phos4you-phosphorus-recovery-from-waste-water-for-your-life/

Phos4You final Technical Report: https://duepublico2.uni-due.de/receive/duepublico_mods_00074788

Conference slides: https://www.nweurope.eu/projects/project-search/phos4you-phosphorus-recovery-from-waste-water-for-your-life/#tab-5

Photos: Kirsten Neumann

The final project conference Phos4You, Essen, Germany, and online, 22-23 September 2021, discussed results of pilot trials of several P-recovery technologies, as presented in the final project technical report **here**.

The conference brought together some 200 participants, partly in-person in Essen partly online.

Phosphorus recovery technologies at full- or pilot-scale engaged in Phos4You are:

- **bioacidification** to release phosphorus from sewage sludges enabling P-recovery by precipitation
- **Veolia STRUVIA** phosphate precipitation
- **Remondis Tetraphos**, **Parforce** and **Phos4Life** P-recovery from sewage sludge incineration ash
- **Euphore** modified incineration with chloride dosing
- **P-adsorption** to crab shell material with **Veolia Filtraflo**
- Acidic **micro-algae** P-removal

Challenges facing water operators

Uli Paetzel, German Water Association and CEO of Emschergenossenschaft Lippeverband (EGLV) opened the conference, underlining the challenges faced by water management authorities because of climate change. The recent floods in Germany have cost some 30 billion € government money. Climate impacts are accentuating social injustices. Emschergenossenschaft and Lippeverband consider that the Circular Economy has an important role in climate actions, including water recycling and recovery of materials from wastewaters, within wider innovation in the water sector. However, water authorities can only move forward if there are stable funding mechanisms and clear objectives set by Government.

Dennis Blöhse, EGLV, outlined the difficulties facing the wastewater treatment plant operator in deciding how to take forward implementation of the German phosphorus recovery regulation. Selecting a technology is one challenge, because although a number are now on offer, all are today still at the pilot or start-up stage. Water operators who move first to implement full-scale take a significant financial risk, both in additional investment / start-up costs for "first" installations, but also the risk of being tied into a technology which may finally prove not to be optimal. Technology is only part of the decisions to be taken: wwtp operators must also define how to organise sewage sludge collection and processing? whether to move to one centralised site? where to implant installations? whether and how risk can be shared between a number of operators and regions? Difficult decisions also concern the legal status of the P-recovery installation: owned by the wwtp operator? by the technology supplier? joint venture?

Anders Nättorp, FHNW, presented scenarios for implementing the Swiss P-recovery obligation, considering nine different technologies and several timing routes, elaborated and assessed with the six main sewage sludge operators and the four Cantons of North West Switzerland. This is summarised in detail in ESPP eNews n°61.

EU Green Deal and the CAP

Gijs Schilthuis, European Commission, DG AGRI, outlined how the Green Deal objectives on nutrients can be addressed via the Common Agricultural Policy.

The **Green Deal** is the European Commission's number one priority. Both the Farm-to-Fork and the Biodiversity Strategies of the Green Deal (see ESPP SCOPE Newsletter n°139) fix a target to reduce nutrient losses by 50% by 2030.

An "**Integrated Nutrient Management Action Plan**" will be developed in 2022 with key objectives:

- Sustainable nutrient application in agriculture
- Stimulate the market for recovered nutrients
- Address nutrient pollution at source
- Sustainability of the livestock sector

The new Common Agricultural Policy (CAP) will be an important tool to contribute to the nutrient loss reduction target. The CAP is currently under revision* (finalisation expected by end 2021).

The new CAP policy requires Member States to develop strategic plans for the period 2023-2027 with a focus on all three dimensions of sustainability (economic, environmental, social). In these new strategic plans Member States must plan how to spend the CAP budget of a total of nearly 400 billion € (2021-2027) divided in around 70% direct payments to farmers and 30% rural development support. To encourage farmers to change agricultural practices, at least 25% of direct support must go to new voluntary "eco-schemes" and at least 35% of rural development support to voluntary agri-environment-climate actions.

All support must respect "**conditionality**", which means that subsidies to farms not respecting certain listed environmental regulations and a list of good agricultural and environmental standards will be reduced. This system of "conditionality" has been reinforced with the addition of a reference to the Water Framework Directive, complementing, for example, the Nitrates directive. This aims to help implement the Water Framework Directive provisions. But farmers must in any case respect the legal obligations regarding water quality protection as stemming from the directive.

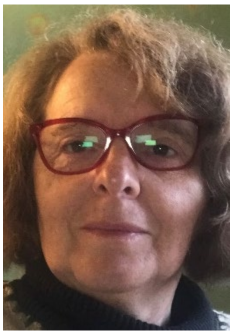
The **voluntary environmental schemes** will be defined by Member States within a European framework. One of the possible themes for such voluntary environmental schemes is "Nutrient Management". The Commission will verify these schemes with Green Deal objectives, but conformity with these objectives will not be a legal obligation under the new CAP.

The Commission proposed FaST **(Farm Sustainability Tool) for Nutrients**, would have required all farms to calculate their nutrient balance (inputs, offtakes). Use of this tool will, however, not be obligatory in the legislation, but be part of Farm Advisory Services that Member States must offer to farmers. The Commission is proceeding with pilot trials of FaST at nine sites in 8 Member States. The Commission has also launched a study into methodologies for assessing nutrient requirements (https://fastplatform.eu/).

Bio-acidification of sewage sludge to release P

The bio-acidification process developed by INRAE France, now with Veolia (see SCOPE Newsletters n°s 134 and 138) has been demonstrated through Phos4You at two sewage works, and **shows potential to economically release and recover > 50% of phosphorus in sewage sludge (bio-P or iron chemical P removal sludges), so achieving the requirements of the Swiss and German P-recovery legislations**.

Sugar-rich organic by-products are used, in a bioacidification unit upstream of sludge digestion, to feed endogenous lactic acid bacteria, which spontaneously develop, and cause phosphorus solubilisation from sludge by a combination of pH lowering, fatty acid release and reduction of iron (III) to iron (II). The solubilised phosphorus can then be recovered by precipitation, for example as calcium phosphate by lime dosing using the Veolia STRUVIA process. The organic by-products, added at a ratio of 0.5-1 gCOD/VS (Chemical Oxygen Demand in the organic by-product / volatile solids in the sludge), are valorised by significantly increased methane production in the sludge digester.



Marie-Line Daumer, INRAE Rennes, France, summarised preliminary tests performed to design and run a 5 m^3/day pilot bioacidification unit, which was then tested at Lille Marquette (France) and Tergnier (near Reims, France) municipal wastewater treatment plants, France, both operating chemical phosphorus removal. Pilot trial results were consistent with previous laboratory tests, showing 40 – 70 % phosphorus dissolution, with better results with iron compared to aluminium P-removal sludges.

Cédric Mebarki, Veolia, outlined conditions for the economic viability of this P-recovery process. The bio-acidification, with sludge from a sewage works using iron for chemical P-removal, can reliably solubilise (enabling recovery) sufficient phosphorus to respect the German P-recovery ordinance obligation to reduce sludge phosphorus below mgP/kgDM before digestion. Phosphorus is recovered at low cost by dosing only lime, as calcium phosphate sludge, of sufficient quality to be used by the fertiliser industry (after drying, transport). Economic feasibility depends on:

- A local, reliable, low-cost, high-sugar organic by-product to feed the process
- Energy or methane recovery in the sludge digester (valorisation of the by-product carbon)
- Local fertiliser industry user for the recovered calcium phosphate (e.g. blender)
- Cement industry will take the P-depleted sludge at better financial conditions (P is a cement retardant)

P-recovery from sewage sludge incineration ash (SSIA)

Andreas Rak, Remondis, updated on the implementation of the **TetraPhos** process to recover phosphoric acid from SSIA. The process dissolves phosphorus from ash using phosphoric acid (acid leaching). The resulting phosphoric acid is then purified (see ESPP-DPP-NNP Nutrient Recovery Technology Catalogue). The full-scale installation at Hamburg is currently in the commissioning stage. Pilot plant tests at Elverlingsen (see SCOPE Newsletter n°129) with four different ashes showed consistent recovery (in the phosphoric acid) of > 80% of the phosphorus (from the input ashes). Part of the iron and aluminium in the ash is recycled back to the water treatment plant for phosphorus removal. The leached ash goes to landfill with the same or lower landfill class.

Josien Ruijter, HVC Groep, The Netherlands, explained that HVC and Slibverwerking Noord-Brabant (SNB) together incinerate around half of the 1.5 million tonnes/year dewatered sewage sludge produced by The Netherlands 17 million population. For nearly ten years now they have been looking for a technology to recover phosphorus from the resulting 60 000 t/y SSIA ash. A decade ago, technologies were untested, whereas today there are several available. A joint venture is now being foreseen with Remondis to build a plant to treat these 60 000 t/y of ash, at the SNB site, Moerdijk, The Netherlands, with the aim of commissioning in 2025. To select a technology, extensive data on SSIA characteristics are important, and dialogue with water treatment operators concerning future expected changes in sewage and ash. Drivers for P-recovery are the current landfill disposal costs of ash, return of recovered iron and aluminium salts to sewage plants for P-removal, sales of phosphoric acid, with questions around the valorisation of the leached ashes.

Jürgen Eschment, Parforce, presented the process of the same name currently under scale-up (see ESPP-DPP-NNP Nutrient Recovery Technology Catalogue). In this process, hydrochloric or nitric acid are used to leach P from SSIA, followed by iron/aluminium removal, membrane electrodialysis (to remove calcium, magnesium, heavy metals), to produce a purified phosphoric acid. The pilot plant (1 tonne/day ash) has been tested with a number of different inputs (ashes, phosphate minerals) since 2018 showing recovery of 83% - 90% of P (from input to phosphoric acid). This process produces no gypsum: minerals (e.g. Ca, Mg) and heavy metals are transferred to a liquid stream, from which heavy metals can be precipitated by lime precipitation and calcium chloride or calcium nitrate can be recovered. The leached ash residue (mainly silicate) goes to landfill or possibly could be used in the cement industry. An LCA, in the Phos4You Technical Report, concludes that the impacts of Parforce phosphoric acid production are significantly higher than for conventional production (from phosphate rock) for the categories of climate change, freshwater eutrophication and fossil resource scarcity, but the impact of Parforce for the category of mineral resource depletion is much lower.

P-recovery from sewage sludge

Daniel Klein, Georg Schmelz Emschergenossenschaft, and **Frank Zepke, EuPhoRe**, presented testing of the pilot **EuPhoRe** installation at the Dinslaken municipal waste water treatment works, Germany (see SCOPE Newsletter n°129). A visit to the pilot was also organised for conference participants. The 100 kg/h large-scale continuous-operation pilot has been operated for multiple batch campaigns since 2019, with different sludges from Emschergenossenschaft and Lippeverband.

Photo: site visit, EuPhoRe pilot, Dinslaken, EGLV.

The EuPhoRe process uses a rotary kiln reactor for the sewage sludge treatment, with specifically three zones, with different oxygen status / temperature conditions, and magnesium chloride dosing, to produce an ash in which the phosphorus shows higher plant availability than in ashes from standard fluidised-bed incinerators, and which heavy metal levels are reduced (the reduced heavy metals are evaporated as their chlorides and separated in the flue gas cleaning system). Total residence time in the rotating drum is c. 3-4 hours. The process ensures the IED (Industrial Emissions Directive) temperature/time conditions for incineration (850°C, 2s). Input to the pilot plant is pre-dried sewage sludge, but in combination with a solid fuel incineration plant (waste to energy) no pre-dryer would be required and dewatered sludge could be input directly (in this case, the sludge is dried in the first part of the rotating drum using secondary heat).

Chemical analysis shows that, with sewage sludge from works using iron chemical P-removal, the phosphorus in the EuPhoRe ash is 50 – 80% NAC soluble (neutral ammonium citrate) and 70 – 90% citric acid soluble. The EU Fertilising Products Regulation 2019/1009 requires 75% NAC solubility for a product to be labelled as a "Mineral fertiliser", but this requirement is not specified for "Inorganic" macronutrient fertilisers (Annex I, PFC1(C)I(a)). Ryegrass pot trials presented show around 2/3 growth with EuPhoRe ash compared to mineral phosphate fertiliser (TSP).

Using 3% magnesium chloride (w/w input sludge % dry matter), 95% of cadmium, lead and mercury, up to 20 % iron and 20-85% of copper, chrome, nickel and zinc are removed from the ash stream, gasified, then recovered in a low-volume waste stream in the unit gas cleaning. The magnesium remains in the ash, where it has fertiliser value. The presence of sulphates in the sewage sludge prevents corrosion problems being caused by the chlorides.

Successful trials of grinding and granulation of the ash have been carried out with the agricultural supplies company Raiffeisen **Hunsrück Handelsgesellschaft mbH**, full-scale in a commercial mixer, combining ground EuPhoRe ash from the pilot plant with calcium carbonate (recycled from drinking water) and potassium sulphate.

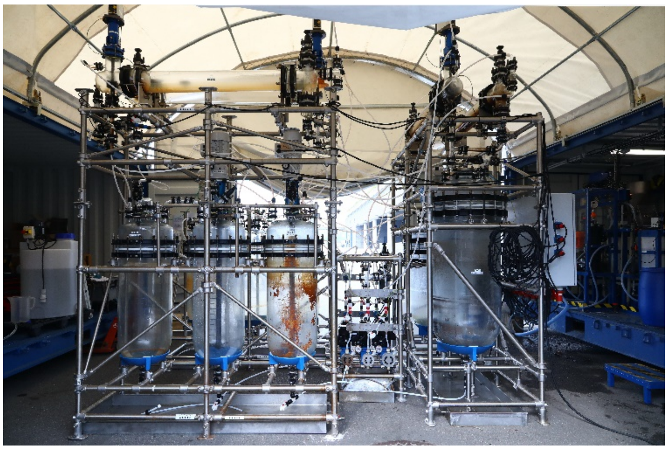
Two full scale EuPhoRe plants using similar kilns but not for P-recovery are in operation in Switzerland and a full scale EuPhoRe plant for P-recovery is under construction at Manheim, Germany, for 135 000 t wet weight dewatered sewage sludge per year (23 – 29% DM), with commissioning planned for 2022.

Zaheer Ahmed Shariff, Université of Liège, presented the **PULSE** concept for P-recovery from dried sewage sludge (see SCOPE Newsletter n°134), using hydrochloric acid at pH 0 or -1 (1.5 – 2 mol/l acid), followed by solvent extraction to remove heavy metals, then precipitation as calcium phosphate.

Iron precipitates from the organic solvent as iron hydroxide and other metals could possibly be recovered in the future. To date, 60% - 70% P-recovery from the sludge is achieved and heavy metal levels in the recovered calcium phosphate are below EU Fertilising Products Regulation limits. The leached sludge solids are washed to recover acid which is recycled into the process, leaving some acid in the sludge. Total carbon in the precipitated calcium phosphate (after further washing) is 3% – 6% and a sample tested by Phos4You showed organic carbon of 5%.

The process has been tested at pilot scale, with a mobile pilot, in Belgium and Scotland: batch capacity c. 90 kg sludge.

Photo: PULSE pilot tests, Université de Liège



Hubert Halleux, Prayon, summarised tests of calcium phosphate produced by the PULSE process (pilot scale, above). The material showed variable levels of P (7% - 14% P), presence of chloride (could be resolved by washing), and too high levels of carbon (see above) making it not useable for the production of phosphoric acid because of foaming and because the colour of gypsum could be deteriorated. However, the material could be used as a raw material for phosphate fertiliser production. Also, the water solubility of the material was low, probably because of presence of insoluble calcium, iron and aluminium phosphates.

Photo: granulation of the PULSE material.

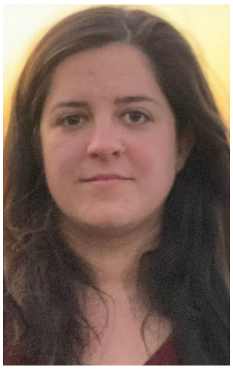
Prayon is also developing two processes to recover phosphorus from sewage sludge incineration ash: acid leaching using phosphoric acid, then purification of the resulting phosphoric acid by ion exchange and membrane (this process will soon be tested at semi-industrial scale in Varna, Bulgaria); and acid leaching using hydrochloric acid to produce di-calcium phosphate (Ecophos technology).

P-removal and recovery in smaller wwtps

Alberto Pistocchi, European Commission Joint Research Centre (JRC), summarised the quantitative significance of phosphorus discharges from smaller agglomerations. Some 300 ktP/y are estimated to reach EU seas, of which around half from sewage works and half from diffuse sources. Of this, around 25 ktP/y losses could be avoided by further improvements in P-removal in larger sewage works and a similar amount by P-removal in small sewage works (< 10 000 p/.e.). The population in smaller agglomerations is estimated, with large uncertainties, to be up to 75 million people.

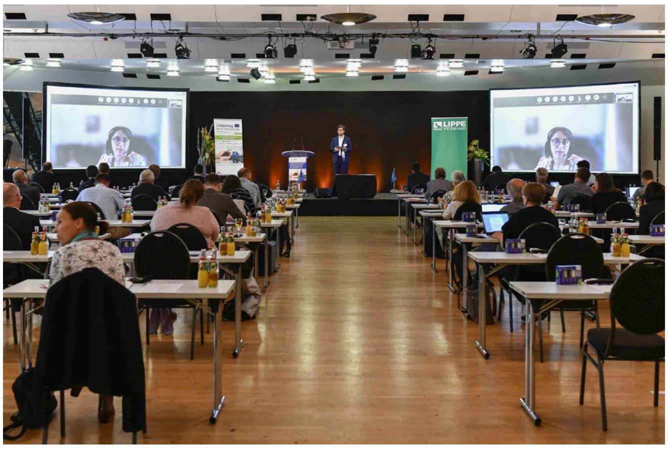
Szabolcs Pap, University of the Highlands and Islands, Scotland, presented pilot results of testing **alkali-activated crab carapace material** (seafood processing waste) for P-adsorption in a **Veolia Filtraflo**™ unit as a tertiary treatment at Bo'ness wwtp (**Scottish Water**, secondary treatment only without P-removal). The pilot installation had a flow rate of 200 l/h and was operated 10 hours/day for a total of 1 ½ months. The system was able to reduce P down to c. 0.5 mgP_{-total}/l, requiring renewal of the crab carapace material after 18 - 37 hours. The P-enriched crab carapace material showed c. 1.3%, low levels of heavy metals and no detectable bacterial pathogens. P Pot trials showed that the P-enriched crab carapace material was an effective slow-release P-fertiliser.

Claran O'Donnell and Joe Harrington, Munster Technological University, Ireland, presented pilot scale trials of a **Veolia Struvia**™ unit, as a tertiary treatment at the Macroom wwtp (Irish Water, secondary treatment only without P-removal), treating 12 000 l/day (that is 1% of the wwtp's 5 000 p.e. flow), and using lime dosing to precipitate a calcium phosphate sludge. The unit was operated on a continuous basis for 12 weeks. A P-removal efficiency of around 60% was achieved, reducing P to c. 1.7 mgP_{-PO4}/l, and also 40% removal of COD.



Ania Escudero and Ohle Pahl, Glasgow Caledonian University, Scotland, presented pilot trials of a microalgae photobioreactor, with input of primary effluent after sedimentation, again at Scottish Water Bo'ness wwtp. A 75l and then a 500l capacity installations were tested. The 500l unit was operated with a hydraulic retention time of 2 – 4 days, so effectively treating 125 – 250 l/day. The tank used internal lighting (0.4 amp LED) and was heated/cooled to 22 – 24 °C. Both P and N removal were achieved. P removal was unreliable for the first two months of operation, then reliable for the second two months of operation at 50-75% removal. The algae used, *Chlamydomonas acidophila*, requires an acidic medium of pH3, so chemicals input was necessary to acidify, and then to neutralise before discharge. However, because this species is dominant at low pH, the system maintained long term stability as a monoalgal culture and showed no foam or biofilm formation. Moreover, this species can fix C from both inorganic and organic sources, and removed around 50% of the COD from the primary effluent, which is close to COD removal reported for conventional secondary treatment.

Therefore, this process appears to be promising as a secondary-tertiary treatment in small WWTPs. Pathogens and organic contaminants assessed were non-detectable in the algae.



Phos4You website: [*https://www.nweurope.eu/projects/project-search/phos4you-phosphorus-recovery-from-waste-water-for-your-life/*](https://www.nweurope.eu/projects/project-search/phos4you-phosphorus-recovery-from-waste-water-for-your-life/)

Phos4You final Technical Report: [*https://duepublico2.uni-due.de/receive/duepublico_mods_00074788*](https://duepublico2.uni-due.de/receive/duepublico_mods_00074788)

CRU Sustainable Fertilisers Conference

CRU Sustainable Fertilizer Production Technology Forum, Online, 20-23 September 2021

https://events.crugroup.com/sustainableferttech/

This new online conference centred on sustainable production and ESG (Environmental and Social Governance) in the Fertilisers Industry, covering phosphorus and nitrogen fertilisers.

The first edition, September 2021, brought together some 250 industry participants.

There is currently a strong focus on **greening ammonia production**. The **Ammonia Energy Organisation** and **CRU** presented a comprehensive overview. Measures include moving away from coal to methane as feedstock, capturing CO_2 which is generated in considerable amounts when making ammonia this way, and electrifying the production process. It is predicted that green methods will become cheaper and the traditional Haber Bosch cost go up if any serious CO_2 penalties are implemented, with cost meeting somewhere in 2040. Ammonia is increasingly seen as fuel and energy storage medium, with e.g. ships being converted to run on ammonia instead of fuel oil.

Greener and cleaner ammonia

GIZ (Germany) presented an initiative (**Nitric Acid Climate Action Group**, 15 member states) to reduce the amount of nitrous oxide set free during the production of nitric acid. This is a much more powerful greenhouse gas (265 times) than methane or CO_2. NACAG offers contributions to policies, technological advice to industry for nitrous oxide abatement, and even financial support. Nitrous oxide abatement technologies are available but not yet widely implemented.

ThyssenKrupp highlighted the challenges for blue ammonia, which require carbon capture and reuse (CCU) or its permanent storage underground (CCS). When applying CCU it is hard to prevent CO_2 from escaping to the atmosphere after some time, e.g. when urea fertilizer, a sink for CO_2 is used by plants. Options were presented to capture CO_2 from the process gas, and flue (heating) gases. An example is to use amines as capturing medium. The technologies are ripe, are best applied in large plants, and can be retrofitted onto existing plants.

One option is to gradually increase electrochemical hydrogen feed into existing plants while capturing CO_2 (hybrid plant), as presented by **BD Energy Systems** and **PegasusTSI**. Another contribution can come from improving the internal se of heat in the plant by optimizing steam systems (presented by Engro).

IFA, the global fertiliser industry association presented their initiative to promote sustainability in fertiliser production, focusing on CO_2 reduction and nutrient stewardship. Topics include green and blue ammonia, ammonia as fuel, phosphogypsum, precision agriculture, specialty fertilisers, and carbon programs. Top priorities are a green ammonia technology roadmap, and CO_2 reduction.

Clariant presented their catalyst system used in steam methane refoming (SMR), the hydrogen production step preceding the actual ammonia synthesis in a Haber-Bosch ammonia plant. This saves up to 20% of CO_2 emissions by improving energy efficiency – there is less steam produced in the SMR this way. Catalyst systems are also offered for various other hydrogen production routes and for the water gas shift reaction which comes after the SMR.

Stamicarbon presented their plan to construct a medium-sized green ammonia plant in Kenya. The plant uses geothermal and solar power, both available in abundance locally, to produce hydrogen followed by a traditional ammonia synthesis. This is then converted to ammonium and calcium nitrates (200 kt/y). A similar process is being offered by **ThyssenKrupp**. Stamicarbon also presented an improved scrubber for urea plants.

Saipem have developed an electrochemical nitrogen removal technology for wastewater (SPELL) which produces no sludge. It can be used e.g. in the nitrogen industry. They also offer an improvement to urea plants, which increases plant capacity and/or efficiency.

Phosphate fertilisers

Ostara highlighted its Pearl technology to produce struvite from wastewater, which has been implemented in 23 wastewater treatment plants, mainly in North America. Overall recovery efficiencies from wastewater vary, but are typically in the 10-25% bracket (P recovered in struvite / P in sewage works inflow). Ostara's struvite process is also offered for gypsum stack leachate treatment. Struvite is a slow-release fertiliser. It can be blended with water soluble MAP to optimise crop phosphorus use efficiency and minimise P runoff from fields.

Dupont Clean Technologies presented ways to improve heat use and recovery in sulfuric acid plants at phosphoric acid production sites. Such plants derive their energy from burning sulphur, so this is non-CO_2 derived heat.

Phosphogypsum valorisation

The well-known **Novaphos** process (formerly JDC/IHP, see SCOPE Newsletter n°86) was presented, which produces phosphoric acid and a construction material, from phosphate rock, with the petcoke in a thermal process. It can also be used to process phosphogypsum into sulfuric acid and construction material.

A similar approach for phosphogypsum is offered by **ThyssenKrupp**. Phosphogypsum is heated, releasing SO_3 which is converted into sulfuric acid, and cement clinker. Even though it is an energy intensive route, it should be compared to cement making, which uses similar amounts of energy. The quality of the cement clinker may be a challenge. TK offers gypsum purification processes to make multiple uses of gypsum possible, including the back conversion to sulfuric acid.

Prayon presented their tailormade solution to phosphogypsum (PG). Local constraints for stacking have led to the development of a processing route via hemihydrate gypsum, which is self-drying during temporary storge, and is then supplied to an adjacent gypsum/plaster producer. The need for gypsum quality limits the types of phosphate rock that can be used. The Central Prayon Process has been developed for general use for all types of rocks. Prayon also uses a big data strategy to ensure maximum P efficiency and gypsum quality (gypsum should have low P content).

Technip Energies (T.EN) presented approaches to phosphogypsum reuse, to address challenges of acidity, P content, and impurities (radioactive elements, organics, heavy metals, fluoride). The processes use screening, hydrosizing and filtration to obtain a PG suitable for plasterboards, etc.

CRU's "Phosphates 2022" conference will take place in Tampa, Florida (and online) 7 – 9 March 2022,

https://events.crugroup.com/phosphates/home

ESPP members

Calls for abstracts

- **Webinar on "Legacy Phosphorus"**
  2 Feb. 2022, 13h-17h CET
  http://www.phosphorusplatform.eu/events
  deadline for abstracts = 15th December 2021

- **ESPC4 - 4th European Sustainable Phosphorus Conference**
  Vienna, Austria and online, 20-22 June 2022
  www.phosphorusplatform.eu/ESPC4
  deadline for abstracts = 30th December 2021