4th European Sustainable Phosphorus Conference (ESPC4) & 5th Phosphorus Research in Europe Meeting (PERM5)

Vienna & online, 20-22 June 2022

320 participants in Vienna, Austria, and a further 80 online, from more than 30 countries worldwide, joined the 4th European Sustainable Phosphorus Conference, making it the **biggest conference on phosphorus ever worldwide**. With PERM (the 5th Phosphorus Research in Europe Meeting), a total of 20 plenary and parallel sessions showed over 60 presentations as well as nearly 50 posters, bringing a wide range of content on links between phosphorus and climate change; global, EU, national, regional and city public policies; recycling technologies; recovered fertilisers and soil science.

Above all, the Conference provided unique opportunities for networking, for the first time since Covid, with extended breaks, dedicated Swapcard contact and conference networking app, an exceptional social event hosted by Vienna City in the Town Hall's fabulous Festivities Hall, a site visit and the young researchers' get together.

This SCOPE Newsletter summarises the plenary presentations and conclusions of the parallel sessions. All presentation slides and posters, and video recordings of plenaries and selected parallel sessions are now online in the ESPP Swapcard conference networking app space, accessible to all online and in-person registrants.

After this success, candidatures are open to organise the next European Sustainable Phosphorus event in 2024: contact ESPP.

Conference web page (ESPC4 and PERM5) and book of abstracts: https://phosphorusplatform.eu/espc4

All slides, posters, recordings are available to registrants only at: https://app.swapcard.com

Summaries of previous European Sustainable Phosphorus Conferences:

- ESPC3, Helsinki 2018: SCOPE Newsletter n°127

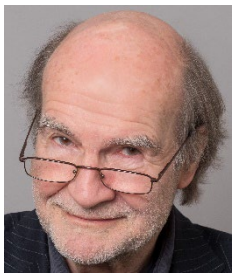
- ESPC2, Berlin 2015: SCOPE Newsletter n°111

- ESPC1, Brussels 2013: SCOPE Newsletter n°092

Contents

From left to right: Jürgen Czernohorszky Councillor for Climate and Environment, Vienna City Council, Johanna Bernsel, European Commission, Ludwig Hermann, Proman (conference organiser) and ESPP President and Rainer Kronberger, Vienna City Administration. Conference moderator: Sonya Van Renssen.

Editorial



The 4th European Sustainable Phosphorus Conference (ESPC4) finally took place, four years after ESPC3 and after two times rescheduling. Yet, in June 2022 the concern of being infected by Covid-19 was overshadowed by the war in Ukraine, by the shortage of food supplies in African and Middle East countries, by skyrocketting prices for energy and fertilisers and by disrupted supply chains, among others for phosphates and potash from Russia and Belarus. While phosphates and potash supplies may be replaced from other countries, a shortage of nitrogen fertilisers may be faced in 2023 due to temporarily shut down N capacities as a result of gas price increases. All these reasons now make it urgent to accelerate efforts on nutrient recycling, and to use all recources and in particular nutrients more efficiently, while increasing resilience and balancing costs. Regrettably humanity seems to need emergencies to get going. ***Ludwig Hermann, ESPP President***

Conference sponsors' visions

EasyMining

Pär Larshans, EasyMining (Ragn-Sells Group), explained that Ragn-Sells is a family-owned company led by environmental convictions. A century ago, the company was already recycling nutrients with horse transported latrines in cities. Today, EasyMining's aim is to **implement large-scale recovery of high quality, purified nutrients for use in Organic Farming and in animal feed**, with heavy metals removed and where valuable recycled. EasyMining has developed full-scale phosphorus recovery from sewage sludge incineration ash (Ash2Phos), potassium recovery from municipal refuse incineration ash (Ash2Salt) (see the ESPP-NNP-DPP Nutrient Recycling Technology Catalogue) and is now pilot testing nitrogen recovery (Re-Fertilize, see ESPP eNews n°62).

Borealis LAT

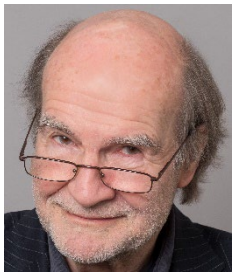
Wolfgang Hofmair, Borealis LAT Group, presented the company's actions promoting digital farming and circular plant nutrition. The company is one of Europe's large mineral fertiliser producers and suppliers with an extensive distribution network. Borealis provides benefit to farmers through performance logistics, delivering high quality fertilisers for site-specific application on the field. Based on satellite data, the actual nitrogen demand is measured. This enables fertiliser planning and precision application, according to soil and crop needs. **Becoming Vienna´s partner in closing the P-cycle is part of Borealis' sustainability vision**: "**Safely produced and applied NP/NPK fertilizers, with highly soluble phosphate from Vienna´s mono incinerated sewage sludge ash".**

Wien Energie

Teresa Schubert, Wien Energie, explained that the City-owned company ensures engineering for waste, water and electricity management and infrastructure. The "**Waste2Value**" concept, which is demonstrated at Wien Energie's site Simmeringer Haide, aims to optimise sustainable valorisation of organics, for example in sewage sludge and paper recycling residues, by steam gasification. In a dual fluidised bed gasifier, a bubbling reactor will generate syngas, which will be catalytically converted to fuel for the City's buses and other vehicles. A circulating reactor will burn the gasification residues providing the energy for gasification and carbon free ash for phosphorus recovery by any of the currently available technologies.

4th European Sustainable Phosphorus Conference

Climate, energy and nutrients



Ludwig Hermann, ESPP President, opened the conference, underlining the considerable advances made in policies and technologies for nutrient recycling since the first European Sustainable Phosphorus Conference in Brussels in 2013.

Today brings a considerable acceleration in both challenges and opportunities, with the **current crises in energy costs, fertiliser supply and food security** resulting from the war in Europe and also from climate change.

These crises confirm the urgency of the European Commission's Green Deal objectives to address climate emissions and decouple resource consumption from economic growth. In particular, the target to reduce nutrient losses by at least -50% by 2030, without deteriorating soil fertility.

Local nutrient recycling is essential to address these environmental challenges, to reduce risks related to global uncertainties, and to improve Europe's agricultural resilience and food security.

Jürgen Czernohorszky, Councillor for Climate and Environment, Vienna City Council, welcomed delegates to the beautiful city of Vienna. He explained that moving to mono-incineration of the city's sewage sludge (nearly 2 million people in total) is coherent with Vienna's ambitious climate and environmental objectives.

Sewage sludge mono-incineration ensures elimination of organic contaminants and generates energy for the sewage works electricity need and feed renewable heat energy into the district heating network. The City is working with the fertiliser company, Borealis, who produce mineral NPK fertilisers in Austria (Linz) to develop processes to recycle phosphorus from the sewage sludge incineration ash to quality fertilisers.

Franz Josef Radermacher, Research Institute for Applied Knowledge Processing (FAWn), Ulm, asked questions which launched heated debate in the conference.

Can we hope to avoid environmental and climate catastrophes without ending population growth, if every world citizen is to have the life quality which (many) enjoy in Europe?

Climate change is a global problem, linked to global emissions. China, India, Africa and other countries emissions are already or soon will be as high as Europe's. Should we invest in European resilience (including the circular economy) or should our investments be made in these countries where action is more urgent?

How to continue to cooperate globally in the current uncertain future of supply-chain problems, war and sanctions ?

Wenfeng Liu, China Agricultural University, Beijing, underlined the links between climate change, nutrient losses and eutrophication.

Studies show that extreme climate events and increased precipitation are linked to increased phosphorus losses (e.g. Ockenden 2020 DOI*). Estimates suggest that climate change will by 2090 lead to +31% higher losses of phosphorus than in today's wet years, +75% compared to today's average Liu 2020*). Seven billion people worldwide will thus face increased phosphorus losses, not prevented by dilution. Climate change will also cause warming of many aquatic systems, which is linked to algal blooms (Ho, 2019).

Climate change can thus be certainly expected to worsen eutrophication, but the relation is complex.

Phosphorus Use Efficiency is critical to reducing phosphorus losses (Lun, 2017 DOI) and application levels are today higher than thresholds in many regions (Obersteiner 2013 DOI, Steffen 2015 DOI).

To reduce phosphorus losses by 50% will require optimising application, recycling crop residues and reducing soil erosion (Liu 2018 DOI, Springmann 2018 DOI).

** These papers are summarised in SCOPE Newsletter n°137 special issue: Climate Change, Nutrients and Catchment Management*

Local, regional, national policies and actions

Baltic: reducing nutrient losses and Recycling Action Plan

"HELCOM's Nutrient Recycling Strategy aims to support recycling as part of a holistic agri-food system, reducing nutrient losses"
Lotta Ruokanen, HELCOM

Lotta Ruokanen, HELCOM, explained that the Baltic remains highly impacted by eutrophication, despite significant reductions in nutrient inputs achieved by the nine HELCOM contracting parties around the Sea.

The Baltic Marine Environment Protection Convention (HELCOM) Ministerial Meeting of October 2021 confirmed the commitment to implement by 2030 all actions in the updated Baltic Sea Action Plan (BSAP), including the aim of the "Baltic Sea un affected by eutrophication". The Plan includes the HELCOM nutrient input reduction scheme, defined in 2007 and revised in 2013 and 2021. It defines Maximum Allowable Limits (MAIs) for Total Phosphorus and Total Nitrogen for each of the seven Baltic Sea sub-basins and Net Nutrient Input Ceilings (NIC) for each sub-basin and for each country in the basin (for HELCOM contracting parties: Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland Russia and Sweden, and for other countries in the catchment: Belarus, Czech Republic, Ukraine) as well as (for Nitrogen) for airborne input and shipping.

The 36 eutrophication actions of the Baltic Sea Action Plan also include the principle of a **Regional Nutrient Recycling Strategy** and this was also adopted in the 2021 HELCOM Ministerial Meeting. This Strategy sets the aim to manage nutrients sustainably in all HELCOM countries, securing the productivity of agriculture and minimising nutrient loss to the Baltic Sea environment through efficient use of nutrients and cost effective nutrient recycling. **Actions of the HELCOM Nutrient Recycling Strategy** include enhancing the use of recycled nutrients in agriculture, developing safety requirements for recycled fertilisers, advancing towards field-level fertilisation planning and farm-gate N and P nutrient balances, enhancing knowledge and advisory services, setting market incentives for recycled fertilisers and developing a view for a holistic and sustainable food system including nutrient recycling,.

HELCOM actions on phosphorus recycling will combine with other 2021 BSAP actions on e.g. precision farming and soil structure improvement to reduce losses, and on reductions in ammonia and greenhouse gas nitrogen emissions.

Switzerland, Germany: implementing P-recovery regulations

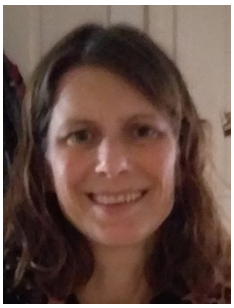
"Switzerland is looking how to fund investments for P-recovery, estimated at 4 €/person/year".
Sibylla Hardmeier, Swiss Federal Office for the Environment

Sibylla Hardmeier, Swiss Federal Office for the Environment (FOEN/BAFU), reminded of the importance of phosphorus as an essential element and a key factor in the food supply. Global reserves however are finite and geographically concentrated, and dependency on certain countries (in particular Russia) are accentuated by cadmium limits.

Switzerland imports around 15 000 tP/y, of which 6 200 tP/y in animal feed and 5 800 tP/y in fertilisers and chemicals. There are some 5 700 tP/y in Swiss sewage sludge and 1 200 tP/y in meat and bone meal (animal by-products), so potentially enough to more than cover Switzerland's P fertiliser use. The Swiss Waste Ordinance (ADWO, 2015, see SCOPE Newsletter n°129) **requires phosphorus to be recycled, by 2026, from sewage sludge or sewage sludge ash (all sewage is incinerated since 2006) and from meat and bone meal**.

The Swiss Federal Office for the Environment is leading a cooperative approach (**SwissPhosphor**) involving water operators, the cement industry (which currently combusts 22% of Switzerland's sewage sludge), the cantons and user industries.

Four phosphorus recycling plants are planned: Zuchwil (Phos4Life), Oftringen (Phosphor26), Lucerne (RealPhos), Bazenheid (ZAB).



"Implementation of Germany's legal sewage P-recycling obligations should enable replacement of around 40% of mineral P fertiliser"
Andrea Roskosch, German Federal Environment Agency

Andrea Roskosch, German Federal Environment Agency (UBA) explained the German legal requirement for phosphorus recycling from sewage, applicable from 2029 / 2032 for sewage works > 100 / 50 000 p.e. This is fixed by the 2017 update of the Sewage Sludge Ordinance (AbfKlärV, see SCOPE Newsletter n°129).

Phosphorus recovery is only required if the phosphorus concentration in the sewage sludge is > 2% P (dry matter). In some cases, P-recovery in the water treatment plant can bring the P level below this 2% limit.

Four P-recovery plants are under construction or announced: Haldensleben (SeraPlant), Hamburg (TetraPhos), Mannheim (Euphore), Offenbach (Euphore), with two others announced: Bitterfeld (Ash2Phos) and Altenstadt (AshDec).

Significant investment in sludge mono-incineration is expected to be required, probably doubling current capacity, in order to replace sludge combustion in coal-energy, cement or mixed waste incineration (co-incineration) plants.

Phosphorus recycling from sewage sludge is thus expected to be around 65% by 2029, corresponding to around 40% of mineral fertiliser use. This is significant given that Germany is one of Europe's three biggest agricultural producers, with around 15% as value of EU agriculture.

Possible further action in Germany to promote P-recovery could include revision of water and fertiliser regulations, and banning of all agricultural application of sewage sludge (which continues to be allowed for sewage works < 50 000 p.e. under the 2017 Sewage Sludge Ordinance). The German Government political coalition contract announces recovery of other nutrients, but to date no plans have been announced.

Cities and regions taking action for phosphorus

"Public policy intervention is needed to support placing on the market of recovered phosphates" *Daniel Klein, EGLV regional water authority, Germany*

Daniel Klein, Emschergenossenschaft and Lippeverband (EGLV), Germany, presented progress made by this public water authority towards implementing the German P-recovery obligation, presented above. EGLV provide water services to a total of 3.6 million people in the highly industrialised Ruhr area.

A **Euphore** pilot plant has been constructed and operated at EGLV's Dinslaken sewage treatment plant: 11 M€ budget EU Phos4You project, 100 kg (wet weight) dewatered sludge per hour (see ESPP-DPP-NNP Nutrient Recycling Technology Catalogue). In the German funded R&D project AMPHORE (see ESPP eNews n°48) a 3t ash/day pilot will be built at and tested at Bottrop, in cooperation between EGLV and three other water authorities (4 mono-incinerators operating, 1 in planning). This pilot will test the **Parforce** process to solubilise P from ash using acid, then purification of phosphoric acid.

EGLV emphasises the importance of a regional strategy to share risks and ensure scale. EGLV also emphasises the **importance of supporting markets for recovered phosphorus materials**, by incentives or other policy tools.

"For Zürich Canton, P-recycling from sewage sludge incineration ash is part of the overall urban mining strategy and sludge management optimisation" *Leo Morf, AWEL Canton Zürich*

Leo Morf, AWEL Canton Zürich, explained how the Canton (1.6 million inhabitants) has defined since 2006 an overall policy for sludge management and phosphorus recycling, that is ten years before it became mandatory in Switzerland. More than 150 communities in the Canton produce around 100 000 t sewage sludge per year (30% DM) from 72 sewage treatment works.

After assessing different solutions for P-recovery from wastewater, sludge or ash, the Canton concluded in 2009 that a centralised new **mono-incineration at a single site (Werdhölzli sewage treatment plant) with P-recovery from the ash offers the optimum for energy, CO_2 emissions and P-recovery** according to the criteria defined by the Canton. Construction of the mono-incinerator achieved 94% support in the public enquiry process, and is now operational since 2015 and the ash is temporarily stored in landfill pending P-recovery.

Técnicas Reunidas SA was selected as industrial partner by the Foundation ZAR on behalf of the Canton of Zurich. The goal was to develop a P-recovery process (**Phos4Life**) from the ash, using known technology (solvent extraction), to produce purified phosphoric acid (commodity chemical or for use in fertiliser production). Based on trials of a 0.7 kg ash/hour pilot continuously operated for a total of 7 weeks from December 2017 to July 2018 (see ESPP-DPP-NNP Nutrient Recycling Technology Catalogue), feasibility and costing are currently underway for a 40 000 t ash/year plant at Zuchwil. This plant will take the 15 000 t/y ash produced by the Zürich Werdhölzli mono-incinerator and 25 000 t/y ash from elsewhere in Switzerland. This feasibility study will be completed end 2022 and will provide a base for decision on construction.

Arabel Amann, Wien Energie, summarised developments in Austria. Financed by the Austrian Science Fund a phosphorus flows study was performed by TU Wien for the year 2013 (DOI). This concluded that significant reductions in phosphorus imports could be achieved by improving human diet (20%) and animal feed (20%) and that recycling offers the highest potential (23% for sewage, 16% from meat and bone meal). The national Water and Waste Management Association (ÖWAV) published a position paper in 2014 stating that **over half of Austria's phosphorus fertiliser use could be replaced by P-recycling from sewage** (LINK).

In 2017, the Austrian Federal Waste Management Plan (LINK) fixed a (not legally binding) objective of widespread phosphorus recycling.

To date in 2022, the draft revision of the Austrian Waste Incineration Ordinance (see ESPP eNews n°70) will require either incineration of sewage sludge for all sewage works > 20 000 p.e. and recovery of 80% of phosphorus from ash, or use of the ash for fertiliser production, or recovery of 60% of influent phosphorus in the water treatment system. The last option is not feasible with existing systems but may be possible with new developments.

"Vienna is working with Borealis to resolve obstacles to using sewage sludge incineration ash in fertiliser production"
Florian Huber, Vienna City Council and Arabel Amann, Wien Energie

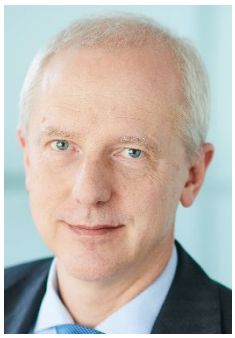
Florian Huber, City of Vienna and **Arabel Amann, Wien Energie**, outlined **Vienna's objectives for combining climate efficiency with phosphorus recovery** in sewage sludge management. Six sewage sludge digesters have been installed recently, which produce methane used for electricity production. Combined with centralised sewage sludge mono-incinerator, this will ensure high energy efficiency, and frees incineration capacities for sewage sludge from other cities or for other phosphorus-rich wastes.

Use of the sewage sludge mono-incinerator ash in fertiliser production has been trialled full-scale by fertiliser producer Borealis in Austria, with the ash being mixed with phosphate rock in acid digestion. The process tests were successful, but only a small percentage of phosphate rock can be substituted by the ash in the Borealis process,. The City has now launched a project to process the ash into an intermediate material compatible with substitution of 100% phosphate rock in fertiliser production, and with possible recovery of iron and silicate sand. Objectives are to start the full-scale use of part of the City's ash at Borealis' plant in coming months and to develop a recycling concept within the next 4-5 years with the **aim of recycling all phosphorus in the City's sewage sludge ash to fertiliser products by 2030**.

One remaining challenge is to obtain all required permits from local regulators to allow intake of waste (ash) at the Borealis site in Linz.

Business perspectives

Crisis and opportunities



"The European fertiliser industry wants to develop nutrient recycling, but unfair competition from imports must be prevented".
Jacob Hansen, Fertilizers Europe

Jacob Hansen, Fertilizers Europe, says now is **an exciting time to be in the fertiliser industry**, with huge changes coming. Climate policies and the EU Green Deal open challenges and opportunities for industry, whilst at the same time the current price and supply crisis for nitrogen, phosphorus and potentially potassium question how we can continue to feed Europe.

Russia used to supply 40% of the gas used for ammonia production by the EU fertiliser industry, one third of imported ammonia, one third of imported phosphorus, and Belarus supplies two-thirds of potassium. Europe will continue to need imports to support food production, but **recycling can also be a key element in reducing imports and increasing resilience**. Manure and MBM (meat and bone meal ash) offer important P-recycling potential, as well as sewage.

Fertilizers Europe is fully positive to phosphorus recycling, but will not compromise on product quality. Recycling should ensure that quality products, with plant-available phosphorus, are delivered to farmers. This also implies logistics, as fertiliser is used seasonally.

The priority remains **PUE (Phosphorus Use Efficiency)** to both optimise P-consumption and reduce losses.

Fertilizers Europe is actively engaged in **Green Ammonia**. This will combine production of ammonia from hydrogen (produced by electrolysis using renewable electricity) with use of ammonia for energy storage, as a fuel (ammonia has c. 50% higher energy density than liquid hydrogen, and is easier to store and handle) and in cleaner chemicals production, as well as for fertilisers. The first full-scale green ammonia plant started production in Puertollano, Spain, in May 2022. This plant will supply ???% of the EU fertiliser industry's current ammonia needs from renewable electricity.

However, for Europe's fertiliser industry to implement Green Ammonia and nutrient recycling, this must not be undercut by imported cheap fertilisers produced in countries not implementing climate and environmental policies. Fertilizers Europe supports the **extension of ETS (Emissions Trading System) to ammonia emissions and fertiliser production**, subject to a **Carbon Border Adjustment mechanism (CBAM)**, to ensure that imports from producers not paying ETS are taxed according to their carbon intensity.

"Global P prices can be expected to come back down, but global demand will remain strong". *Alberto Persona, Fertecon / S&P Global Commodity Insights*

Alberto Persona, Fertecon (part of S&P Global Commodity Insights), discussed market perspectives for fertiliser and other uses of phosphorus and perspectives for recycling, given the current price and supply crisis.

Phosphate rock (above) and phosphoric acid (nearly) prices are now back to levels of the 2008 price peak. White phosphorus (P_4) prices had increased around seven-fold by the end of 2021 in some markets. All phosphorus chemicals are showing similar trends.

These increases are only partly linked to supply-demand, and **mainly a result of trade disruptions**: export duties instigated by the US, export quotas in Russia and Turkey, export bans in China, and now sanctions following Russia's attack on Ukraine. In 2008, global trade helped resolve the phosphorus price peak, whereas trade frictions seem to be increasing today. **Recycling thus offers a route to reduce geo-political dependencies on imports**.

However, it is important to underline that behind this price peak is a **four-fold disconnect between increases in trade prices and production costs** (the latter have only increased slightly). This means that prices will at some time come back down. Long-term prices may come back to around 150 €/tonne P_2O_5 for phosphate rock and 700 €/tonne P_2O_5 for phosphoric acid.

Beyond the overall phosphorus supply – price crises, other perspectives are also important, including questions such as:

- With **pressure on CO_2 emissions**, **what is the future for P_4 production**, with high-energy thermal furnaces?
- If oil consumption is reduced, for climate reasons, this will **reduce sulphur supply from refineries**. How to produce phosphoric acid? Can Green Ammonia lead to develop instead the nitric acid route?
- How will Russia sanctions impact the market for **igneous phosphate rock**, which has much lower cadmium levels?

In this context, P- recycling has some economic advantages. In addition to supply-chain resilience (alternative and local supply) and green credentials, recycling requires low capital investment (relatively small installations and logistics, compared to mineral fertiliser production), an advantage when investors are nervous of big projects because of trade instability. Investors however are also expecting prices to come back down, as indicated above.

Worldwide, phosphorus fertilisers remain under-used in many regions, because of economic or logistics difficulties, and **ongoing global growth in overall P-rock demand can be expected**, but with variations and complexities between different regions.

ESPP member company visions

Ostara

"Recovered Crystal Green Pearl struvite ensures lower P run-off from fields than conventional mineral P-fertiliser, lower greenhouse emissions (per unit crop yield) and better LCA"
Matt Kuzma, Ostara

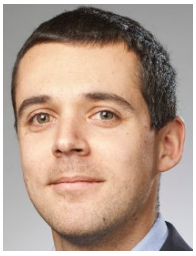
Sulzer

"Contributing to phosphorus sustainability by providing efficient and durable equipment, and by promoting repairability and recycling of pumps and agitators to customers"
Christian Guillaume, Sulzer (Flow Equipment Div.)

Kemira

"Our business is safe and clean water and P-removal down to low levels. In cooperation with Veolia, the ViviMag® process*, now being pilot tested in Leipzig, allows P-recovery after chemical P-removal using iron salts" *Jean-Christophe Ades, Kemira*
** = see ESPP – DPP- NNP Nutrient Recycling Technology Catalogue*

Roullier



"Phosphea, European leader in animal feed phosphates, offers innovative solutions to improve feed P-use efficiency. Regulatory barriers to recycled P in animal feed need to be addressed"
Clément Houllier, Roullier (Timac-Agro, Phosphea)

Veolia

"We treat 6 billion m³ of wastewater per year, worldwide. Our vision of phosphorus recycling routes includes agricultural use of compliant sewage sludge and processes such as struvite, PhosForce*, ViviMag*, Pontes Pabuli*"
Matthias Staub, Veolia Germany
** = see ESPP – DPP- NNP Nutrient Recycling Technology Catalogue*

ESPP member company visions

Holcim

"The cement industry sees continuing recovery of energy and minerals from sewage sludge in cement production as compatible with phosphorus recycling, by P-recovery in the sewage plant or by a thermal treatment integrated in the cement production process and is engaged in several projects*
Christophe Guyot, Holcim
** ERZO-HOLCIM AG, FlashPhos, KlimaPhoNds, CEMSUISSE*

VaLoo

"Separate treatment of sanitation waste streams avoids contamination with heavy metals and enables efficient recycling of all nutrients to safe fertiliser products. VaLoo advocates for a paradigm shift, leading our current sewage management system into the age of circular sanitation."
Michel Riechmann, VaLoo (Circular Sanitation Network Switzerland)

Clariant

"Our company has both financial and non-financial targets. Our aluminium phosphinate flame retardants have an excellent environmental and health profile, and are also available as bio-based carbon feedstock grades. In addition, we are striving to compensate the high energy footprint of our key raw material P_4 by finding renewable energy based sources"
Eva-Maria Leuschner, Clariant

Metso-Outotec

"We are frontrunner in sustainable technologies, end-to-end solutions and services for the aggregates, minerals processing and metals refining industries globally. Outotec is committed to sustainability and to reducing greenhouse emissions, and is engaged with P-recycling technologies including AshDec* and ViviMag *"
Tanja Schaaf, Metso-Outotec
** = see ESPP – DPP- NNP Nutrient Recycling Technology Catalogue*

NuReSys

"We recover phosphorus, as struvite fertiliser product, as part of integrated sewage works P-management. We are now widening to recover potassium struvite, elemental sulphur and nitrogen"
Wim Moerman, NuReSys

N2 - Applied

"Our on-farm units* use (renewable) electricity to stabilise and nitrogen-enrich manure slurries, reducing greenhouse emissions and ammonia losses and improving crop nitrogen use efficiency" *Henk Aarts, N2-Applied*
** = see ESPP – DPP- NNP Nutrient Recycling Technology Catalogue*

Biomasa Peninsular

"As a research & innovation SME, we developed in consortium an innovative biorefinery producing bioethanol and bio-based organo-mineral fertilisers from the organic fraction of solid municipal waste (MSWOF), contributing to nutrient recycling & green chemistry"
José-Maria Gómez, Biomasa Peninsular

Prayon

"Prayon aims to take forward phosphorus circularity as a quality phosphate product manufacturer (use of secondary P in production), a technology provider and as a market partner with worldwide commercial presence"
Hubert Halleux, Prayon

Ductor

"Ductor aims to be leader in sustainable biogas and fertilisers, using specific anaerobic digestion microbiology and integrated nitrogen recovery. We convert* high-nitrogen organic wastes to biogas and nitrogen mineral and organic fertilisers, with reduced greenhouse emissions" *Léonie Boller, Ductor*
** = see ESPP – DPP- NNP Nutrient Recycling Technology Catalogue*

ESPP member company visions

Yara

"Yara's circular economy approach will create sustainable and scalable business solutions, addressing P, K and N recycling, Partnerships and cooperation are key to combine business operations with sustainability and deliver new, circular solutions for plant nutrition."
Marina Ettl, Yara

EU policies

"Europe still needs greater incentives to increase the safe recycling of nutrients, especially for phosphorus" *Virginijus Sinkevičius European Commissioner for the Environment*

Virginijus Sinkevičius European Commissioner for the Environment, underlined that with food security and strategic autonomy high on the political agenda, phosphorus sustainability is important. Phosphorus supplies are extremely limited, it is on the EU list of Critical Raw Materials, and some important supply sources of rock are contaminated with cadmium and other pollutants. Russia is an important phosphorus supplier and the war in the Ukraine is compromising supply. Fertiliser costs have increased dramatically. **The need for phosphorus recycling is thus higher than ever before**.

Today emissions to the environment of phosphorus and nitrogen are too high. **The Green Deal, in both the Farm-to-Fork and Biodiversity Strategies, set the specific target to reduce nutrient losses by 50%.** The Integrated Nutrient Management Action Plan, currently being defined and to be adopted in 2022, is the tool to achieve this target.

The Integrated Nutrient Management Action Plan should improve reporting and monitoring, focus on nutrient pollution hotspots and support nutrient sustainability in agriculture and industry.

Despite EU legislation for 30 years now, more action is needed. The Industrial Emissions Directive will be widened to cover more livestock production units (at present only large pig and poultry farms are covered, see ESPP eNews n°66). The Fertilising Products Regulation offers market opportunities to organic and recycled fertilisers. Mandatory separative collection of biowastes from 2023 will increase availability of quality raw materials for organic fertilisers. EU funding of research into improving recycling technology will continue.

Johanna Bernsel, European Commission DG GROW, summarised the new EU Fertilising Products Regulation 2019/2009 (FPR), which enters into force in July 2022 and is the first deliverable of the EU Circular Economy Package. The declared objective of this Regulation was to **replace 30% of EU use of mined phosphate by recovered P by 2030**. This today looks achievable.

This regulation will give the CE-mark to recycled fertilisers, soil improvers, growing media and biostimulants, enabling access to the whole EU market, and ensuring reputation and public and farmer confidence.

Important aspects of the new Regulation are also that:

- The CE-mark for fertilising products gives **EU End-of-Waste status to the final product** (not to the input materials – CMCs)
- **National fertilisers can continue to be defined and sold** on Member States national markets ("optional harmonisation") allowing a wide range of recycled fertilisers to be used locally
- **Implementation is ready**. Although "Harmonised Standards" are not yet available for some new testing requirements, "Technical Specifications" are defined and can be used. Several "Notified Bodies" are already in place to carry out produce Conformity Assessments.

The European Commission has made efforts to ensure that fertilising product manufacturers and distributors are informed about the new FPR regulation. A detailed "**Frequently Asked Questions**" document is already online, and is progressively updated and a Technical Guidance Document will be developed. The info session organised by the European Commission (23 May 2022) is recorded online here. However, actions are now also needed to inform producers of secondary materials interested to supply these for fertiliser production.

The FPR regulates fertilising products placed on the market but does not regulate their use. The Integrated Nutrient Management Action Plan is thus needed to achieve the Green Deal nutrient loss reduction targets.

"INMAP (the EU's planned 'Integrated Nutrient Management Action Plan') will realise the Green Deal 50% nutrient loss reduction target, with the support of the Common Agricultural Policy, and with revision and strengthened implementation of existing EU policies" *Andrea Vettori, European Commission DG Environment*

Andrea Vettori, European Commission DG Environment, presented the ongoing work towards the **Integrated Nutrient Management Action Plan (INMAP),** which aims to address the environmental impacts of nutrients, ensuring a higher efficiency in their use and taking also into account the consequences of Russia's war on the Ukraine.

Indeed, **increasing efficiency in use would reduce reliance on imports**.

The context is known and recognised:

- in Europe, P exceeds planetary boundaries by 2x, and N by 3.3x
- nutrient losses impact fisheries, tourism, drinking water, biodiversity
- despite considerable efforts in EU policies (in particular the 1991 Urban Waste Water Treatment and Nitrates Directives and the 2000 Water Framework Directive), losses remain too high to water and air, mainly from agriculture and wastewaters.

The **Green Deal (Farm to Fork and Biodiversity Strategies) therefore fixes targets to reduce nutrient losses by 50% by 2030,** without deteriorating soil fertility, resulting in a reduction of 20% in fertiliser use.

INMAP intends to act in the following areas:

- monitoring and reporting
- reducing nutrient losses at source
- focus on nutrient hotspots
- safe nutrient recycling
- sustainable food production and consumption
- reviewing legislation, compliance
- R&D, international cooperation (cf. Horizon Europe "Clean environment and zero pollution CL6-2022-zeropollution)

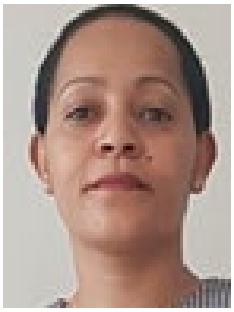
In particular, the following will be important tools for INMAP:

- **CAP (Common Agricultural Policy) Member States "Strategic Plans".** These are submitted for validation to the European Commission and should be Green Deal compatible
- **Revisions of EU Directives** on waste water, sewage sludge, air quality (ammonia emissions), Industrial Emissions Directive
- Proposed new **EU Soil Health law**
- Implementation of the Waste Framework Directive obligation for **separative collection of municipal biowaste by 2023**

The **Common Agricultural Policy** represents one third of the EU budget and supports changes in agricultural policies. The Member States' "Strategic Plans" will be critical for implementation of INMAP.

Global policies and actions

"UNEP supports the efforts of partners and stakeholders in demonstrating sustainable phosphorus management" *Sinikinesh Jimma, United Nations Environment*



Sinikinesh Beyene Jimma, United Nations Environment, presented UN actions on nutrients. She emphasised that excessive nutrient use and pollution impacts climate, biodiversity and water quality, and that sustainable nutrient management is essential for secure food production.

To address this, UNEP has two stakeholder forums, the Global Partnership on Nutrient Management (GPNM) and Global Wastewater Initiative (GW^{2}I).

UNEP and the Global Environment Fund (GEF) have launched projects to address nutrient losses from land to coastal and marine ecosystems. Following United Nations Environment Assembly resolutions, this led to the launch of the global research project on nitrogen losses "International Nitrogen Management System"

Concerning phosphorus, after supporting a project around the Laguna de Bay, Manila, Philippines (2017, see here), GEF is now co-funding a pilot project for sustainable water basin phosphorus management with stakeholder cooperation, in the Villarrica Lake basin, Chile (uP-Cycle, at launch phase).

The United Nations Environment Assembly (UNEA) emprises the importance of sustainable management of phosphorus to reduce global water pollution and enhance food security, in 2019 and again in March 2022 (see ESPP eNews n°33 and n°67).

"The 'Our Phosphorus Future' report lays the foundations for a coherent, global research initiative towards phosphorus sustainability" *Will Brownlie, CEH Edinburgh / University of Edinburgh*

Will Brownlie, CEH Edinburgh (Centre for Ecology & Hydrology) and University of Edinburgh, presented the just-published "**Our Phosphorus Future**" report (see ESPP eNews n°67). This project was initiated by the call for a global initiative on science to support phosphorus stewardship signed by over 500 scientists and launched at the 3rd European Sustainable Phosphorus Conference, Helsinki 2018 ("Helsinki Declaration" see ESPP SCOPE Newsletter n°127). With UK government and ESPP funding, and UNEP support, the Our Phosphorus Future project has engaged over 80 scientists and experts from more than 20 countries, resulting in a 390 page report identifying challenges and possible solutions for phosphorus reserves and uses, P in food systems, agricultural P use, P and water quality, P-recycling and P-recovery and consumer behaviour. A 24-page Policymakers Summary was published for ESPC4 and is now online.

Our Phosphorus Future proposes a **global goal for phosphorus sustainability of "50:50:50",** that is reducing phosphorus losses -50% and increasing P-recycling +50% by 2050. This could save farmers 20 billion US$ fertiliser costs and cut pollution impacts by 300 billion US$.

Next steps planned are a pilot project led by CEH and the Chile Ministry of the Environment with UNEP/GEF funding support (**uP-Cycle**, 2 million US$ UNEP funding) testing concerted catchment phosphorus management and P-recycling (see UNEP presentation above).

In parallel, the Our Phosphorus Future (OPF) report highlights the opportunity to develop a United National Environment Assembly (UNEA) resolution on phosphorus (following the recognition of the importance of phosphorus within the two UNEA resolutions on Sustainable Nitrogen Management already in 2019 and 2022, see UNEP presentation above), and the opportunity to develop a global research project on phosphorus sustainability, with involvement of stakeholders through UNEP's partnerships.

Nutrient Platforms in action

Nutrient Platforms in place in Europe

Chris Thornton, European Sustainable Phosphorus Platform (ESPP, established 2014), emphasised the key role of the Platform's 55 members, without whom ESPP would not exist (the Platform is funded only by membership fees).

Key challenges for ESPP today are :

- **supply chain pressures**, resulting from Russia's war on Ukraine. How to convert this urgent crisis into lasting action on recycling, Phosphorus Use Efficiency (in fertilisers, feed) and dietary change?
- Links to **climate change**: phosphorus losses and eutrophication, effects on Phosphorus Use Efficiency

ESPP's current actions include work on the EU Integrated Nutrient Management Action Plan (INMAP), Critical Raw Materials list update, water policy & sewage sludge, recycled nutrients in Organic Farming, EU Algae Initiative, the EU 'Taxonomy' (green funding criteria, for which the project includes P-recycling from sewage), continuing development of the EU Fertilising Products Regulation and on organic (carbon-containing) fertilisers and links to national / regional policies and Platforms, and to global actions.

ESPP is also widening our action to include nitrogen recovery and recycling, with a literature search launched and the objective of establishing a **Nitrogen Recovery Action Group**.

Tabea Knickel, German Phosphorus Platform (DPP), explained that DPP (established 2015) is an active knowledge and communications network in Germany, with today some 75 members.

DPP's mission statement is "**to promote the recovery of phosphorus and the sustainable use of the recovered products**". The context is the German national regulatory P-recovery obligation (see UBA presentation above).

DPP takes active positions on policy. DPP's **Policy Memorandum 2020** (here in German, summary in ESPP eNews n°49), which includes proposals to develop markets for recovered phosphates.

DPP is currently working in particular on safe authorisation of biochars and hydrocarbons in fertilisers, recycling of phosphorus from animal by-products, and on preventing possible moves to "temporarily store" sewage sludge incineration ash instead of implementing P-recovery.

Nathalie Tijdink, Netherlands Nutrient Platform (established 2013), explained that the Platform addresses phosphorus as a critical, finite resources but also recovery of nitrogen, potassium and micro-nutrients.

The Netherlands Platform is cross-sectoral, with members in the water treatment industry, recycling technologies, fertilisers, research, consultancy and two national Ministries (Infrastructure & Water; Agriculture, Environment & Food Quality).

The Platform is working on new ways to enable networking and on **facilitating market access for recovered nutrients**. Currently, the Netherlands Platform is taking this forward by drawing up a sector agreement, the "Nutrient Deal", to push ambitions further. The Deal will be backed by a study on stakeholder opportunities for action.

Nutrient Platform projects are also under development in **Ireland** (All Ireland Phosphorus Platform), **Italy, Sweden, Switzerland** and **V4 (Visegrad)** countries (Czech Republic, Hungary, Poland, Slovenia) – see here https://www.phosphorus-platform.eu/platform/nutrient-platforms

Updates from the USA

Jacob Jones, North Carolina State University, presented the newly-funded US research project **STEPS** (US National Science Foundation's Convergence Research Center for Phosphorus Sustainability), see ESPP eNews n°59.

This interdisciplinary project will receive 5 million US$/year funding for five years, possibly plus a further 5 years. Funding will enable opening of posts and recruitment of around 80 new researchers for the period (40 senior, 40 postdocs, plus c. 30 undergraduates/summer students).

Matt Scholz, US Sustainable Phosphorus Alliance (established 2016), presented the Alliance's activities around research, communications and knowledge transfer.

The Alliance a dozen paying members from fertilisers, technology, the water sector, consumer product sustainability and research.

The Alliance organises expert webinars to develop understanding and information (see https://www.youtube.com/c/SustainablePhosphorusAlliance).

The Alliance also hosts working groups, for example on P-Transport Modelling (losses of phosphorus from land), and GIS-P (geographic information system for sustainable phosphorus management, providing access to regional data on phosphorus flows, legislation, etc).

Perspectives in the USA include the update of the 2018 **Farm Bill (2023-2028),** which it is hoped will support conservation farming, and the possible update of the **definition of WOTUS** ("Waters of the United States") in the Clean Water Bill. The definition has varied between presidential administrations, and it is likely that the Biden administration will take a more expansive view than the Trump administration's view that essentially limited application to navigable waters. The extension to other streams, rivers and lakes could significantly reinforce requirements for P-removal and for reductions in P losses.

ESPC4 parallel sessions

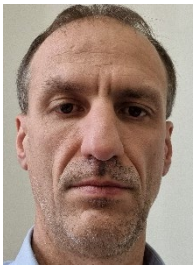
Nutrient recovery operating experience

Moderator/rapporteur: Karyn Georges, Isle Utilities & Veronica Santoro, ESPP

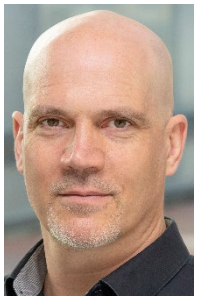
This session featured presentations from **ICL, Prayon, Vivimag, EasyMining, N2 Applied, ENDEV** and **Phos4Life**. Details of these processes are in the ESPP – DPP-NNP Nutrient Recycling Technology Catalogue. These presentations confirm **that P-recovery technologies are today available**, offered by recognised industrial operators, proven at the pilot scale, with full-scale installations coming online, producing high-quality recycled phosphorus products. Different technologies are adapted to different contexts and input material: sewage sludge incineration ash, sewage works with chemical P-removal using iron, on-farm nitrogen use improvement, integrated sewage sludge treatment for nutrient recovery.

Nutrient recovery technologies address phosphorus, but also in some cases, nitrogen and potassium, and are concerned about the high quality of the final product, including heavy metal content, as well as reducing greenhouse gases emissions.

Phosphorus recovery from ashes



Moderator/rapporteur: Paulo Pavinato, University of São Paulo & Christian Adam, Federal Institute for Materials Research and Testing (BAM)



Presentations from **FHNW** and **ERZO**, **Abonocare**, **TU Wien**, Fraunhofer IKS (**DreiSATS**), **BAM** and **University of Brescia – INSTM** included:

- results of a survey of sewage sludge incineration ash (SSIA) across Europe: identification of sewage sludge incinerators, analysis of phosphorus and heavy metal contents
- different processes to purify SSIA to remove heavy metals and allow safe recycling
- proposed combination of P-recovery from ash and valorisation of remaining mineral in cement production.

This session showed that a range of different approaches to P-recovery from sewage sludge incineration ash continue to be researched (in addition to existing technologies already being deployed, see session above).

Biochars and hydrothermal carbonisation

Moderator/rapporteur: Christian Del Valle Velasco, Université Laval, Canada & INRAE & Tabea Knickel, German Phosphorus Platform (DPP).

Presentations show full-scale plants today already operating, or pilots planned, recycling nutrients (see ESPP – DPP- NNP Nutrient Recycling Technology Catalogue) via HTC or pyrolysis processes:

- Full-scale: **Pyreg** is processing food waste to biochar fertiliser in Switzerland, and sewage sludge in Sweden and the Czech Republic (biochars from sewage sludge are authorised as national fertilisers in these two countries)
- Full-scale: **TerraNova** combine hydrothermal carbonisation with P-recovery (as a calcium salt)
- Demonstration pilot planned: **TreaTech** – **moRECo** (**FHNW**) combine hydrothermal carbonisation with P-recovery, ammonia recovery
- Research: **Abonocare**, **University of Copenhagen**: looking at different options for leaching P for recovery, at making P in biochars more plant available.

A key take-away is the need to prepare dossiers on the safety of manure biochars for the European Food Safety Agency (EFSA) and on sewage sludge pyrolysis / HTC products to support a request for inclusion into the EU Fertilising Products Regulation.

Emerging nutrient recovery technologies

Moderator/rapporteur: Ana Robles, IRTA, Ghent University / Biorefine Cluster & Ana Soares, Cranfield University

This session presented BioPhree, LIFE Enrich, Hias How2O AS, Fertimanure, Phos4You, Sea2Land, LIFE Newest and FlashPhos.

Phosphorus recovery technologies exist (see sessions above) and new processes are in the pipeline. Questions are asked as to their sustainability (Life Cycle Analysis).

These new technologies will require new training and competence in sewage works. Collaboration with the supply chain is needed to ensure that recycling technologies correspond to the needs of users (for the resulting recycled P product) and of the water industry.

New fertilisers for nutrient sustainability

Moderator/rapporteur: Chris Thornton, ESPP & Veronica Santoro, ESPP

Presentations included three Lex4Bio project presentations, looking at different recycled nutrient materials and different European soils (pot trials, P extraction methods, soil P leaching), risk of nutrient losses in the Ebro basin (Spain), producing and testing different recycled nutrient materials (Fertimanure), comparative consequential LCAs.

Conclusions are that most of the recycled nutrient materials (as tested) show crop fertiliser effectiveness for P comparable to, and soil P loss lower than, for mineral fertiliser. There is however a very high variability in P-release between different recycled fertiliser materials, depending partly on soil conditions. Soil Olsen P can be inadequate to predict P fertiliser need, P loss. Overall LCA of organic fertilising products or algal biomass can be higher than for mineral fertilisers if inputs for production are not wastes.

Policies and regional actions for phosphorus sustainability

Moderator/rapporteur: Lukas Egle, European Commission JRC (Joint Research Centre) & Geneviève Metson, Linköping University, Sweden.

Presentations from University of Rostock (Germany), HERA Spa (Italy), Albert-Ludwigs University of Freiburg (Germany), Kompetenzzentrum Wasser Berlin (Germany), Vahanen Environmental Consulting OY – AFRY Project (Finland), European Commission (JRC Ispra, Italy), RWTH Aachen University (Germany).

These showed different approaches, generally with interactions of multiple objectives, in particular linking energy, cost and climate to nutrients.

Quantitative and qualitative information on phosphorus flows, including spatial data, is important to identify opportunities for optimising P management or for recovery and recycling, and so for identifying drivers and defining policies.

Data must to be brought together from different scales and different systems, including agriculture, wastewater, food and feed, fertilisers …) in order to support Life Cycle Analysis, Life Cycle Costing and policy making.

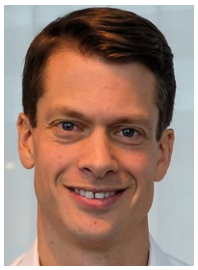
A key question is the impact of the EU Common Agricultural Policy (CAP) which strongly influences regional phosphorus use and possible actions.

ESPC4 final panel

Heide Spiegel, Austrian Agency for Health and Food Safety (AGES), underlined that phosphorus is a limited, non-renewable resource. This means that it is imperative to improve the agricultural use efficiency with agronomic recommendations, and to recycle nutrients in secondary, organic sources, such as sewage sludge, compost, digestate. Vienna City's project with Borealis is exemplary. However, for phosphorus recycling implementation, the time from projects to market is too long.

"We need to act now to implement the safe use recycled phosphorus"
Heide Spiegel, Austrian Agency for Health and Food Safety

For **Peter Wiwen-Nilsson, Race For The Baltic**, much has been done to reduce nutrient inputs to the Baltic, but 7 000 t/y of phosphorus too much still reaches it and eutrophication continues to deteriorate. The Baltic still has the largest dead zone in the world. None of the EU Member States around the Baltic Sea has achieved the first (2015) Water Framework Directive quality status objectives, and none of them has achieved the second deadline objectives (2021). Implementation of this existing legislation is thus the priority.



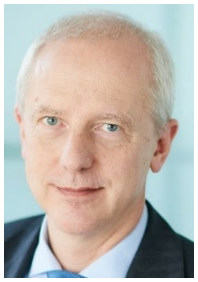
"Race For The Baltic sees municipalities looking for solutions for sustainable sewage sludge management and ready to pay for recycling"
Peter Wiwen-Nilsson, Race For The Baltic

For **Johanna Bernsel, European Commission DG GROW**, the EU Water Framework Directive quality status objectives are a key driver for improving phosphorus management and reducing losses, both from sewage and from agriculture. These will be included in the EU INMAP (Integrated Nutrient Management Action Plan) currently under development.

"Phosphorus recycling should be 'polluter pays', not paid by the water user. This should be considered in future European Commission policies"
Johanna Bernsel, European Commission DG GROW

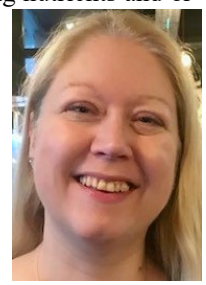
Jacob Hansen, Fertilizers Europe (the European fertiliser industry federation), underlined the considerable regional differences across Europe, both in fertiliser requirements and use and in access to secondary nutrients. The fertiliser industry can help provide logistics to transfer nutrients from manure-intensive regions to where they are needed for crop production. However, a systems approach is also needed, including producing more animal feed protein in Europe to reduce imports.

Mineral fertiliser production is not expected to expand in Europe, so industry aims to develop use of secondary nutrient streams. Recovery and logistics costs must however be born by "polluter pays" to enable the EU fertiliser industry and farmers to remain competitive with imports and competitive when exporting on the world market. For sewage phosphorus recycling, this means cities should bear the costs.



"The EU fertiliser industry has the logistics and market know-how to develop P-recycling, but costs must be 'polluter pays' " *Jacob Hansen, Fertilizers Europe*

For **Tamsyn Kennedy, Scottish Water and UKWIR (UK Water Industry Research),** the water industry's responsibility is to clean water. Phosphorus recovery is currently not economic, so if required by legislation, then the additional cost is passed to consumers, increasing the cost of living. In Scotland, sewage sludge goes to agriculture, returning nutrients and organic carbon to soil. There is no economic demand for recovered P products.



"Chemical P-removal from sewage is cheap and effective. How can P-recovery become a priority?" *Tamsyn Kennedy, Scottish Water and UKWIR*

For **Else Bünemann, Research Institute of Organic Agriculture (FiBL),** a more holistic approach to P-recycling is needed. Life Cycle Analysis of recycling technologies should be developed. Risk assessments of contaminants in sewage sludge, manure or secondary nutrient products should be carried out because at present the capacity of healthy soil systems to degrade organic contaminants is often underestimated.

"The food system needs to change to be balanced for all nutrients and for carbon" *Else Bünemann, Research Institute of Organic Agriculture (FiBL)*

Different **conference participants** suggested that:

- Agricultural practices can be modified to better mobilise soil P, including inter-crops, legumes
- Inappropriate standards for animal feeds and human food can limit nutrient recycling
- Quality, including low contaminant levels, should be the criteria for authorising uses of recycled nutrients, not the origin of the secondary material
- Recycling of organic carbon in secondary nutrient streams is important, both in Europe and back to countries producing foods or feed imported into Europe, in order to ensure soil health.
- Currently water users and tax payers bear the costs of eutrophication and water quality deterioration. These costs should be "polluter pays".

Ludwig Hermann, ESPP President, concluded that this fourth European Sustainable Phosphorus Conference demonstrates that in many places phosphorus sustainability and recycling have progressed from talking to doing.

Several P-recovery processes are now mature. Large-scale facilities are under construction, and will place recovered phosphorus on the market as fertilisers, animal feed or as "commodity" chemicals for industry.

Frontrunner cities, regions and public water authorities (e.g. Vienna, Zürich, Hamburg, Helsingborg, Schkopau, Emscher-Lippeverband) are taking projects from ideas to real life implementation, with support of innovative companies, both SMEs and large groups.

EU **regulatory obstacles** however are still a problem for use in animal feed and for recycling phosphorus from animal by-products.

However, **phosphorus sustainability and recycling are mainly driven by regulatory requirements**, as is true for most environmental progress (in particular, for sewage treatment). Where regulators have put in place P-recovery obligations at the Member State level, businesses are now active with hundreds of millions of Euros mobilised.

Further regulation and implementation is therefore needed. Hopefully the new **EU Integrated Nutrient Management Action Plan (INMAP),** currently being defined, will ensure this.

New economic systems are needed, based on "polluter pays" and including environmental and social costs. Current economic models favour linear consumer - waste – pollute systems not circularity. New economic systems should make recycling competitive and take into account impacts on the environment and resource consumption.

5th Phosphorus in Europe Research Meeting

Organised with:

BIOREFINE CLUSTER EUROPE

Ludwig Hermann, ESPP President, opened this 5th PERM (Phosphorus in Europe Research Meeting) by summarising conclusions of ESPC4 (see above) and of previous PERM meetings.

PERM4 (June 2021, online) showed that there is wide and active R&D on nutrients but concluded that there is a real **challenge to transfer results of projects to implementation** by policy makers, by the water industry, by farmers.

PERM4 also identified a number of **research needs**:

- improve coordination between projects, including with national and regional projects
- assess impact of projects, after completion
- coherent data on nutrient flows, LCAs, fertiliser tests
- evidence of climate change – nutrient management links
- data on costs of environmental and social impacts, to support social accounting
- research into social aspects, regulatory aspects and fiscal policies
- support of scale-up of R&D through to market

Summaries of previous PERMs

***PERM4**, online, June 2021, 370 participants, with Biorefine, SCOPE Newsletter n°141*

***PERM3**, Rimini, November 2018, with Smart-Plant, ESPP eNews n°28*

***PERM2**, Basel, October 2017, with Phos4You SCOPE Newsletter n°126*

***PERM1**, Berlin, 2015*
conclusions published by the European Commission
summary in SCOPE Newsletter n°111

Erik Meers, University of Ghent, outlined key sources of information and cooperation for R&D into nutrients:

- Biorefine Cluster brings together more than thirty R&D projects working on nutrient recycling and bioresource recovery. The Cluster is no-cost and based on a formal commitment on cooperation. The objectives are to increase impact together, including by defining joint positions and proposals, and with shared communications tools.
- ESPP-NNP-DPP Nutrient Recycling Technology Catalogue summarises nutrient recovery processes which are at least at the pilot stage. Practical data is provided on input materials, output products, fate of contaminants, with a short summary of the process and contact details of the technology supplier/developer.
- Nutriman (Horizon 2020 funded) has developed an online "farmer platform" with information on around 40 nutrient recovery technologies / products.
- Nutri2Cycle Lighthouse Demo Network (Horizon2020) presents fourteen pilot nutrient recovery projects or field tests of recovered products.Biorefine Nutrient Recycling Community

Ana Robles Aguilar, University of Ghent, introduced the **Biorefine Cluster Europe** and the "**Nutrient Recycling Community**" (an initiative of Biorefine Cluster and Fertimanure). The Nutrient Recycling Community aims to facilitate exchange of information between R&D projects, develop new projects, share common research methodologies, possibly share researchers. The Community has defined five subgroups:

- Technologies for nutrient recovery (lead: FERTIMANURE)
- Agronomic performance of recycled fertiliser products (lead: LEX4BIO)
- Sustainability assessment and LCA (lead: NOVAFERT)
- Policy (lead: NUTRI2CYCLE)
- New business models and market opportunities for recycled fertilisers

For information about the Nutrient Recycling Community, contact: info@biorefine.eu. For details of the Working Groups, or to actively participate please contact any of the members of the management team: Margherita Genua Margherita.Genua@UGent.be, Ana Robles Aguilar Ana.RoblesAguilar@UGent.be, Erik Meers Erik.Meers@UGent.be, Nimisha Edayilam Nimisha.Edayilam@UGent.be, Laia Llenas laia.llenas@uvic.cat.

Questioning greenhouse impacts of digestate

Bente Føreid, NIBIO, presented studies on greenhouse gas emissions from digestate during composting and soil application, suggesting that work is needed to mitigate emissions.

Digestate produced from the organic fraction of municipal solid waste or food wastes was used. **Soil application of both liquid and solid fractions of digestate showed significant greenhouse emissions** of nitrous oxide N_2O.

Composted digestate showed low greenhouse emissions in soil application, but **methane and N_2O emissions during composting of the digestate were significant** (considerably higher than in composting of raw food waste). The reason for the higher methane emissions was a microbial community adapted to methane production, imported with the digestate.

Possible solutions to mitigate emissions in composting of digestate were tested: different anaerobic digestion operating temperatures, heat treatment of digestate before composting. This suggested that hygienisation at 70°C decreased greenhouse emissions during composting. Higher temperature during the digestion process (thermophilic) also decreased emissions.

Conclusions are that **there are significant greenhouse gas emissions from both soil application and composting of digestate, but that emissions from digestate composting can be mitigated**.

EU R&D funding programmes

Federico de Filippi, CINEA (EU European Climate, Infrastructure and Environment Executive Agency) presented the LIFE programme 2021-2027.

"**Circular Economy and Quality of Life**" is one of the four LIFE sub-programmes, with a budget of 1.35 billion €. LIFE project objectives can be to develop and demonstrate eco-innovative technologies, promote best practices and behavioural change or catalyse large-scale deployment of solutions.

Nearly 120 projects related to water have been funded 2014-2020, with total EU contribution of 154 million €. Of these, 36 specifically address resource recovery from water treatment.

These include, for example, NEWEST, Servyeco Spain, developing and testing bio-sourced materials as coagulants for P-removal from wastewater (see ESPP eNews n°16) and Sludge2resource, Müllverbrennung Kiel GmbH, Schleswig-Holstein Germany, sewage sludge mono-incineration with P-recovery (as phosphoric acid) from the ash.

Katja Klasinc, European Commission DG RTD (Research and Innovation), outlined opportunities for nutrient research in **Horizon Europe**.

Research funding under Horizon Europe will aim to **contribute to the Green Deal objectives**: Zero Pollution Ambition, Farm to Fork and Biodiversity Strategies, Circular Economy Action Plan (see SCOPE Newsletter n°139)

Horizon Europe Cluster 6 covers "**Food, bioeconomy, natural resources, agriculture and environment**" and includes specifically IA7 Circular Systems, IA5 Food Systems, IA6 Bioeconomy, IA3 Agriculture, IA4 Seas and Inland Waters. Expected impact refers to "Sustainable and circular management of natural resources, … prevention of pollution … potential of the bioeconomy" (see Horizon Europe Strategic Plan 2021-2024).

Calls relevant to nutrients in the Cluster 6 Work Programme 2021-2022 include "Clean Environment and Zero Pollution" (inc. e.g. regional N/P targets, agriculture nutrient budgets, environmental impacts of alternative fertilisers, innovative nutrient governance, nutrient recovery BAT, demonstration regional nutrient projects)

On nutrients, the objective is to keep European nitrogen and phosphorus flows within safe ecological boundaries. R&I gaps identified are:

- **Basic research on N and P thresholds** in air, water, soil
- Modelling and assessment of **N and P emissions**
- **Uptake of technologies** for N and P recycling to fertilisers
- **Environmental impacts of recycled fertilisers**
- Transition pathways to integrated nutrient management, in particular at the **regional level**

Projects already funded include NAPSEA, NUTRIBUDGET, NEW-HARMONICA, NORDBALT-ECOSAFE, FERPLAY, NOVAFERT. Evaluation of submissions to other calls is ongoing. These projects add to the important body of research and innovation funded by Europe on nutrients and water resource recovery under Horizon 2020, where some 40 major projects are recently closed or still underway (including: INCOVER, SMART-PLANT, POWERS TEP, REWAISE, WATER-MINING, WIDER-UPTAKE, B-WATERSMART, ULTIMATE, RUN4LIFE, NEXTGEN, HYDROUSA, WALNUT, OPTAIN, SABANA, WATER-AGRI, ZERO-BRINE, SYSTEMIC, SCALIBUR, RUSTICA, SEA2LAND, CIRC4LIFE, LEX4BIO, WATER2RETURN, FERTIMANURE, NOMAD, CIRCULAR AGRONOMICS, NUTRI2CYCLE, GO-GRASS, SolAce, ECOBREED, TomRes, NUTRIMAN, NUTRISHIELD, SEA2LAND, BlueBio.

ESPP research member visions

BETA Technological Center

"The 'Circular Bioeconomy' is the future for sustainable rural development, and nutrient sustainability and recycling is vital, because agriculture is the biggest user. We aim to bring R&D knowledge to rural stakeholders and farmers"

Laia Llenas Argelaguet, BETA Technological Center (UVIC-UCC), Spain

CETAQUA

"We want to move forward from wastewater treatment to biofactories, with nutrient recovery instead of nutrient removal, making sustainable fertilisers for farmers. This needs not only technologies, but also economic tools, investment and end-user engagement (farmers, consumers)"

Adriana Romero Lestido, CETAQUA, Spain

WETSUS

"R&D continues to be needed to make known nutrient recovery technologies better performing and lower cost, but also to find innovative new recycling routes, with better understanding of basic chemical science"

Leon Korving, WETSUS, The Netherlands

Lex4Bio

"Fertiliser nutrient use efficiency must be improved, depending on crop needs in different regions and climates. Bio-sourced fertilisers need further research and field testing to combine nutrient recycling with use efficiency in the field"

Kari Ylivainio, LUKE, Finland

MonGos

"Indicators are needed to monitor the Circular Economy. We propose indicators on nutrient removal and recovery and Life Cycle Assessment for monitoring the Circular Economy performance of wastewater treatment"

Marzena Smol, Mineral & Energy Economy Research Institute, Polish Academy of Sciences

University of Stuttgart

"The University of Stuttgart develops projects with holistic approaches, such as FlashPhos, RUN and twist++, which do not only develop P-recovery technologies, but aim to close the loops by meeting the needs of both residue producers and the users of recycled nutrients.)"

Matthias Rapf, University of Stuttgart - ISWA

FlashPhos

"We intend to take forward to demonstration scale previous pilot research on electro-thermal production of white phosphorus (P_4) from sewage sludge, with the aims of resolving the problems posed by iron content and of using directly dewatered sewage sludge as it comes from the sewage works."

Lukas Pohl, University of Stuttgart - ISWA

PERM5 parallel sessions

New and recycled phosphorus fertilisers

Rapporteur: Veronica Santoro, ESPP

Moderator: Olivier Bastin, ESPP

Presentations addressed the topic of how to improve phosphorus availability in soils, using microbes or crop genotype improvements; efficiency of char-based organo-mineral fertilisers; farmers' perceptions of bio-sourced fertilisers.

Takeaways are:

- **Standardisation of methods is needed for pot trials** of phosphorus availability from new fertilisers, as dose, time, and substrate effects are often neglected.
- Exploiting **microbial functional traits related to P solubilisation** can be an efficient strategy to increase phosphorus availability, but this requires preliminary screening. Four strains of **actinobacteria** were identified as promising thanks to their ability to promote root growth, allowing for a better soil exploration.
- A screening of potato genotypes may pave the way for the identification of **phosphorus efficient genotypes** and involved genes that can be used as markers.
- In tests, **organic P(K)-char fertilisers** provided the same fertilisation efficiency as triple superphosphate, with lower nitrate leaching and nitrous oxide emission rates.
- **Farmers' intention to use recycled fertilisers** is positively affected by perception of benefit and low risks. To in-crease the willingness to pay, it is better to use differentiated marketing strategies for livestock intensive and non-intensive regions.
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Regional approaches to nutrient management

Rapporteur: Chris Thornton, ESPP

Moderator: Robin Harder, Swedish University of Agricultural Sciences, Sweden

Presentations looked at public policies, corporate sustainability and mapping nutrient flows in Germany, Ireland, Netherlands, Visegrad countries (Poland, Hungary, Czech Republic, Slovakia), Finland and internationally.

Takeaways are:

- **Different drivers in different regions**: P-recovery legislation, greenhouse emissions reductions, biogas production, regional policy, ESG reporting or green investment ("Taxonomy")
- **Need for data on flows, qualities, spatial distribution** … but existing data systems are inadequate (Eurostat, NUTS)
- **Sewage sludge quality** (P content, contaminants) will define technology choices, regional planning
- Importance of **stakeholder engagement**, e.g. concerning safety, operational resilience, user needs & demand
- Need for **holistic approach** (energy, different materials, nutrients, water) and to include social, economic factors

Iron – phosphorus interactions in P-recycling

Coordinated by Wetsus.

Rapporteur: Bengt Hansen, Kemira, Sweden

Moderator: Leon Korving, Wetsus, Netherlands

The biogeochemical cycle of phosphorus is closely coupled to that of iron. This session addressed both fundamental chemistry The session covered fundamental as well as practical experiences, including both removal of iron phosphate from different streams, as well as to how to use recovered iron phosphate. Presentations covered iron-P interactions in wastewater, agriculture runoff and farmland, bio-availability of iron bound phosphates, aspects of iron-P chemistry and potential of recovered vivianite (iron (II) phosphate).

In one study, ferric phosphate (that is Iron(III) phosphate) was surprisingly soluble with Olsen P analysis compared with some other recycled products. This result was contradictory to results from another study where bio leaching of P was less efficient when iron in vivianite (ferrous phosphate) was oxidized to ferric phosphate.

How P is linked to iron, is precipitated in or adsorbed in soil is influenced by many parameters: molar ratio of Fe/P, concentration of P, aging (mineralisation) etc. There is more need to identify and quantify the different iron phosphate substances.

The key conclusion is the **need for better understanding of iron – phosphate chemistry**, to support phosphorus recovery and phosphorus removal in wastewater treatment, and to understand the implications of iron content of recycled fertilisers for agriculture.

Nutrient recovery from dairy industry

Coordinated by REFLOW.

Rapporteur: Ipan Hidayat, BETA Technological Centre (UCC-UVIC), Spain

Moderator: Jan-Philip Uhlemann, Wageningen University and Research, Netherlands

This session addressed technologies for nutrient and resource recovery from dairy industry processing wastewaters, agronomic value of recovered fertilisers from dairy and environmental impacts / life cycle analysis. Several of the presentations concerned HTC (hydrothermal carbonisation) as a route to recover energy and nutrients, including looking at the impact of hydrochar on crop field greenhouse gas emissions.

Presentations also addressed biological phosphorus removal (EBPR) and development of a calculator for field application of recycled fertilisers.

Conclusions are that **dairy processing wastewaters offer a potentially interesting opportunity to recover nutrients** (as well as energy, organic carbon), because of high nutrient concentrations and low contaminant levels. This can also mitigate wastewater disposal costs, particularly as dairy processing is often situated in nutrient Vulnerable Zones or regions with nutrient surpluses linked to livestock production.

Phosphorus interactions in soils

Rapporteur: Kari Ylivainio, LUKE, Finland

Moderator: Victoria Barcala Paolillo

Presentations showed studies of phosphorus, organic carbon and pH in soil under differing P fertilisation conditions.

Long-term field studies of "P drawdown" in Belgium and the Czech Republic showed differing results. Seven years without P application in initial high-P soil showed no drop in soil P nor soil C_{-org}, whereas in the Czech republic 21 years without P application led to lower soil P and lower crop yield.

Studies of different fertilisers, soil phosphorus and modelling showed that increasing soil C_{-org} can compete with phosphorus for clay sites, so increasing soil P solubility, depending on soil type.

Overall, **soil P behaviour and so fertilising strategy is highly dependent on different soil types** and conditions.

New technologies for nutrient recovery

Rapporteur: Francesco Fatone, Università Politecnica delle Marche (UNIVPM), Italy

Moderator: Matthias Zessner, Vienna University of Technology (TU-Wien), Austria

The technologies presented covered nutrient recovery and management from sewage sludge, agricultural digestate and in the animal feed industry, in particular thermochemical and membrane processes. TRL was generally high, but information was often not available on economic aspects. Energy efficiency is important, as it will influence cost. Further information is also needed on overall environmental footprint, taking into account chemicals used in the process. The concentration of nutrients in the inflow stream treated is important, as phosphorus concentration in sewage varies across Europe and will significantly impact application of technologies. Overall, **further work is needed to optimise technologies for different input streams, and to ensure high-quality, agronomically valuable final output products**.

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