ESPC4 and PERM 20-22 June 2022

Updated programmes, including speakers for parallel sessions and posters, are now online for ESPC4 (4th European Sustainable Phosphorus Conference) and PERM (Phosphorus Research in Europe Meeting), plus site visit and young researchers networking event, 20-22 June 2022, Vienna, Austria. Nearly 200 participants are already registered. **Make sure YOU don't miss the first major international meeting on sustainable nutrients since the start of Covid**, with the European Commission and international organisations, leading companies, scientists and stakeholders. Networking tools will ensure information sharing, contacts and exchange between participants. Register now. Capacity is limited to 300.

https://phosphorusplatform.eu/espc4

Looking for research support for literature search tasks

ESPP is looking for researchers to carry out, in coming 3-6 months, paid, one-off literature search – analysis tasks on nitrogen recovery and on safety of animal by-product ashes. Offers are welcome for one or both of these two separate tasks from research students, institutes, individuals or other organisations. Offers are requested (price, short outline of method and data bases to be used, CV and relevant knowledge) **by 31st May 2022**. Full details of tasks can be found on the ESPP website HERE.

"Legacy Phosphorus" in soils: SCOPE Special published

ESPP's SCOPE Newsletter Special Issue (with BOKU) on "Legacy Phosphorus" accumulation in agricultural soils, maintaining crop yields and minimising losses to water, is now published (download here). This SCOPE Newsletter Special outlines presentations and conclusions of the ESPP – BOKU webinar, 2nd February 2022, and summarises 19 selected key, recent scientific publications. Themes covered include: defining "Legacy P", data and long-term trials, modelling the time needed for P "draw-down", what is a "significant" reduction to crop yield?, phosphorus traps and management practices, agronomic recommendations, crop P efficiency, challenges of soil P testing.

ESPP – BOKU SCOPE Newsletter n°142 Special Issue (May 2022) "Legacy Phosphorus in agricultural soils: Maintaining crop yields and minimising losses to water" www.phosphorusplatform.eu/Scope142

EU tenders, consultations, meetings

EU tender to develop guidance for EU Fertilising Products technical documentation

The European Commission (DG GROW) has announced a tender ("low-value contracts procedure") to support development of guidance for technical documentation for CE-mark products under the FPR. **Deadline for submitting interest: 25th May 2022**. The supplier will draft a proposed Guidance Document for elaboration of technical documentation necessary for Conformity Assessment of EU Fertilising Products under Regulation 2019/1009, intended for use by companies wishing to obtain the CE-mark for their products to place on the market, and also for Notified Bodies and market surveillance authorities.

European Commission "Ex-ante publicity of middle and low-value contracts" HERE or contact DG GROW.
Deadline for submitting interest: 25th May 202

EU online information meeting on Fertilising Products Regulation (FPR) implementation

23rd May 2022 10h-17h online (registration deadline 16th May), European Commission (DG GROW) information event for companies, Member States and stakeholders on FPR implementation, inc. conformity assessment, REACH, transitional arrangements and harmonisation. Possibility to submit questions in advance to the European Commission using the registration form HERE: it is requested to check that questions are not already addressed in the Commission's online "Frequently Asked Questions" document before submitting.

Registration (deadline 16th may 2022) HERE Meeting agenda and other information HERE (direct link).on CIRCA in the publicly available "Commission Expert Group on Fertilising Products" dossier.

EU consultation on circular economy monitoring

EU public consultation, open to 3rd June 2022, on indicators for monitoring EU circular economy policies, with the aim of updating the ten existing indicators here. The existing indicators are aluminium (EU self-sufficiency, end-of-life recycling rate); municipal waste generation and recycling rate; all non-mineral waste generation and recycling rate; food waste; recovery rates for packaging, e-waste and construction waste; overall circularity rate for all materials, trade in recyclable raw materials, private investment and jobs in circular economy, number of patents, green public procurement. The consultation document states as objectives new indicators will focus on areas of the 2020 Circular Economy Action Plan (ESPP eNews n°42), in which "Food, water and nutrients" are one of seven targeted value chains, and on links between circular economy and climate and zero pollution policies. Objectives are also to develop material footprints. In all cases, indicators will be based on available data sources, from either official statistics or science.

ESPP will input to suggest that the following indicators should be added:

- EU self-sufficiency and end-of-life recycling should be included for all EU CRMs (Critical Raw Materials, including 'Phosphate Rock' = P in any form, and 'Phosphorus' = white phosphorus - P_4), as well as for aluminium (bauxite is a CRM). Data is collected by EU JRC for regular updates of the CRM list.
- Reuse/recycling rate for resources in wastewater: nutrients (phosphorus and nitrogen), organic carbon, water – see recommendations of Preisner, Smol et al., 2022, in ESPP eNews n°64. Data should be available in Member State reporting for the Urban Waste Water Treatment and Sludge Directives.
- Recycling rates for nutrients in agri-food waste. Food waste should be monitored not only in "tonnage" but also in nutrient content (see e.g. study by Nestlé and WRAP UK in ESPP eNews n°36). Food industry by-products, including slaughterhouse wastes and animal by-products, should also be included, because these are probably an overall more significant secondary resource than end-of-chain food waste.
- Total losses of phosphorus to surface waters, as this is indicative of non-circularity and is also linked to climate change, in that climate change accentuates eutrophication but also eutrophication can lead to significant methane losses (see ESPP SCOPE Newsletter n°137). Data should be available through European Environment Agency statistics and Water Framework Directive Member State reporting.
- % of nutrients applied to farmland coming from secondary sources versus mineral fertilisers (for phosphorus, nitrogen). Data should be available through Common Agricultural Policy nutrient farm balance reporting.
- Levels of contaminants in secondary materials which pose obstacles to reuse and recycling, in particular PFAS in sewage sludge, pharmaceuticals in manure and in sewage sludge. Data is available in Water Framework Watch List monitoring and in science publications.
- Phosphorus footprint of EU food production, indicative of final consumption of the CRM 'Phosphate Rock', of food-chain nutrient efficiency and of phosphorus recycling. Recognised methodologies exist, see e.g. phosphorus footprint of food in Brussels, Papangelou et al.2021 in ESPP eNews n°58.

EU public consultation, open to 3rd June 2022, "Circular economy monitoring framework - revision" HERE. Input is 4000 characters max text plus optional document upload.

EU consultation on sustainable food production

EU public consultation, open to 21st July 2022, on food sustainability and resilience. The declared objective is to develop a horizontal framework law on food systems to ensure an integrated food system approach. The Commission aims to address links between health, environment and food, including long-term food security, taking into account impacts on climate, biodiversity, rural livelihoods and competitivity, reductions in pesticide use and pressures on water, soil and air quality, animal welfare. The public questionnaire addresses aspects such as consumer information, costs and prices, standards, research, which stakeholders should be engaged, policy approaches, governance and which environmental and social aspects should be prioritised (including circularity, Q9). Specific questions address food sustainability information and labelling, public procurement of food for schools and public institutions, certain aspects of dietary choice (sugars, salt, saturated fats, red meat …), food advertising and marketing.

EU public consultation, open to 21st July 2022, "Sustainable EU food system – new initiative" HERE.

EU consultation on Environmental Liability

Public consultation to 4th August 2022 seeks input to the evaluation of the Environmental Liability Directive 2004/35/EC. Questions for the general public and specialist stakeholders seek views on objectives and priorities, effectiveness in supporting the polluter-pays principle and in preventing environmental damage, mandatory financial guarantees and insurance, implementation of the existing Environmental Liability Directive and interactions with national regulations, reporting and access to information, exemptions, applications to groups of companies and multinationals, cost effectiveness of the Directive.

"Environmental Liability Directive (evaluation)", public consultation (questionnaire) to 4th August 2022 HERE.

Policy

Update: P-recovery in proposed EU green investment list ("Taxonomy")

The final EU report on sustainable finance (the "Taxonomy") continues to include 'Phosphorus recovery from waste water' as a listed technology eligible for green investment funding. This follows a public consultation on the draft report in September 2021. Technical corrections from ESPP's input to this public consultation have been taken into account in the finalised report (clarifications regarding recovery routes, phosphate rock/white phosphorus as Critical Raw Materials, inclusion of reference to the new EU Fertilising Products Regulation …), but ESPP's proposals for substantive changes have not been included. **ESPP strongly welcomes that phosphorus recovery is included in the EU's proposed list of some 60 economic activities eligible for green funding**, but regrets that only recovery of phosphorus is considered (not e.g. nitrogen or potassium recovery), that only recovery from municipal waste water is included (not e.g. from manure, animal by-products or food waste). ESPP welcomes that the criteria have been somewhat widened to include recovery in the waste water treatment plant (wwtp), stating "mainly phosphate salts …", with a minimum recovery rate of 15% of wwtp incoming P, or after incineration with a minimum 80% recovery from the input material (ash). ESPP welcomes that the recovered P must "be a material with a real market demand … ensuring its reasonable functional use".

"Platform on Sustainable Finance's report with recommendations on technical screening criteria for the four remaining environmental objectives of the EU taxonomy" 127 pages, and Annex 675 pages, published by the European Commission 30th March 2022 HERE.

ESPP pushes nitrogen recovery in Waste Gas BAT BREF

As a member of the EU Industrial Emissions Directive Forum, ESPP has made input to the draft update of the Common Waste Gas Management in the Chemical Sector Best Available Techniques document. The draft document shows that although abatement of ammonia and nitrogen / nitrous oxide emissions is widespread, recovery is today little implemented. ESPP has input that EMS (Environmental Management Systems) should identify recovery potential and opportunities in gaseous waste streams and possible technologies for recovery, reuse or recycling, in particular of nitrogen, as a function of technical feasibility and logistics (potential recovery quantity). ESPP notes that a range of recovery technologies exist including "scrubbing" and regenerative adsorption or precipitation. The European Commission has responded that recovery is already included through other channels in this BREF (in particular BAT4 which requires an "*integrated waste strategy … including recovery*") and that the currently underway (see below) revision of the Industrial Emissions Directive aims to better align with circular economy and climate objectives.

"Best Available Techniques (BAT) Reference Document for Common Waste Gas Management and Treatment Systems in the Chemical Sector", draft for update https://eippcb.jrc.ec.europa.eu/reference/

Industrial Emissions Directive (IED) revision targets Circular Economy

The European Commission has published the legislative proposal for the IED which fixes environmental requirements for permitted installations in Europe. Key proposals include Circular Economy objectives, and widening to livestock. The Industrial Emissions Directive (which will become the Industrial Emissions Portal Regulation) defines conditions for the BAT BREF documents which are legally applicable to all permitted installations in Europe in covered sectors (some 50 000 sites today). The revision aims include contributing to resource efficiency and the Circular Economy, reducing toxic chemical use,

improving coherence on water, air and greenhouse emissions, enhancing innovation and widening scope, in particular to livestock production (at present only large pig and poultry farms are covered, not cattle production and not smaller rearing units). ESPP's input to the prior consultations underlined Circular Economy, innovation and the livestock sector (21_4_2021). The Commission's regulatory proposal will now go to the European Parliament and Council.

IED revision "Proposal for a Regulation of the Industrial Emissions Portal", 4th April 2022
https://ec.europa.eu/environment/publications/proposal-regulation-industrial-emissions-portal_en

European Commission not positive on "RENURE"

In an answer to a European Parliamentary question, the European Commission shows no intention to authorise use of "RENURE" (SafeManure) materials above N application limits in Nitrates Directive Vulnerable Zones. The question from a Flanders MEP, a region with high livestock density, Tom Vandenkendelaere, suggested that the manure-based materials assessed by the JRC "RENURE" report could be temporarily "derogated" from Nitrates Vulnerable Zone manure N application limits as a response to current price and supply pressure on fertilisers. The Commission reply notes that manure N application is not limited outside Nitrates Directive identified "Vulnerable Areas" and that no Member State has to date requested a derogation for RENURE materials, and reminds that the Farm-to-Fork targets of reducing nutrient losses by 50% by 2030, this reducing fertiliser use by 20%. The Commission states that the Integrated Nutrient Management Action Plan (INMAP), under preparation (public consultation closed April 2022, see ESPP eNews n°65) "*will consider further options for recycling nutrients in a holistic approach to reduce nutrients pollution*".

ESPP has expressed concerns about the RENURE agronomic criteria as published, which specify (inorganic N/total N) and (organic carbon/total N) ratios, can be met by certain untreated manures, most liquid fractions of manure, or by raw manure spiked with 10% urea (see ESPP eNews n°47). Such materials would be excluded only because RENURE excludes untreated or spiked manure. ESPP does however support the exemption, from the Nitrates Directive application limits for manure "even in a processed form", of mineral fertilisers (as defined in the EU Fertilising Products Regulation, i.e. < 1% organic carbon) recovered from manure, by derogation or interpretation and not by an amendment of the Nitrates Directive.

Parliamentary question for written answer E-000797/2022, Tom Vandenkendelaere (PPE) "Follow-up question: exception for the use of RENURE because of high prices for chemical fertilisers" HERE and European Commission answer E-000797/2022 given by Mr Sinkevičius (2nd May 2020) HERE.

EFSA paper on research on food & feed safety and the Circular Economy

Literature search for EFSA study focusses on novel food and feed, but concludes that a review is needed on recycling from sewage, manure and organics to fertilisers. EFSA (European Food Safety Agency) organised a stakeholder consultation in 2021 to input to a two-year study on "Food and Feed Safety Vulnerabilities in Circular Economy". ESPP commented the need to look at safe nutrient recycling, including secondary materials in fertilisers, growing algae for animal feed or microbial protein on waste streams, chemical recycling of nutrients from wastes to feed or food (see ESPP eNews n°61). EFSA have now published a paper from Harper Adams University, UK, based on a literature search, analysis of EU R&D projects and on the above stakeholder consultation. The first section of the paper (Objective 1) identifies relevant practices in the food and feed production chain. Practices cited include use of organic wastes streams, recycling of animal by-products, crop and crop processing waste, fish and crustacean wastes. The second part (Objective 2) was a literature search, limited to "novel foods and feeds" (27 000 articles identified and computer analysed including 26 primary research studies). The third part of the paper (Objective 3) characterises emerging risks, but this is based only on the information on novel foods and feeds. Lastly the paper recommends that future reviews focus on emerging risks beyond the question of novel foods and feeds, in particular: using municipal sewage, manures (inc. insect frass) as fertilisers, using wastewaters for irrigation and using animal by-products in fertilisers.

"Food and feed safety vulnerabilities in the circular economy", K. James, A. Millington, N. Randall, EFSA Supporting Publications, vol. 19, issue 3, March 2022 7226E https://doi.org/10.2903/sp.efsa.2022.EN-7226

Scientists say EU needs a "nutrient directive"

An opinion article in Nature Reviews suggests the need for an integrated nutrient directive to regulate agricultural application of nitrogen and phosphorus, taking into account nutrient balances and regional variations. The authors suggest that this is needed to achieve the Farm-to-Fork target of reducing nutrient losses to the environment by 50% (see SCOPE Newsletter n°139). Current nutrient regulations are considered to be failing: the target ecological status of the Water Framework Directive is widely not being achieved. ESPP notes that Grizzetti (JRC) et al. concluded in 2021 that current EU policies could reduce N losses by -14% and P losses by -20% (ESPP eNews n°55), indeed not near the Farm-to-Fork targets. The authors suggest that current EU directives are failing because they are scattered in different policies, often target only one nutrient, and target environmental levels, not sources. The authors emphasise the need for regional differentiation in measures, depending on local soil, crops, climate, environment, etc. ESPP notes that this is already the case with the Water Framework Directive (under which measures are defined at the water basin level), but that this Directive targets impacts not sources. The authors' proposal is for a nutrient directive which limits agricultural nitrogen and phosphorus application. It is not clarified how this might interact with the EU's Common Agricultural Policy, in which the European Commission's proposal to monitor nutrient balances at all farms was rejected by Parliament and Council (FaST tool, ESPP eNews n°31).

"The EU needs a nutrient directive", M. Wassen et al., Nat Rev Earth Environ 3, 287–288 (2022), DOI.

Swedish Water calls for ban on all PFAS chemicals

Swedish Water, representing Swedish municipalities, assesses problems of PFAS chemicals, and regulatory and market options, concluding that a group ban on all PFAS chemicals is needed, with only very limited exceptions. The report presents the history of PFAS use and increasing awareness of environmental and health risks, underlining that PFAS are "eternity chemicals", accumulating in nature and difficult and expensive to decontaminate and eliminate. PFAS clean-up could cost a billion Euros for Nordic countries only. Surveys of retailers and consumers show that the market is already trying to move to PFAS-free products, but that this is difficult as information is often not available for imported products. The federation concludes that a ban on PFAS chemicals is needed, as proposed in 2020 by the European Commission under the Green Deal – EU Chemicals Strategy (ESPP eNews n°49). Swedish Water underlines that this should cover all PFAS chemicals ("group ban") to avoid false substitution of one PFAS chemical by a similar one, and that exemptions from the ban for "essential uses" (as proposed in the EU Chemicals Strategy) should be "very restrictive"

PFAS Report, Svenskt Vatten (Swedish Water https://www.svensktvatten.se/), rapport R2022-1, April 2022, 58 pages, in Swedish with English summary HERE.

US 250 M$ funding for "American-made", innovative fertiliser investments

The US government (USDA) is calling for public comment (until 16th May) on a proposed 250 million US$ funding support programme for US production of innovative, sustainable, independent fertiliser production. The cited aims are to bring production and jobs back to the USA, to offer more choice for American farmers and to increase competition in the fertiliser industry and to ensure more reliable and resilient supply in the context of the war in Europe.

"USDA Announces Plans for $250 Million Investment to Support Innovative American-made Fertilizer to give US Farmers more choices in the Marketplace", US federal Department of Agriculture, 11th March 2022
"USDA Publishes Requests for Information on Fertilizer, Seed, Retail to Address Growing Competition Concerns in the Agricultural Supply Chain", 18th March 2022.

US EPA aims to accelerate actions against eutrophication

58% of US rivers and 45% of lakes have too high phosphorus levels. An EPA 'Memorandum' announces partnership action with agriculture, states, tribes and territories and use of the Clean Water Act, including extending TDMLs. Actions indicated including "fulfilling Farming Bill requirements to devote significant resources to water protection", watershed planning tools, financing Clean Water Act flexible regulatory framework such as technology development, market based approaches, water quality trading. EPA will reinforce numeric nutrient criteria into Water Quality Standards, support innovative permitting for point sources (wastewater treatment works) and use Clean Water Act mechanisms to define TDMLs (Total Daily Maximum Loads) for the 26 000 nutrient-impaired water bodies which today do not have nutrient TDMLs and to ensure implementation of TDMLs where they are defined.

"Accelerating Nutrient Pollution Reductions in the Nation's Waters", US EPA (Environmental Protection Agency), 5th April 2022 and HERE

Research

"Roadmap" for new nutrient sources for Organic Farming

Final report from EU-funded H2020 project RELACS on recycled nutrient products for Organic Farming shows little progress, **makes no recommendations for action, proposes further discussion and research.**

The report's lead author is from IFOAM EU (European Organic Farming federation), with editors from IFOAM, FiBL (the Research Institute of Organic Agriculture) and the University of Copenhagen. The report is based on 5 national workshops with Organic farmers and advisors, scientists and national authorities, and a European concluding workshop.

The report underlines the Organic Farming objective of feeding plants through the soil ecosystem. Manures from non-organic farms and rock phosphates are considered the most problematic external plant nutrition inputs to Organic Farming, because of contaminants and consumption of non-renewable resources. The report concludes that the importance of nutrient supply to Organic Farming has been underestimated to date, with risks of soil nutrient depletion and of reduced productivity.

The report proposes to develop the recycling of societal waste streams in order to ensure the nutrient supply of Organic Farming. As a first step, the RELACS project assessed three recycled nutrient materials only: AshDec calcined phosphates from sewage sludge incineration ash, Ostara struvite from municipal wastewater and anaerobic digestate (from biowaste, green waste, food waste – manure is not cited as an input material). The first two of these already benefit from a positive Opinion of the EU scientific committee on Organic Farming (EGTOP, 2/2/2016) and the third is already authorised in the EU Organic Farming Regulation. ESPP regrets that RELACS has not considered the 23 detailed recycled nutrient product fact sheets, produced by companies (coordinated by ESPP) and transmitted in December 2021. However, these led to the constructive "reflections" paper on the acceptability of recycled phosphorus fertilisers in European Organic Agriculture, published by FiBL 29th September 2021 (ESPP eNews n°60), which provides possible criteria for analysing which recycled phosphorus products are likely to be accepted in Organic Farming.

The report concludes from the workshops that the acceptance by Organic Farmers of the three products considered is generally good, also indicates concern about microplastics and organic residues in calcined phosphates. This shows that better

information of Organic farmers and stakeholders is needed, in that this is not pertinent for a product is derived from sewage sludge incineration ash.

The report's proposals are to "*update*, agree and adopt an evaluation framework for compatibility of external nutrient inputs with the principles of Organic production*". It is stated that the development of this framework will start by IFOAM launching a Working Group. The report also recommends further research, including long-term trials of recycled nutrients in Organic Farming, fate of contaminants (in particular copper and zinc), nutrient needs for Organic Farming and potential resources. Farm advice on nutrient balances is also recommended.

** The word "update" should be replaced by "develop", because no such "evaluation framework" exists to date.*
ESPP previously wrote to IFOAM EU on 20th April 2022 (HERE) requesting that IFOAM renew action to request inclusion of struvite and calcined phosphates into the EU Organic Farming Regulation (following the joint letter already signed with ESPP 17/6/2020 HERE) and engage consideration of other recycled nutrient products, including certain recovered nitrogen products.
Contentious Inputs in organic farming Systems), Horizon 2020, "Deliverable No 7.5: European roadmap for phasing-in new nutrient sources", M. Calmels, IFOAM EU et al., 7th April 2022 HERE.
"Reflections on the acceptability of recycled P fertilisers for European organic agriculture", 29 September 2021, V. Leschenne, B. Speiser, FiBL https://www.betriebsmittelliste.ch/fileadmin/bml-ch/documents/stellungnahmen/Recycled_P_fertilisers_v2_Sept_2021.pdf

Higher P fertiliser needed to achieve Sustainable Development goals

Modelling suggests that a 22 – 30 % increase in P input is needed (for 16 years, world total) to achieve the SDG 2.3 for smallholder farm productivity, resulting in only 1% increase in P runoff. UN Sustainable Development Goal (SDG) 2.3 sets the target to double productivity of smallholder farms as important to achieve SDG2 zero hunger. Based on data from Brazil where soils with high P-fixation are today approaching the point where a "maintenance" fertiliser application becomes possible without crop yield loss, and assuming that yields are not limited by other nutrients or climate, this leads to estimate that 50 kgP/ha/y application over the period 2015 - 2030 would eliminate P limitation of crop yield in five regions where smallholder farms are dominant and where P application is today low: Sub-Saharan Africa, North Africa, South-East Asia, India, Middle East. P limitation of crop yield is also present in Eastern Europe, Australia and parts of China, South America, New Zealand, but these regions have fewer smallholder farms. Overall, the five assessed regions will require a total (for 16 years) of 74 MtP fertiliser input, that is 39% higher (for these regions) than a baseline scenario, and representing 22 – 30% compared to a global total today of 15 – 21 MtP/y (this number is from the ESPP Factsheet estimate of global P uses, assuming increased P input comes only from mineral fertiliser, and assuming unchanged P fertiliser use in the rest of the world). This increased consumption might not continue beyond 2 or more decades as soil P stores are established in soils and farmers can then move to a maintenance fertilisation strategy.

"Phosphorus for Sustainable Development Goal target of doubling smallholder productivity", C. Langhans, A. Beusen, J. Mogollón, A Bouwman, Nature Sustainability, col. 5, Jan., 2022, 57-63, DOI.

Perspectives for sewage nutrient recycling in Austria

Around half of Austria's sewage sludge currently is valorised in agriculture. Around half this sludge going to agriculture is first composted, with 95% of sewage sludge compost achieving Quality criteria. A significant part of sewage sludge (c. 20%) goes to agricultural land either directly or after dewatering only. In all cases, sludge applied to land is today used subject to heavy metal limits and to nutrient requirements of crops. Austria produces around 240 000 t/y of sewage sludge (dry matter), of which 99% from sewage works > 2 000 p.e. This contains some 6 400 tP/y of phosphorus. Heavy metal levels in Austrian sewage sludge have decreased considerably over recent decades, but questions remain over other contaminants such as microplastics or pharmaceuticals. An Austrian study suggests that microplastics levels may relate principally to the sewer system and to industrial discharges (Sexlinger 2021). National monitoring of pharmaceuticals show very significant reduction in composting, but nonetheless detection of one pharmaceutical (carbamazepine) in soil after sewage sludge compost application. The authors conclude that evidence-based limits for organic contaminants in sewage sludge used in agriculture need to be developed, as well as upstream actions to reduce inputs to sewage. Mono-incineration of sewage sludge with phosphorus recovery can be an important route where contaminants prevent agricultural use.

"Best Available Technology for P-Recycling from Sewage Sludge - An Overview of Sewage Sludge Composting in Austria", B. Stürmer, M. Waltner, Recycling 2021, 6, 82. DOI. One of the authors is from the Austrian Compost and Biogas Association.

P-recovery headed to replace nearly half of German mineral P fertiliser use

Study estimates that German sewage P-recycling legislation will lead to recovery of 70 – 77 % of sewage P, that is up to 43 % of mineral P fertiliser consumption. Only 16 % of German sewage sludge was used in agriculture in 2019, around half of the 2010 level, as a result of new fertiliser legislation with tighter N application limits for farmers (implementation of the Nitrates Directive) causing competition with manure, and of new waste legislation, with sewage sludge contaminant limits. The German sewage sludge ordinance (AbfKlärV 2017, detailed in SCOPE Newsletter n°129) will ban agricultural sludge use and require P recovery (if sludge contains > 2%) from all sewage works > 50 000 p.e. by 2032. Based on this legislation and on data on sludge P content and sewage works sizes, with different scenarios, the study concludes that 71 – 80 % of Germany's sludge will be incinerated (0 – 14% used in agriculture), 70 – 77 % of P in sewage will be recovered (including via use in agriculture), and also 31 – 53 % potassium, 36 – 52 % calcium, 40 – 52 % magnesium but only 0 – 16% nitrogen. For phosphorus, this would represent up to 43 % of German mineral P fertiliser use.

"Future nutrient recovery from sewage sludge regarding three different scenarios - German case study", T. Sichler et al,, J. Cleaner Production Vol. 333, 2022, 130130 DOI

Recycling P from fish processing waste to fish feed

Fish bone meal and dicalcium phosphate (DCP) extracted from fish bones showed to be effective P sources in aquaculture fish feed. Trials were carried out in heated, recirculating aquaculture production of African Catfish (*Clarias gariepinus*), comparing feeds including P recovered from fish processing wastes to commercial DCP. The recycled P materials were produced from fish heads from a local Monkfish processing company (South Africa). The heads were treated by enzymatic protein hydrolysis, then rinsed, to leave cleaned bones. Fish bone meal was produced by drying @ 50°C then grinding. Recovered DCP was produced by leaching with 1M phosphoric acid then DCP precipitation by adding lime. The trials showed good fish growth with both recovered and commercial P in feed, with no significant differences in fish growth (body weight), feed conversion rate, body condition (mortality, serum parameters, bone mineral composition). The authors conclude that these phosphate materials recovered from fish processing wastes are a viable replacement for commercial dicalcium phosphate in aquaculture feed.

"In-Vivo Evaluation of the Suitability of By-Product-Derived Phosphate Feed Supplements for Use in the Circular Economy, Using Juvenile African Catfish as Model Species", J. Swanepoel, N. Goosen, Waste Biomass Valor (2022) DOI.
"Optimization of phosphate recovery from monkfish, Lophius vomerinus, processing by-products and characterization of the phosphate phases", J. Swart, A. Bordoloi, N. Goosen, J. Sci. Food Agric., 99: 2743-2756 DOI.

Scenarios for future phosphorus demand for batteries

Papers discuss implications for phosphorus demand if Lithium Iron Phosphate batteries (LFP) become predominant in electric vehicles, concluding possible need of 2 MtP/y, that is c. 10% of currently mined phosphate rock. An initial paper by Xu et al. 2020 discussed potential future demand for several critical materials for production of electric vehicle EV batteries worldwide 2020 – 2050 (automotive only). This paper mainly addressed lithium, cobalt, and nickel (copper, graphite and silicon also in annex). A comment paper by Spears et al. 2022 suggested that phosphorus should also be considered, in Lithium Iron Phosphate (LFP) batteries. In response to this, the original authors published a response 2022, estimating demand for phosphorus. In a scenario with 50% electric global fleet EV penetration by 2050 ("SD scenario"), based on estimated annual electric vehicle sales and battery capacity requirements, and if 60% of the EV battery capacity is Lithium Iron Phosphate batteries (compared to near zero today), then Xu et al. estimate that c. 3 MtP per year of phosphorus will be required by 2050, of which around one third may come from recycling of end-of-life batteries, resulting in an **annual net demand of c. 2 MtP/y by 2050**. This estimate is based on an assumed 1:1 atomic ratio between phosphorus and lithium in LFP batteries, multiplied by the molecular weight ratio (4.5:1 w/w). The estimate for total lithium used in batteries included the electrolyte and the cathode, whereas the lithium iron phosphorus in LFP batteries concerns the cathode only. On the other hand, use of phosphorus compounds for fire safety in battery electrolytes, membranes or structures/casings is not taken into account. These points are not expected to significantly modify the overall estimate. Also, the estimate covers use in light vehicles only, whereas significant additional demand is possible in batteries for trains and buses, other vehicles, and network energy storage. Xu et al. (2022) indicate (after correction*) that this estimate for P demand for LFP could consume approximately as much phosphorus as is used today in all industrial uses. ESPP estimates that 2 MtP/y (in 2050) would represent **around 10% of current mined phosphate rock production** (see ESPP Factsheet). Detailed data and calculations are provided in the Supplementary Information available online for each of the three papers.

"Future material demand for automotive lithium-based batteries", C. Xu et al., Communications Materials 2020:1-99 (Nature), DOI.
"Concerns about global phosphorus demand for lithium-iron-phosphate batteries in the light electric vehicle sector", B. Spears, W. Brownlie, D. Cordell, L. Hermann, J. Mogollón, Communications Materials 2022:3-14, DOI.
"Reply to: Concerns about global phosphorus demand for lithium-iron-phosphate batteries in the light electric vehicle sector", C. Xu et al., Communications Materials 2022) 3:15 DOI.
** ESPP has noted (confirmed by the authors) that the dotted line in fig. 1a in Xu et al. 2022 is based on an error in correction of P_2O_5 to P, so should be 2x higher.*

Analysing contaminants in wastewater recovered materials

Levels of certain industrial chemicals, pharmaceuticals and heavy metals were tested in a range of materials recovered in wastewater treatment plants, such as precipitated phosphates, ion-exchange, hydrolysed sludge, bio-polymers. The recovered materials were generated in the EU Horizon2020 SMART-Plant R&D project. The industrial chemicals analysed were polycyclic aromatic hydrocarbons PAH (e.g. naphthalene) and chloralkanes (e.g. chloroparaffins). Levels were generally orders of magnitude lower in the recovered materials than regulatory limits in fertilisers in any identified country. Heavy metals were also generally orders of magnitude lower than the new EU Fertilising Products Regulation limits, except in one material produced by thermal hydrolysis of sewage sludge from Pyttalia wwtp, Athens. Pesticides were generally not detectable. Of the pharmaceuticals analysed, several antibiotics were found at levels up to 600 ng/g DM in samples of sewage sludge, compost and recovered bio-polymers (PHA, cellulose): ciprofloxacin, azithromycin, clarithromycin. Antibiotics were not detectable or showed an order of magnitude lower concentrations in recovered struvite and in calcium phosphates recovered via ion-exchange.

"Determination of multi-class emerging contaminants in sludge and recovery materials from waste water treatment plants: Development of a modified QuEChERS method coupled to LC–MS/MS", B. Benedetti et al., Microchemical Journal 155 (2020) 104732, DOI
"Assessment of the significance of heavy metals, pesticides and other contaminants in recovered products from water resource recovery facilities", N. Rey- Martínez et al., Resources, Conservation & Recycling 182 (2022) 106313, DOI.

Phosphorus is most widely limiting nutrient on land

Global modelling suggests that 43% of land area is naturally limited by phosphorus, compared to only 18% by nitrogen, with the remainder co-limited by both nutrients or only weakly nutrient limited. Phosphorus is already recognised as the limiting nutrient in nearly all freshwater systems (lakes, rivers, reservoirs), which is why even limited phosphorus losses from land to water can cause eutrophication problems (algal growth). This study confirms the importance of P limitation for terrestrial ecosystems, and so its implications for potential to limit carbon uptake in response to elevated atmospheric carbon dioxide. The model is based on eleven predictors, covering local climate, soil and vegetation factors. Results show good correlation to published field data. Nitrogen tends to be more limiting at higher latitudes and altitudes. Phosphorus is limiting in general in tropical, subtropical and temperate deciduous forests, Mediterranean biomes, tropical and temperate grasslands, savannas and shrubland. The authors note that climate warming may favour biological nitrogen fixation, so mitigating nitrogen limitation and increasing areas concerned by phosphorus limitation.

"Global patterns of terrestrial nitrogen and phosphorus limitation", E. Du et al., Nat. Geosci. 13, 221–226 (2020) DOI.

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