Events

Postponement ESPC4 and PERM to 2022

Given the ongoing international corona virus situation, it is decided to postpone ESPC4 and PERM (4th European Sustainable Phosphorus Conference and European Phosphorus Research Meeting) to 2022, Vienna, as a physical conference (previous planned dates, now cancelled, Vienna 31st May – 2nd June 2021). New 2020 dates will be announced shortly, in **Vienna**, **probably June 2020**.

https://www.phosphorusplatform.eu/espc4

CRU Phosphates 2021: "the" phosphate industry event

Members of ESPP benefit from a 10% reduction for registration to "**Phosphates 2021**", **online 23-25 March 2021**. This is the only major global event for the phosphate mining, processing, phosphorus chemicals and phosphate fertiliser industries, and brings together over 400 industry participants every year. This year's Phosphates conference is online, with virtual exhibition and networking centre, interactive discussion groups, conference presentations with Q&A. Registration prices are considerably lower than usual.
https://events.crugroup.com/phosphates/register

Webinar series: recycled nutrients in Organic Agriculture

FiBL and RELACS are organising five 2-hour webinars to exchange between researchers and Organic Farming stakeholders to gather knowledge on potential risks of use of recycled fertilisers, e.g. organic contaminants, pathogens and microplastics.

Introduction – 3 March 2021, 14h-16h Paris time (CET)

Organic contaminants and other risks, - 11 March 2021, 10h -12h Paris time (CET)

How to recycle nutrients from household wastes and the food industry, 17 March 2021, 14h – 16h Paris time (CET)

How to recycle nutrients from human excreta, 12 April 2021, 14h – 16h Paris summer time (CEST)

Socioeconomic aspects and final discussion , 22 April 2021, 10h – 12h Paris summer time (CEST)

To register, contact: kurse@fibl.org

EIP-Agri "Healthy Soils" event

The call for participants is open to 14th February for the EU R&D EIP-AGRI seminar on healthy soils, 13-14 April 2021. The aim is to share knowledge, experience and innovation concerning on-farm actions to improve soil health, related to productivity, nutrient cycling, water, carbon sequestration and climate change.

Call for expression of interest to 14th February 2021 here.

EU policy

Call for input: manure and animal by-products in EU fertilisers

ESPP has discussed with the European Commission DG SANTE obstacles to nutrient recycling from animal by-products into EU fertilisers. To date, DG SANTE has only requested an EFSA Opinion (European Food Safety Agency) on those animal by-products which are already authorised for use as fertilisers (subject to certain constraints) under the Animal By-Product Regulation 142/2011. This mandate not given to EFSA until May 2020, whereas animal by-products were already an empty box in the EU Fertilising Products Regulation since March 2016 – see ESPP eNews n°50. DG SANTE indicated that EFSA has space to assess (for use in CE-Mark fertilisers) other recycled nutrient products derived from animal by-products, and suggested that industry submit dossiers to EFSA, via Member States. If your company produces a fertilising product from animal by-products, which you wish to be eligible for the CE Mark (under the EU Fertilising Products Regulation), please contact ESPP to discuss possibly preparing a dossier.

Call for input: recycling nutrients into animal feeds

The above meeting with EC DG SANTE also concluded that the current regulatory obstacles to recycling of secondary nutrients into animal feeds should be addressed. The EU Animal Feed Regulation 767/2009 (art. 6(1) and Annex III $1 and $5) currently excludes materials derived from manure "irrespective of any form of treatment" or from municipal or industrial wastewater "irrespective of any further processing". This means that recovering commodity chemicals (e.g. phosphoric acid) from such secondary nutrients is problematic, in that it could be considered that these should only be sold subject to traceability and labelling "not to be used in animal feeds". It was agreed that ESPP should collate short dossiers from companies operating such recovery processes, summarising possible secondary nutrient inputs, final products, process, contaminants, safety and potential market. The European Commission will then consider possible approaches to this problem. Please contact ESPP if your company wishes to provide input to this.

EU policy for algae

ESPP made input to the public consultation (closed 18th January 2021) on development of an EU policy for the algae sector. ESPP underlined that the proposed Roadmap did not actively address actively address the important potential for recycling of secondary nutrients and CO2 to feed algae (Circular Economy), that is combining algal production with wastewater and/or offgas cleaning. Algae production is already used full scale to treat municipal wastewaters, in particular for nutrient removal, thus recycling secondary nutrients to feed the algal production and enabling nutrient recovery. Algae can also be used to treat other wastewaters, including digestate. ESPP underlined that use of secondary streams is the only sustainable way to supply the nutrients needed if algae are to be produced large-scale, e.g. for biofuels. ESPP's consultation input requests actions to clarify the eligibility of waste-grown algae for use under EU fertilisers and animal feed regulations, subject to appropriate safety criteria, and to define safety standards for algae grown on waste streams.

Public consultation "Blue bioeconomy - towards a strong and sustainable EU algae sector", closed 18th January 2021, contributions consultable here.

Recycled nutrients in Organic Farming

ESPP has engaged with IFOAM Organics Europe and the EU project RELACS (Replacing Contentious Inputs in Organic Farming Systems, or Improving Inputs for Organic Farming, see ESPP eNews n°33 and n°40) to identify which recycled nutrient products could be acceptable or desirable as inputs to Organic Farming. The EU Organic Farming Regulation 2018/848 specifies as a principle "*recycling of wastes and by-products of plant and animal origin as input in plant and livestock production*". The Organic Farming movement also has concerns about not using input materials which facilitate intensive farming, agronomic behaviour of recycled fertilisers, needs for different nutrients, chemicals used and LCA of recycling processes, possible contaminants. ESPP has submitted, for consideration by IFOAM and RELACS experts, twenty Fact Sheets, prepared by companies operating nutrient recycling processes, presenting product case studies different recycled nutrient products, including ash-recovered materials, struvites, biochars/pyrolysis, P, N, K, S and Fe materials.

EU consultation on Soil Strategy

A public consultation questionnaire is open on the future EU Soil Strategy **to 28 April 2021**. ESPP made input to the Roadmap for this consultation in December 2020. ESPP's input to the current consultation will underline the importance of nutrients and of organic carbon for soil quality and fertility, links to EU water, sewage sludge and Farm-to-Fork policies, the value of recycling of nutrients and organic carbon, and the need to reduce contaminants in secondary nutrient sources (e.g. PFAS, persistent plastics additives, veterinary pharmaceuticals).

EU public consultation questionnaire "Healthy soils – new EU soil strategy"
https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12634-New-EU-Soil-Strategy-healthy-soil-for-a-healthy-life

Nutrient stewardship and farmers

ESPP President, Ludwig Hermann, presented European phosphorus flows, phosphorus recovery possibilities and the SYSTEMIC project at a conference on "Sustainable Nutrient Supply" organised by the Government of the Austrian Federal State (Bundesland) Upper Austria, 9th December 2020, with around 100 farmers and agricultural stakeholders. The presentation addressed the overuse of nitrogen and phosphorus resources, planetary boundaries and EU water quality targets in the context of the European Green Deal and the Farm-to-Fork Strategy. The new EU Fertilising Products Regulation was summarised, and an overview of approaches and techniques for P-recovery and recycling was presented, with success stories from different countries. The presentation will be summarised in an article to be published in April 2021 in the journal "Der Pflanzenarzt", circulated to 2 500 farmers and agricultural advisors.

Conference recording: https://blickinsland.at/boden-wasser-schutz-tagung-2020/ (in German)

EU consultation : Zero Pollution Ambition

Open to 10 February 2021. See ESPP eNews n°50.

"EU Action Plan Towards a Zero Pollution Ambition for air, water and soil" HERE

EU consultation: industrial and agricultural emissions

Open to 23rd March 2021. See ESPP eNews n°50

Public consultation "IED-EPRTR-Revision-OPC-2020" https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12583-Industrial-pollution-revision-of-the-European-Pollutant-Release-and-Transfer-Register-/public-consultation

Public and specialist consultations: Sewage Sludge Use in Farming

The public consultation on the Sewage Sludge Directive is **open to 5 March 2021.** Key questions concern contaminants and nutrient and organic carbon recycling. See ESPP eNews n°50

Additionally, a **targeted stakeholder consultation** has been mandated to Trinomics, and information is being collected via specific questionnaires, from wastewater and sludge processing stakeholders, agricultural and consumer associations, academics and experts, NGOs. If you wish to input to this specialist consultation, you should contact Trinomics by email here.

Public consultation on the Sewage Sludge Directive HERE

Phosphogypsum

IFA aiming for 100% use of phosphogypsum

The International Fertilizer Association (IFA) second phosphogypsum report outlines how to achieve the objective of 100% safe and sustainable use of phosphogypsum (PG), a major by-product of phosphoric acid production from phosphate rock, which in the past has often been stacked as a waste (PG is mainly calcium sulphate, resulting from the reaction of sulphuric acid with phosphate rock). The report outlines quality protocols and regulatory trends for PG use, and presents innovative case studies and country cases. Uses, depending on PG properties, can include agriculture, road building and cement production. PG provides sulphur and calcium to soils and the report presents examples of trials carried out in partnership with science and regulators in Canada (poplar, willow, squash, potato), Russia (rice, soybean, corn, wheat, flax), Kazakhstan (cotton), Morocco (rape, barley, maize). The case of Brazil is presented, where some 10 million tonnes / year of PG are today produced. Agricultural use in the Cerrado region improves the acid soil and provides sulphur, need by soybeans. Brazil now uses all PG currently produced and has started 'mining' historic waste stacks, with the objective of depleting these in the coming 7 years or so, enabling return to farming of the land currently used for the stacks.

"Phosphogypsum Leadership Innovation Partnership", IFA, 2020. HERE.

Prayon: near 100% phosphogypsum recycling

Prayon, Engis, Belgium, is presented as a case study in the IFA document (above), as the company today recycles almost 100% of its nearly 800 000 t/y of phosphogypsum (PG) production to agriculture (8%) and construction products (production of stucco plaster by Kauf, 92%). This has been enabled by a reengineering of the production process and new purification technologies over recent decades, to generate a clean, quality PG, whilst at the same time increases P recovery rates from phosphate rock, improving phosphogypsum filtration and drying. The PG used in agriculture brings calcium and sulphur, but also retains water. This water retention property has also been shown to enable biodiversity improvement (anthrosol species).

"Phosphogypsum Leadership Innovation Partnership", IFA, 2020.

Phosagro: phosphogypsum valorisation in road building

The Russia Federal Road Agency has approved hemi-hydrate phosphogypsum (HHPG) as a roadbed material for all classes of roads. This follows R&D led by Phosagro, using both HHPG. Tests show that the pressure on soils is nearly three times lower using HHPG than with conventional granulates, because the HHPG forms a high-strength lightweight slab, spreading pressure and so reducing deformations of road surface materials. The HHPG offers high tensile strength and elasticity, performs well in marshy terrain and is resistant to deformation when frozen. Use of sand and granulates can be reduced by 45 – 75%, so reducing environmental damage from quarrying, and enabling significant cost savings. To date, some 180 000 m2 of road have been build using HHPG, with up to 11 years of road life already.

"Phosphogypsum Leadership Innovation Partnership", IFA, 2020.

EU Fertilising Products Regulation

Public consultation on STRUBIAS (Fertilising Products Regulation)

The final EU public consultation on the "STRUBIAS" criteria for struvite and phosphate salts, ash / ash derived materials and biochars and pyrolysis materials is **extended to 15th February 2021.** It is ESPP's understanding that this consultation is a formality, prior to official publication of the criteria. The criteria have been discussed at length in the JRC STRUBIAS group and in the EU Fertilising Products Expert Group (ESPP is a member of both). ESPP will input indicating that we support the proposed criteria, which are important for placing on the market of recycled fertilising products and for the roll-out of nutrient recycling technologies, and that the criteria proposed are the result of detailed consultation and dialogue. ESPP will underline the problem that animal by-products (including manures) cannot yet be included in STRUBIAS fertilisers, because DG SANTE has not yet engaged the process of defining Animal By-Product 'End-Points' for relevant STRUBIAS materials and has not yet submitted a mandate for this to EFSA. ESPP also regrets that sewage sludge biochars are excluded in the proposed STRUBIAS criteria and reminds of the JRC commitment to further research this question.

https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12136-Pyrolysis-and-gasification-materials-in-EU-fertilising-products
https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12162-Thermal-oxidation-materials-and-derivates-in-EU-fertilising-products
https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12163-Precipitated-phosphate-salts-and-derivates-in-EU-fertilising-products

Technical adjustments of the EU Fertilising Products Regulation

A public consultation on technical modifications to the Annexes of the EU Fertilising Products Regulation is **open to 2 March 2021.** As for the STRUBIAS annexes above, this consultation is intended to be a formality, prior to official adoption. The modifications concern traces of substances subject to limits for food and feed (limit values, labelling), clarifications concerning fertilising products which also have a plant protection effect, typologies of micronutrient fertilisers, contaminants in certain growing media, acceptance of natural, biodegradable and soluble polymers (e.g. in processing and handling additives), chelating agents, tolerance rules for labelling, fiberised plant materials, category 2 & 3 animal by products (including manures) in composts and digestates.

Public consultation open to 2 March 2021 "Fertilising products - technical update
https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12135-Technical-amendments-to-the-annexes-to-the-Fertilising-Products-Regulation

Industry joint letter on additives and REACH

ESPP coordinated late 2020 a joint letter to the European Commission, DG GROW, expressing a number of questions on interpretation, and industry concerns about practicality of implementation of the new EU Fertilising Products Regulation (FRP). The points raised concern treatment of technical additives in CMCs (Component Material Categories), unreacted processing agents, chemical reactions between additives and CMC materials, and related REACH registration requirements. We have now received a detailed and documented reply from DG GROW. For a number of the points raised, the Commission concurs that questions exist and indicates that clarification will be included in Commission interpretation guidance (FAQ: Frequently Asked

Questions document). The Commission's answer also clarifies for some aspects what actions fertilising products manufacturers need to take with their supply chain to ensure that additives respect FRP-specific REACH requirements.

European Commission "FAQ" for the Fertilising Products Regulation – note that this document is updated regularly - here.
Joint industry letter and European Commission reply here.

Research

Phos4You videos on P-recovery

The EU Interreg project Phos4You has published several short videos offering overviews of routes for phosphorus recovery from sewage recovery. An 'Overview' (1'40) summarises different routes via sludge incineration or from sewage sludge, adapted to both smaller rural or larger urban wastewater treatment plants. Recovery via sludge incineration is summarised for the EuPhoRe process (1'11), where phosphorus is retained in the sludge ash used as fertiliser, tested by Emschergenossenschaft at Dinslaken, Germany, or other processes (presented by Innovatherm, 1'18) where the phosphorus is recovered as e.g. phosphoric acid. Trials of P-recovery via micro-algae or using fishery-waste adsorbents, appropriate for smaller sewage works, are presented (Glasgow Caledonian University, Veolia FiltraflowP, 1'34)

Phos4You videos.

Science reviews on algae for wastewater treatment

A review of micro-algae in wastewater treatment from Heriot-Watt University, Edinburgh, summarises data from nearly 40 studies. These are essentially laboratory work, with only two using reactors > 1 m3. Most of these studies show, in laboratory conditions, the ability of micro-algae systems to reduce phosphorus to low levels (e.g. < 0.5 mgP/l). Technologies are discussed including algae freely suspended in water, biofilms and algae immobilised in beads. No economic data are provided. The paper concludes that "micro-algae systems incur little or no operational costs", but this ignores maintenance costs for cell immobilisation, biofilms, membranes, or inputs of light or CO2. A second review from China, summarises different micro-algae strains used, technologies (including diagrams: open ponds, photo bio reactor (PBR), membrane PBR, microalgae film, multilayer bioreactors, …). 11 studies testing with real wastewater are identified, but only one of these provides a cost estimate (0.1 US$/m3 operating costs, Sheng 2017).

"Integrating micro-algae into wastewater treatment: A review", S. Mohsenpour et al., Science of the Total Environment 752 (2021) 142168, DOI.
"Microalgae-based wastewater treatment for nutrients recovery: A review", K. Li et al., Bioresource Technology 291 (2019) 121934, DOI.

Sustainable diets are good for health

Two new studies confirm that diets which are good for the environment are also good for health.

Jarmul et al. reviewed literature on the environmental footprint of 'sustainable' diets, finding 18 studies (412 data points), covering 12 diet patterns, 7 health endpoints and 6 environmental endpoints. For nearly 90% of data points, sustainable diets showed positive health effects. Sustainable diets showed on average -25% lower greenhouse emissions (-70% lower for vegan diets), but water use (often) and land use (sometimes) were higher for sustainable diets, compared to baseline diets. Phosphorus use was generally estimated to be slightly lower (often reduction less than -10%) for sustainable diets, with nitrogen use showing somewhat larger reductions.

Scheelbeek et al. 2020 analysed real data from 557 722 participants for health outcomes and 5747 participants for environmental footprints from three UK cohort studies (EPIC, Biobank, NDNS), concluding that less than 0.1% adhere to all nine UK Eat Well Guide (EWG) recommendations, but 31% adhere to at least five of these recommendations. Health outcomes were recorded after 3 – 20 year follow-up, and showed 7% reduction in mortality for intermediate/high (compared to low) adherence to EWG recommendations. Environmental footprint was calculated from detailed food data from the participants, and showed that adherence to recommendations led to - 1.5 kg CO2eq/day and - 23 l water use/day.

"Climate change mitigation through dietary change: a systematic review of empirical and modelling studies on the environmental footprints and health effects of 'sustainable diets' ", S. Jarmul et al. 2020 Environ. Res. Lett. 15 123014 DOI.
"Health impacts and environmental footprints of diets that meet the Eatwell Guide recommendations: analyses of multiple UK studies", P. Scheelbeek et al., BMJ Open 2020;10:e037554 DOI.

Crab shell waste tested for P-removal from sewage effluent

Within the Phos4You Project (INTERREG VB North-West Europe), Veolia (with the FILTRAFLO^{TM}-P system) and the Environmental Research Institute (North Highland College, UHI, Scotland) are testing processed crab shell waste as a phosphorus adsorbent for tertiary phosphate removal from sewage effluent. Similar approaches have been used previously with other shell and shellfish wastes as P-adsorbents, often after thermal treatment (calcination and sanitisation), including oyster shells (SCOPE Newsletter n°84), mussel shells (SCOPE 89), snail shells (SCOPE 101) and brine-shrimp shells (SCOPE 119).

In this case, the crab shell/carapace (brown crab *Cancer pagurus)* is washed, dried, milled, then treated with potassium hydroxide to generate a stable, easy to handle, granular material (non-respirable), rich in chitosan and calcium carbonate (see

Pap et al. 2020a and 2020b). The material was tested at the Scottish Water Horizons' Development Centre at Bo'ness (operational WWTP), Scotland, operating a pilot-scale reactor (inflow 200 litres/hour, using between 15-20 kg of adsorbent material) for six weeks (four separate trials) as a tertiary treatment option (on secondary treated discharge). Quality assessment of the saturated adsorbent demonstrated c. 8% organic carbon content dw (total carbon c. 15% dw, part is inorganic) and a 1.1 – 1.3% P dw content, as well as other agronomically valuable components such as potassium (partly from the KOH), calcium, magnesium and chitin/chitosan, with very low heavy metal and organic pollutant levels and no target bacterial pathogens. Future work will involve pot (and/or field) plant growth trials to observe P uptake/availability (starting spring 2021).

FILTRAFLO™-P crab carapace-based P-adsorbent https://www.nweurope.eu/media/12161/phos4you_p-rich_biomass_en_nov2020.pdf

Calcined fish bones as fertiliser

Trials show that fish bones calcined at 300°C – 900°C are an effective fertiliser. The fish bones were from Round Sardinella (*Sardinella aurita*) collected from women filleting fish in the port of Saint Louis, Senegal, and were manually separated from offal and heads, then washed and scraped to remove organic tissue. They were then calcined at 300°C, 600°C or 900°C. The lower temperature calcination material contained organic products from collagen and fatty acids, and poorly crystalline hydroxyapatite (HAP), whereas 600°C and 900°C materials showed negligible organics and more crystalline HAP/TCP (tri calcium phosphate). The samples were tested for impact on germination and initial growth of Garden Cress (*Lepidum sativum*), all showing positive impacts in particular the 900°C material. They were then tested for fertiliser effect in 3-week pot trials with maize (*Zea mays*), soil pH 6.7. All three samples showed fertiliser effect (compared to control – no comparison was made to commercial fertiliser) but surprisingly the more crystalline 900°C calcined material (with lower solubility) showed higher maize biomass growth. The authors suggest that this may be because of the 'biostimulant' effect, as shown on the Cress. A previous paper by the same authors showed biostimulant effects on maize of nano-hydroxyapatite functionalised with humic substances, improving early growth, productivity (3 months), rhizosphere bacteria and salt stress resistance.

"Thermal conversion of fish bones into fertilizers and biostimulants for plant growth – A low tech valorization process for the development of circular economy in least developed countries", F. Carella, A. Adamiano et al., J. Environmental Chemical Engineering 9 (2021) 104815, DOI.
"Synergistic Release of Crop Nutrients and Stimulants from Hydroxyapatite Nanoparticles Functionalized with Humic Substances: Toward a Multifunctional Nanofertilizer", H. Y. Yoon, A. Adamiano et al., ACS Omega 2020, 5, 6598−6610, DOI.

Possible significance of phosphine in global P cycles

A review of available information on phosphine (PH3) suggests that this form of phosphorus may be significant in global P cycles, in waste management and in links to climate change, but concludes that data is today insufficient to reach conclusions. Phosphine is a reactive gas which competes with methane and other reactive gases for hydroxyl radicals in the atmosphere, so prolonging their greenhouse impact. It is oxidised in air to phosphoric acid or phosphate ions, which may contribute to cloud formation, also impacting climate. It is estimated that around 40 000 t/y of phosphine is released to the atmosphere, representing around 10% of airborne phosphorus (to put into perspective: estimates suggest atmospheric deposition of P to the Mediterranean Sea is around half of that from rivers and coastal cities, see ESPP eNews n°43). Phosphine concentrations have been shown to be significantly higher in urban areas, and emissions can be related to anaerobic conditions (paddy fields, manure management, sewage treatment). Phosphate can be reduced to phosphine in redox conditions below -300mV. In specific conditions, up to nearly 20% of P removed from sewage in an oxygen limited membrane reactor was released as phosphine, and the authors suggest that this may be a possible route for P-recovery.

"Global phosphorus dynamics in terms of phosphine", W. Fu & W. Zhang, Climate and Atmospheric Science (2020) 3:51 ; https://doi.org/10.1038/s41612-020-00154-7

Study suggests healthier diets increases dietary P intake

A study based on the McCance & Widdowson Composition of Foods Database, suggests that today's average UK (meat-eater) diet has P intake of 1.35 gP/day, has decreased since the 1940s (it was around 1.6 gP/person/day in the 1950's), but could increase if people start to adopt more vegetable intensive diets. Today's average P intake is significantly lower than a vegetarian (1.53 gP/d = +13%), vegan (1.63 gP/d = +20%) or the proposed EAT-Lancet sustainable diet, see ESPP eNews n°48 (1.85 = +37%). Comparison of the Foods Database to data from UK food surveys suggests that the % of diet P coming from processed (as opposed to fresh foods) has increased from around 20% in the 1940's to over 50% in 2016, corresponding to a general increase in consumption of processed foods. The % of diet P in animal products (meat, dairy, eggs, fish) increased from around 48% in 1942 to 59% in 1973 and then decreased back to c. 50% by 2016.

The authors found close agreement between the P load entering sewage work, calculated from detailed Environment Agency data, and the dietary P burden calculated from the diet surveys after accounting for estimated industry contributions.

Increased P intake with future sustainable diets and population growth would result in increased P in the inflow of many sewage works. The authors state that this could result in "greater non-compliance with regulatory targets for P discharge" assuming current treatment levels and if treatment efficiency (% P removed) stays constant as inflow P load increases. The view of ESPP, however, is that that for sewage works with a P-discharge consent, increased inflow P will generally not result in increased P discharge, because discharge is managed to respect the consent level (see Evans 2007), although it may result in increased treatment costs (increased chemical dosing, increased biosolids production). It would also result in increased P inputs to the environment in storm overflows. Some large UK sewage works do not today have a P discharge consent, because they do not discharge into eutrophication sensitive* waters. Around 3% of the UK population are not connected to sewerage and a further c. 3% are connected to small sewage works not subject to P discharge consents (figures taken from the study supplementary information p.3). Additionally, not considered in this study, around 3% of sewage is lost in exfiltration from sewage pipes before reaching the sewage works (from Gilmour et al. 2004). That is, in total maybe 10% of sewage is not entering sewage works with P discharge consents, and for this part increased sewage P levels will partly reach the environment and have environmental impacts.

The authors conclude planning and investment should take into account possible increases in P entering sewage works with healthier diets, in order to maximise recovery and recycling of this phosphorus.

"Plant-based diets add to the wastewater phosphorus burden, K. Forber et al., Environ. Res. Lett. 15 (2020) 094018 https://doi.org/10.1088/1748-9326/ab9271
** the EU Waste Water Treatment Directive 91/271/EEC defines (Annex II) Sensitive Areas as waters which are "eutrophic or which in the near future may become eutrophic if protective action is not taken".*

Organic Farming can only feed the world with food system changes

A food system analysis of global agriculture suggests that a complete conversion to Organic Farming would require a "huge" increase in land use (> +30%) if other changes in the food system are not made, in particular reductions in food waste and in consumption of animal products. Only 20% conversion to Organic Farming would be possible without increasing land use by more than 5%, without other food system changes. Impact on phosphorus surplus is considered negligible, whereas nitrogen surplus would be completely avoided. However, it is noted that nitrogen supply for Organic Farming is a challenge, which previous authors conclude could only be met if cropping intensities were increased and fallow land and intercropping were to be systematically used for legume production, which may not be possible because of e.g. water supply and feasibility of legume production in intercropping in some regions (see Badgley C et al., 2007, Connor D. et al. 2008 and 2013).

"Strategies for feeding the world more sustainably with organic agriculture", A. Muller et al., Nature Comunications, 8, 1290, 2017, DOI.

Calcium phosphate citrate nanoparticles effective in targeting cancer tumours

Tests on mice suggest that phosphate nanoparticles can reduce cancer tumours. A colloid of mesoporous amorphous nanoparticles with a very high surface area (Brunauer-Emmett-Teller > 900 m2/g) was produced by reacting Ca, P and citric acid at a ratio of 5:3:5. The particles were then coated in lipid or casein. These particles are non-toxic and release non-toxic molecules if broken down in the body, but can selectively kill cancer cells. The cancer cells take in the nanoparticles, leading to high intracellular levels of calcium and citrate which kills them. In vivo tests confirmed that the coated particles strongly decreased the viability of cancer cell lines, at concentrations down to 30 µg/l, but did not significantly reduce normal cell viability at up to 100 µg/l. Tests with mice showed that the particles reduced the size of two different aggressive pleural tumours by 40% and 70% after two applications, whereas up to eight applications showed no other adverse effects.

"Synergistic Combination of Calcium and Citrate in Mesoporous Nanoparticles Targets Pleural Tumors", C. von Shirnding et al., Chem 7, 1–15, 2020 DOI.

How not to do Life Cycle Analysis

A paper in Science of the Total Environment by Golroudbary et al. claims in its conclusions that "phosphorus recycling is not a sustainable solution in a longer perspective". The paper claims to compare energy consumption and greenhouse gas emissions for P-recycling with those from phosphate rock mining and mineral fertiliser production. However, the authors seem to misuse data not relevant for P-recycling, and their conclusions are based on an inappropriate LCA allocation of all sewage works emissions to P-recovery, ignoring the fact that the principal function and obligation of the sewage works is to treat sewage.

LCA allocation factors are not mentioned in the paper, whereas a completely inappropriate 100% allocation factor is given to recovered P, zero to N, zero to clean water.

The authors base their analysis of energy demand for P-recycling on only a few papers, in particular Sanders 2003 (pig manure), Ye 2019 (wastewater, no quantitative data on energy or chemicals use), Piippo 2018 (wastewater, comparison of GHG emissions from different sewage sludge treatment routes in Northern Finland), Spångberg 2014 (wastewater, see below) and Buratti 2015 (solid waste).

They conclude that "70% of the GHG emissions from P-recycling is caused by wastewater processing". This claims to be confirmed in the paper's supplementary information, where "Energy requirements for wastewater recycling" are indicated as "179 MJ/0.15 kgP" taken from Spångberg 2014. In Spångberg, it is clear that this energy consumption (179 MJ) is for removing both 1.21 kgN and 0.15 kgP in a sewage works operating chemical P removal, not for removing phosphorus only, and not for recycling these nutrients. Attributing this number only to phosphorus recovery is therefore incorrect. Furthermore, and fundamentally, as the authors themselves point out, sewage treatment and phosphorus removal are in any case necessary for environmental protection. The conclusions comparing energy consumption and GHG emissions for P-recycling from sewage to phosphate rock mining and mineral fertiliser production are thus based on a false starting point.

The use of Sanders 2003 is equally inappropriate. This paper considers the overall LCA of several options for management of pig-manure, mostly assessing nitrogen not phosphorus. Use of this data to draw conclusions concerning emissions related to P-recycling is again incorrect, in that the manure must be managed in any case.

Buratti 2015, used for "solid waste", is also not appropriate. This paper compares composting of food waste to production of chemical fertilisers for the same nutrient value, but again is not relevant for assessing emissions related to P-recycling because the treatment of the food waste is necessary in any case.

The Golroudbary paper is illustrative in several ways: 17 pages of mathematic formulae will not lead to useful results if inappropriate data and system allocations are used; life cycle analyses can be made to say different things depending how the 'Functional Unit' and 'Boundaries' are defined and how emissions are "allocated" to different functions; "peer reviewed" does not mean scientifically meaningful.

Note that the above is not in any way a criticism of the different papers cited by Golroudbary. These papers are respectable studies, which do what they claim to do, and their authors obviously cannot be held responsible for their subsequent misuse.

"Environmental sustainability of phosphorus recycling from wastewater, manure and solid wastes", Science of the Total Environment 672 (2019) 515–524 https://doi.org/10.1016/j.scitotenv.2019.03.439

Stricter nutrient thresholds needed for rivers

An assessment (1) based on nearly 1 000 samples comparing vegetation samples in rivers to nutrient concentrations in the Central-Baltic Region of Europe (Belgium, Denmark, Estonia, France, Germany, Latvia, Lithuania, Luuxembourg, the Netherlands, Poland) suggests that nutrient thresholds currently set by some countries are too high to achieve Good Ecological Status (as defined by the EU Water Framework Directive 2000/60/EC = WFD). The authors, led by the European Commission JRC Ispra, looked at both macrophytes (plants) and phytobenthos (bottom vegetation, algae and plants), concluding that both should be considered, compared to soluble reactive phosphorus (SRP), total phosphorus (TP) and total nitrogen (TN). They compared nutrient levels to EQRs (Ecological Quality Ratios), that is ratios between observed data for macrophytes and phytobenthos and expected 'reference' conditions (natural state in the water body), with assessment using the methods defined by each country in WFD intercalibration, e.g. density, species or taxon variety. They conclude that thresholds for Good Ecological Quality range from 30 - 90 µg/SRP/l and 1.0 – 3.5 mgTN/l, varying with river size, altitude and alkalinity. These are In some cases lower that the boundaries set by Member States which range from 70 to 130 µgSRP/l and 2.3 – 10.0 mgTN/l.

A previous paper (2), led by the same authors at EU JRC Ispra, highlights the wide variety of different nutrient criteria used by EU Member States for quality status assessment under the Water Framework Directive, concluding that in some cases inappropriate criteria may be hindering achievement of good status. Different nutrients (N or P) are used for different water categories, whereas recent research shows that co-limitation is not uncommon. Difference in methods (soluble or total N or P, season of assessment, metrics) mean that thresholds are not comparable. Nutrient criteria are in some cases not clearly related to biological response, and so good ecological status. Criteria fixed by expert judgement tend to be higher (less demanding) than those based on data and modelling. Some countries are using thresholds "significantly above" known limiting nutrient concentrations, or even criteria taken from drinking water standards, which are not intended for this purpose.

(1) "Estimating river nutrient concentrations consistent with good ecological condition: More stringent nutrient thresholds needed Ecological Indicators", S. Poikane (EU JRC Ispra) et al., 121 (2021) 107017 https://doi.org/10.1016/j.ecolind.2020.107017

(2) "Nutrient criteria for surface waters under the European Water Framework Directive: Current state-of-the-art, challenges and future outlook", S. Poikane et al., Science of the Total Environment 695 (2019) 133888, https://doi.org/10.1016/j.scitotenv.2019.133888
See also: "Deriving nutrient criteria to support 'good' ecological status in European lakes: An empirically based approach to linking ecology and management", S. Poikane et al., Science of the Total Environment 650 (2019) 2074–2084, https://doi.org/10.1016/j.scitotenv.2018.09.350

Urban nitrogen budgets overview

An interesting analysis of different approaches to nitrogen flow and stock studies for urban areas. Over 60 studies are referenced and information drawn from around twenty of these is outlined and discussed. Nitrogen budget studies in the past have looked at soil systems, at water (river transported N comparing upstream and downstream of a city), atmospheric emissions, human and animal food chain, waste and wastewater treatment. Several studies note that nitrogen fertilisers are often used at very high rates in urban areas, both on lawns and in small farms on crops such as vegetables. Little data was found on nitrogen flows and losses in solid waste treatment. Wastewater treatment showed more significant nitrogen emissions (N2O, ammonia) both to air and to water and often low levels of nitrogen recycling.

Svirejeva-Hopkins, looking at Paris, suggested that the largest N flow was in human food, with around half of this N being finally converted to N2 in wastewater treatment, but the largest environmental impact was from fossil fuel burning, in particular traffic.

Studies, such as L. Baker 2001, suggesting accumulation of N stocks in cities may be flawed.

Several studies for Beijing (Zhang 2016, 2018, 2020) show that total N flows have increased slowly (+1% per year 1996-2012, with N input to farmland and animal feed falling considerably but transport emissions increasing strongly.

Overall, nitrogen recycling rates tend to be very low, e.g. 7% for Bangkok (Faerge 2001). The authors note the difficulty to compare studies, because methodologies differ, and the need to engage with experts beyond scientists to assess relevant flows and processes.

"Urban nitrogen budgets: flows and stock changes of potentially polluting nitrogen compounds in cities and their surroundings – a review", W. Winiwater et al., J Integrative Env Sciences, vol. 17, n°1, 57-71, 2020 DOI.

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