ESPC4 and PERM

European Sustainable Phosphorus Conference (ESPC4)

20-22 June 2022, Vienna, Austria - and hybrid

Full programmes and speakers are now online for both ESPC4 (4th European Sustainable Phosphorus Conference) and PERM (Phosphorus Research in Europe Meeting), plus site visit and young researchers networking event. A few places are still available for "new" presentations – email us urgently. Over 130 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 both onsite in Vienna and between physical participants and online participants. Register now. Capacity in Vienna is limited to 300.

https://phosphorusplatform.eu/espc4

EU consultations

EU consultation on nutrient management

Open to 26th April 2022. Public consultation on INMAP, the new EU Integrated Nutrient Management Action Plan. ESPP regrets that the proposal largely ignores diet, nutrient recycling, food security and agricultural policy (CAP). The new Plan aims to achieve the objective fixed by the Green Deal to reduce nutrient losses by 50% without deteriorating soil fertility. The European Commission document underlines that nitrogen and phosphorus exceed 'Planetary Boundaries' by 3.3x and 2x and that the latest Nitrates Directive implementation report shows that over 30% of both rivers and lakes and over 80% of marine waters are eutrophic. It is underlined that phosphorus (under the term "Phosphate Rock") is on the EU Critical Raw Materials list and that the environmental costs of nitrogen pollution are 70 – 320 billion €/year (from Sutton et al. 2011 - the costs of phosphorus losses are not estimated). The European Commission's proposed outline for INMAP centres on reducing nutrient losses, to both water and air (for N), including monitoring losses and targeting "nutrient pollution hotspots".

Despite referring to the Circular Economy Action Plan in the introduction, nutrient use efficiency and nutrient recycling are not emphasised and diet is not cited in the proposed INMAP outline. Food security is identified as a challenge in the consultation summary webpage, but is absent from the proposed INMAP outline. ESPP input will suggest that dietary change is the key driver of fertiliser use, of livestock production and of nutrient pollution, as well as of food security, and that developing nutrient recovery and recycling is central to both reducing nutrient losses (N and P losses to water, ammonia air pollution and nitrogen oxides climate emissions) and to reducing dependency on imported phosphate rock and phosphate fertilisers and imported natural gas (for nitrogen fertiliser production). The proposed INMAP outline suggests that Member States should focus on synergies between nutrient pollution reduction and CAP (common agricultural policy) but seems to imply that no modification of CAP is required to improve nutrient management. The outline indicates that INMAP initiatives may include revising legislation if necessary, but does not make proposals to enable funding of nutrient recycling and improved nutrient management, such as confirmation of the inclusion of phosphorus recycling in the EU Taxonomy for green investment funding (see ESPP eNews n°58 and n°59) or extension of carbon credits to saving nitrogen greenhouse gases.

*EU public consultation, open to individuals, companies, stakeholder organisations, **to 26th April 2022** (4000 character free text input, plus possibility to upload a position paper or document). "Nutrients – action plan for better management" (Integrated Nutrient Management Action Plan, INMAP) here ESPP's initial input to the INMAP preparation process, 27_3_2021 is here http://www.phosphorusplatform.eu/regulatory*

EU public consultation: microplastics

Open to 17 May 2022. General public and specialist questionnaire invites opinions on the risks from microplastics, possible regulatory action, willingness to pay more for products with lower microplastics release. Specialist section addresses pellets, tyres, textiles, detergent capsules. Amongst possible actions suggested are "Specific waste water treatments in urban waste water treatment plants" but it is not explained what such treatments might be.

EU public consultation, open to 17 May 2022 "Microplastics pollution – measures to reduce its impact on the environment" HERE.

EU public consultation: mercury

Open to 3 May 2022. Consultation questions whether mercury should be banned in dental fillings and emissions from crematoria limited. Both actions would significantly reduce mercury levels in sewage and biosolids. Further details in ESPP eNews n°64.

EU public consultation, open to 3 May 2022 "Mercury – review of EU law" HERE.

EU Fertilising Products Regulation (FPR)

Status of Fertilising Products Regulation amendments

To date, a "consolidated" version of the Fertilising Products Regulation including amendments is not yet available.

Initial Fertilising Products Regulation (Regulation 2019/1009)	Published Official Journal 25/6/2019	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R1009
STRUBIAS (struvite, biochars and ashes): CMC12 "Precipitated phosphate salts & derivates" CMC13 "Thermal oxidation materials and derivates" CMC14 "Pyrolysis and gasification materials"	Published Official Journal 30/11/2021	https://eur-lex.europa.eu/eli/reg/2019/1009
Technical amendments	Published Official Journal 8/10/2021	
Corrigendum	Published Official Journal 10/3/2022	
CMC11 By-Products	Finalised text adopted by European Commission, March 2022. Now in mandatory 3-month Council – Parliament "objection" period. Publication in Official Journal expected July 2022.	See under "Commission adoption": Here and Here
CMC15 "Recovered high purity materials" (includes nitrogen recovery from off-gases)		
Technical amendments, including post-processing of digestates	Text finalised, now pending formal European Commission adoption, then translation, "objection" period. Publication in Official Journal expected late Summer 2022.	Temporary link on CIRCAB here
Frequently Asked Questions (FAQ)	Non-regulatory Commission 'guidance' document.	Regularly updated here.

Post-processing of digestates and of other fertilising products

Input is needed on the list of examples of processes applied to digestates, before use as fertilising products: send to ESPP before 27th April. The amendment, requested by ESPP and EBA, to clarify that "post-processing" of digestates is allowed under the EU Fertilising Products Regulation has been finalised, and authorises the following: solid-liquid separation, ammonium and/or phosphate removal (for recovery), removal of water, additives necessary for these processes. Currently, the European Commission is preparing a list of examples of such processes to include in a future update of the FPR FAQ (Frequently Asked Questions guidance document). Based on the draft proposed text from the European Commission, ESPP proposes the following list of examples – to which **your comments are welcome to ESPP before 27th April**:

- mechanical separation of the solid/liquid fraction: filtration, ultra-, nano- or other-membrane filtration, including under pressure or vacuum; gravitational separation, such as settling or flotation (including air bubble flotation, centrifuge).

- recovery of nitrogen or phosphorus: ammonia stripping (e.g. by increasing pH by adding e.g. caustic soda, bubbling air through the digestate, increasing the temperature, decreasing the pressure (vacuum), gas membrane separation …) followed by nitrogen recovery; adsorption / ion-exchange; precipitation.

- dewatering: drying by standing, atmospheric drying, using air or hot air, or by using solar radiation, belt dryers, push-turn, fluid bed, and drum dryers, …. ; freeze drying; concentration of the liquid fraction; reverse osmosis and membrane concentration; vacuum evaporation.

All such processes are allowed provided that they lead only to the changes inherent to mechanical separation, nutrient recovery or dewatering, without the intention to otherwise chemically modify the digestate or the fraction.

Such **post-processing is NOT authorised for composts, biochars, food industry by-products or other CMCs** under the Regulation (except in specific cases: CMC1 de facto, CMC2 limited list of processes, CMC7 drying & freeze drying only, CMC12 and CMC13 chemical derivates). In particular, drying / concentration, solid-liquid separation, filtration, nano- or membrane-filtration and reverse osmosis, granulation, compacting, sieving, grinding or pasteurisation would appear to be not possible for most CMCs. Dilution with water would seem to be possible, in that the water is simply a separate CMC (CMC1). An ESPP suggestion to resolve this by amending Annex II to authorise post-processing (without the intention to chemically modify) for all CMCs was taken up by the European Commission and discussed at the EU Fertilisers Experts Group but not finalised, due to requests from Member States and stakeholders for more time to examine the text in detail.

FPR consultation on new CMCs and biostimulants microorganisms planned

At the EU Fertilisers Expert Group 4-5 April 2022 (ESPP is a Member), the European Commission confirmed that a public consultation is planned on secondary materials which are excluded from current CMCs, in order to identify possible future amendments of existing CMCs or materials for which a study of market potential, agronomic value and safety could be appropriate, and to collect relevant data. It is proposed that this consultation will also cover proposed additions to the list of microorganisms eligible for use as biostimulants (CMC7), that is microorganisms which stimulate plant nutrition processes, so improving fertiliser use efficiency. This list currently only includes Azotobacter, Mycrorrhizal fungi, Rhizobium and Azospirillum.

EBIC (European Biostimulants Industry Council) published a detailed position paper (31st March 2022) expressing concern that **CMC7 only allows four genera of biostimulants microorganism, thus blocking both access to the market of microorganism biostimulants which have already proven their potential, and preventing future innovation to improve fertiliser use efficiency**. The EBIC position paper presents sixty microorganisms shown to have plant stimulant effects.

Input is welcome to ESPP on proposed new CMCs *or recycled nutrient materials which are excluded from current Fertilising Products Regulation CMCs. ESPP maintains a working list of such materials, with summary details, here: http://www.phosphorusplatform.eu/regulatory*
EBIC position paper and proposals on microbial biostimulants for CMC7 "The Fertilising Products Regulation should allow microbial plant biostimulants to access the EU market in a way that fosters innovation" (12 pages), 31st March 2022 here

No real progress (again) on Animal By-Products (ABPs)

The EU Fertilisers Expert Group 4-5 April 2022 yet again came up against no real progress from DG SANTE on integrating animal by products into the EU Fertilising Products Regulation. **Compost and digestate, biochar or ash from manure or other animal by-products, as well as identified animal by-products which are today widely used and recognised as safe in Member States, will thus be excluded from CE-mark fertilisers when the Fertilising Products Regulation enters into force in July this year** (e.g. bone meal, feather meal, discarded animal feed or petfood materials …). Questions from Member States and stakeholders were met with effectively no answer from DG SANTE. ESPP criticised DG SANTE's slow proceedings, reminding that the regulatory proposal for the Fertilising Products Regulation, in March 2016, included full detail for all CMCs, and further CMCs have already been finalised by DG GROW and added since then (three STRUBIAS materials, by-products CMC11, recovered ammonia from off-gas and other recovered minerals CMC15), whereas in 2016, for animal by-products, DG SANTE had prepared an empty box (literally) for CMC10. The European Parliament and Council therefore wrote into the Regulation art. 46 that the Commission must initiate assessment of ABPs for inclusion into the Regulation by latest 15th January 2020. DG SANTE's mandate to EFSA for an Opinion was not issued until 30th April 2020. To the 4-5 April 2022 meeting, DG SANTE indicated that two meetings are now planned in late April and May, then public consultation, then adoption into the Fertilising Products Regulation "before the end of 2022" and that work is underway to include into the Regulation three types of animal by-product (and derived product): composts and digestates (of ABPs, such as manure), protein materials, and the list of materials assessed by EFSA (see detailed summary of EFSA Opinion of 30/10/2021 in ESPP eNews n°61). No information was provided on what is on the agenda of these two meetings and has not presented any proposes for criteria, nor for selection of materials, nor for regulatory mechanism ….

EBIC, ESPP and a total of 11 organisations published an open letter on 27th March 2022, to DG SANTE, underlining that manure is a major input material for anaerobic digestion and represents the largest potential for increasing the circular use of nutrients, but will be completely excluded from CE-mark fertilisers in July 2022 (including, manure composts and manure digestates are excluded). The letter notes that animal by-products are already used as fertilisers in Member States under national fertiliser regulations, conform to the Animal By-Product Regulation 1069/2009, with a long history of safe use. For example, in 2018 (the latest official data available), 62,468 controls were conducted in Italy, with only nine cases requiring further investigation for pathogens, and all nine cases were finally determined to be negative for contamination.

Summary of EFSA Opinion of 30/10/2021 in ESPP eNews n°61
EBIC – ESPP – AFAIA – Federchimica Assofertilizzanti, EBA, ECB, ECOFI, Eurofema, Growing Media Europe, Agrar, Unifa joint letter 27th March 2022 www.phosphorusplatform.eu/regulatory

Proposed EU Standards for analysis methods for STRUBIAS materials

Comments are invited to 30th April on a draft list of new EU Standards for testing and analysis of precipitated phosphates & struvite, ash-derived fertilisers, biochars- pyrolysis & gasification materials (STRUBIAS CMCs 12-13-14). The European Commission's draft mandate to CEN for Harmonised Standards development for STRUBIAS is open for comment and proposals, concerning the proposed list of Standards to be developed, existing Standards which can be taken as basis (EU, ISO, national, other) and short description of the parameters concerned. Please send any input to ESPP (ESPP is a member of the EU Fertilisers Expert Group and can forward to the European Commission).

Draft Standards Mandate to CEN for the Fertilising Products Regulation STRUBIAS annexes (CMCs 12, 13 and 14), v 28/3/2021, ***for comments by 30th April 2022*** *available here: www.phosphorusplatform.eu/regulatory*

Policy

SYSTEMIC policy recommendations

The EU-funded Horizon 2020 project SYSTEMIC, addressing nutrient recycling from digestates, project outcome documents include a 6-page policy briefing and material fact sheets for recycled nutrients (recovered ammonium sulphate, mineral concentrate).

SYSTEMIC's policy recommendations underline the need for incentives to stimulate the market for recovered nutrients, for example through **inclusion of carbon savings from nitrogen recycling and bio-based fertilisers in greenhouse policies such as the EU Emissions Trading Scheme and in the Renewable Energy Directive**. In particular, ammonia salts recovered from the digestate have low greenhouse gas emissions during production and application and could partially replace N-fertilisers produced by Haber-Bosch. The saved carbon emissions could be credited to the biogas plant operator, or the carbon emissions from Haber Bosch should be compensated by fertiliser producers and importers by the Carbon Border Adjustment Mechanism (CBAM).

SYSTEMIC underlines the need to progress on inclusion of products derived from animal by-products (in particular from manure) in the EU Fertilising Products Regulation = FPR (see discussion of EFSA Opinion of 30/10/2021 in ESPP eNews n°61).) and requests the admission into the FPR of recovered ammonia salts from stripping (this is now finalised with CMC15) and of **nano-filtration materials**. The latter are covered by the fact sheet on "Mineral concentrate" which are defined as produced by reverse osmosis. ESPP notes that there is at present no proposal to include "Mineral concentrates" or nano-filtrates in the EU Fertilising Products Regulation, and to do so would presumably require defining an Animal By-Products End-Point and so a dossier on process parameters and sanitary safety for EFSA.

SYSTEMIC supports the proposed **RENURE** criteria, which would, if adopted, allow application above Nitrates Directive nitrogen limits of certain forms of processed manure. SYSTEMIC suggests that this would allow these materials to compete with synthetic mineral fertilisers as a nitrogen source in livestock producing regions where manure is abundantly available. SYSTEMIC asks for "harmonised implementation" for all Member States, whereas the RENURE report specifies that, to ensure environmental protection, any Nitrates Directive derogation would be subject to specific regional criteria and constraints under each Nitrates Vulnerable Zone Action Plan.

ESPP has expressed concerns about the agronomic criteria for nitrogen forms in the proposed RENURE criteria which, as published, could be passed by certain untreated manures, most liquid fractions of manure, or by raw manure spiked with 10% urea (see ESPP eNews n°47). Such materials can achieve the proposed RENURE (inorganic N/total N) and (organic carbon/total N) criteria, and 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.

ESPP letter to European Commission requesting action on mineral fertilisers recovered from manure, 10th March 2020 and reminder 27th December 2021 http://www.phosphorusplatform.eu/regulatory
SYSTEMIC project documents https://systemicproject.eu/downloads/
SYSTEMIC project website : https://systemicproject.eu
SYSTEMIC policy note for decision makers: https://systemicproject.eu/systemic-releases-final-policy-note/

Commission moves on EU End-of-Waste (EoW) for plastics & textiles - only

The European Commission has announced that EU EoW criteria will be developed only for plastics and textiles. In the JRC preparatory study, no bio-waste sourced materials were shortlisted. Despite input from ESPP and others. The absence of EU EoW criteria is an obstacle to recycling of nutrients and other materials from wastewater (see Eureau – ESPP – various stakeholder Fact Sheets on algae, fibres and polymer and mineral products recovered from wastewaters, 1st December 2021 here). Certain materials proposed by ESPP, Eureau (the European water industry federation) and other stakeholders were not considered (algae grown using waste inputs) or not addressed as suggested (minerals recovered from ashes became two categories "phosphorus" and "potassium chloride"). Critical Raw Materials were apparently not considered an important criteria (weight = 1/3, and maximum score limited to 2/3 whereas all other criteria had possible scores of 3/3). The "top 5" shortlisted waste streams identified by JRC are: plastics, textiles, rubber from tyres, construction waste (aggregates and mineral wool) and paper & cardboard. The JRC report concludes by proposing to prioritise plastics for development of EU End-of-Waste criteria, with five plastics streams: PET, polyethylene, polystyrene, polypropylene, mixed plastics. The European Commission has then announced that EoW criteria will be developed for plastics and textiles (5th April 2022).

The EU End-of-Waste status for recovered nutrients used in fertilisers is ensured by the EU Fertilising Products Regulation. **ESPP however considers that End-of-Waste (EoW) status can nonetheless be a significant obstacle to nutrient recycling**, in particular for inorganic phosphorus, nitrogen and potassium chemicals recovered from waste streams (e.g. phosphoric acid, ammonia salts) where the absence of EU EoW status can be an obstacle to placing these on the commodity chemicals market, including as 'intermediates' for fertiliser production. ESPP considers that pathogen safety is ensured for nutrient chemicals recovered from ashes, but would need demonstrating for nutrient chemicals recovered from offgas cleaning or other routes. The regulatory status of algae and aquatic plants grown using wastewaters as growing media or waste nutrients or waste CO_2 inputs remains to be clarified. ESPP will continue to pursue these questions with the European Commission.

ESPP input to the EU JRC consultation on selecting priority materials for definition of EU End-of-Waste Criteria, 10_10_2021 http://www.phosphorusplatform.eu/regulatory
Eureau - ESPP and other stakeholders Fact Sheets on secondary products from waste waters (algae, fibres and polymers, minerals), 1st December 2021.
European Commission JRC study "Scoping possible further EU-wide end-of-waste and by-product criteria", March 2022 http://dx.doi.org/10.2760/067213
European Commission announcement, 5th April 2022 "The Commission starts to develop end-of-waste criteria for plastic waste" here.

Pyrolysis & gasification materials: industry to propose EU dossiers for safe biochars

A group of companies and stakeholders will prepare a dossier specifying processing conditions to request an EFSA Opinion on safety of biochars from manures, and launch data collection on contaminants on biochars from sewage. At the webinar of biochar, pyrolysis and gasification, organised by ESPP 15th march 2022, with participant of EFSA (European Food Safety Agency), it was decided to constitute a group of companies and stakeholders who will work together to define process conditions and other specifications, then prepare and submit to EFSA a dossier on safety of such materials produced from manures or other animal by-products. This will be supported by EBI (European Biochar Industry Consortium). Data collection will also be engaged on elimination of organic contaminants (pharmaceuticals, PFAS, industrial and consumer chemicals) in different biochar process conditions.

Summary of webinar and action points are available on request from ESPP info@phosphorusplatform.eu

Research

Regeneration of Lithium Iron Phosphate (LFP) battery electrodes

In Zhang 2022, calcining with sucrose enabled recycling of $LiFePO_4$ back into battery cathode material. End-of-life batteries were disassembled and the LFP cathode plates separated. These were calcined at 300°C (1 hour), then aluminium foil material was removed, then again calcined at 600°C (20 minutes). The material was then well mixed with sucrose (9 -12%), PVDF (polyvinylidene fluoride) and NMP (N-methyl-2-pyrrolidinone) and calcined again at 500 – 750°C, then finally dried onto aluminium foil to produce cathodes. The sucrose calcination coated carbon onto the LFP particles and reduced $LiFe(PO_4)_3$ to $LiFePO_4$. The resulting LFP/C showed good performance as a battery cathode material (lithium transport, charge retention after 200 charging cycles).

In Fan 2022, extraction with sodium hydroxide recovered iron hydroxide and lithium phosphate. End-of-Life Lithium Iron Phosphate (LFP) batteries were charged then disassembled under inert gas. The shell, cathode, anode and separator were separated. The anode was leached with water, recovering LiOH solution, graphite and copper foil. The cathode was immersed in NMP solvent (N-methyl-2-pyrrolidinone) to dissolve PVDF (polyvinylidene fluoride)and so enable separation of aluminium foil. The remaining cathode material was leached with sodium hydroxide (1 mol/l, NaOH:Fe ratio 4.5), so generating a sodium phosphate solution and precipitate of iron hydroxide. The sodium phosphate solution was reacted with the lithium hydroxide solution (from the anode leaching), resulting in lithium phosphate ($LiPO_4$) precipitate and regenerated sodium hydroxide which can be reused in the process. The authors suggest that this room-temperature recycling process could be significantly cheaper than current pyrometallurgy and hydrometallurgy processes.

"Regenerated $LiFePO_4$/C for scrapped lithium iron phosphate powder batteries by pre-oxidation and reduction method"; H. Zhang et al., Ionics (2022). https://doi.org/10.1007/s11581-022-04458-x
"Room-temperature extraction of individual elements from charged spent $LiFePO_4$ batteries", M-C. Fan et al, Rare Met. (2022). https://doi.org/10.1007/s12598-021-01919-6

Algae grown in digestate as animal feed – pathogen safety & regulatory questions

The EU funded ALG-AD (Interreg) project tested microalgae grown in filtered digestate from food waste and/or manure, and found no significant pathogen risk. Questions are raised concerning the Animal By-Product Regulation and other regulatory constraints.

The project studied microalgae cultivated in liquid digestates (after centrifuge solid-liquid separation) as follows:

Origin of digestate (input materials):		Digestate output :	Digester conditions and digestate processing:	Capacity of algae system:	Algae system ran for:
Cooperl, Brittany, France	Pig manure and slaughterhouse wastes (Cat. 2 and 3 Animal By-Products)	400 000 t/y (wet weight)	Mesophilic digester conditions (38°C). Salt is added to the digestate salt at 15g/l (because the algae cultivated in this case is a saltwater species). Digestate is filtered by membrane < 0.2 µm upstream of algae cultivation (this effectively ensures sanitisation)	Volume: 2.5 m^3. Input: 46 l/day.	13 months
Langage AD, Devon, UK	Food waste	20 000 t/y (wet weight)	Mesophilic digester conditions (38°C). Digestate is filtered by membrane of 0.1 µm pore upstream of algae cultivation (this effectively ensures sanitisation)	Volume: 7 m^3 Input: 2.4 l/day.	30 months
Innolab, Oostkamp, Belgium	Food waste and biomass	160 000 t/y (wet weight)	Thermophilic digester conditions (50 °C). Digestate sanitised at 70°C for 1 hour and filtered through paper (pore 10 µm) upstream of algae cultivation.	Volume: 0.75 m^3. Input: 1.2 l/day.	24 months

Pathogen analysis was carried out in the digestate liquid fraction ("DAF" in the report, after filtration) and in the algae, by pathogen growth tests and by metagenomic DNA analysis, for *Clostridium botulinum, Clostridiodes, Mycobacterium, Campylobacter, Listeria, Yersinia* and *Salmonella*.

Results show no detected pathogens in the filtered liquid fraction of digestate from Cooperl or from Langage, nor in the harvested algae grown in these filtered digestates (except in one case, pathogens in algae cultivated in Langage digestate, but not detected in the filtered digestate), but positive results were detected for certain pathogens in both filtered digestate and cultivated algae in the Innolab digestate liquid fraction. The presence of pathogens in the Innolab digestate is surprising in that it is pasteurised post-digester before use for algae cultivation (1 hour @ 70°C). The absence of pathogens in the Cooperl and Langage digestate liquid fractions may be related to the digester operating conditions (temperature – time profile), to addition of salt to the Cooperl digestate or to membrane filtration of the digestate liquid fraction (upstream of the algae cultivation). Metagenomics (DNA) analysis shows negative or weakly positive results for the cultivated algae: pathogen DNA present but pathogens not alive. Overall, pathogens in the cultivated algae do not seem to be significantly different or lower than in the digestate used as substrate.

Even though only Cooperl was taking ABP inputs (manure), **it would have been useful to know whether or not the anaerobic digestors were operated to EU Animal By-Product (ABP) Regulation End-Point sanitisation requirements** (standard transformation parameters for biogas transformation residues as specified in Section 1 of Chapter III of Annex V to Regulation (EU) No 142/2011), in that digestate from digesters operated to such requirements should have safe levels of pathogens. This information was not available. Nevertheless, all three anaerobic digester plants confirmed compliance with national legislation for use of their digestate as fertiliser

The project concludes that pathogen levels are generally safe in algae cultivated in filtered digestate from AD plants taking manure or food waste as inputs.

The ALG-AD project considered the regulatory status of digestate-grown algae, concluding that:

- Use **in animal feed** of algae grown using manure (Cat. 2 ABP) digestate as substrate, is prohibited by the Animal By-Products Regulation 1069/2009 art. 31 and by the Animal Feed Regulation 767/2009, which prohibits the use of manure "irrespective of any form of treatment".
- **Algae species to be used as feed material must be notified if not listed** in the "Catalogue of Feed Materials" (Regulation 2017/1017 updating 68/2013) or the "Feed Materials Register". The species utilised in ALG-AD are included in these lists, so can be used, subject to appropriate safety measures.
- **Different regulations are potentially applicable** to the use of algae and algae extracts in animal feed, for different categories of animals (farmed, pets, zoo, fur animals), for feed additives, for compound feed or medicated feed. This makes any use of digestate-grown algae very complex.
- **Algae can be labelled as "Organic",** but the Regulation listing authorised inputs in Organic Farming 2021/1165 specifies that only certain "fertilisers … and nutrients" may be used for algae cultivation. This Regulation authorises the use of "Biogas digestate containing animal by-products co-digested with material of plant or animal origin …" with "Factory farming origin forbidden"

ALG-AD (Interreg) project website.and "Safety Analysis" report https://www.researchgate.net/project/ALG-AD-3

Long-term land use of sewage biosolids and antimicrobial resistance

Four decades of sewage sludge application to cropland near Malmö, Sweden, shows not to modify soil antibiotic resistance bacteria or gene levels, and does not result in levels of concern of copper or zinc. Soil was tested in a field trial plot where sewage biosolids have been applied every four years 1981 – 2017 (up to 12 t/ha dry weight per application) and a range of crops grown, before and two weeks after the 2017 biosolids application, also with comparison to application of nitrogen fertiliser. Raw, digested and stored sludge were also analysed. Analyses covered bioavailable copper and zinc (which are known to cause selection for antibiotic resistance, see Song 2017 in ESPP eNews n°54), 16 antibiotic molecules compounds metagenomics (DNA indicative of MRG and BRG = metal and biocide resistance genes), ampicillin-, tetracycline- and -resistance *E. coli* (bacterial colony cultivation). None of the tested antibiotics were found in soil prior to the 2017 biosolids amendment, showing that these pharmaceuticals were not persistent in soil. The antibiotics were found in some samples 15 days after biosolids application (and in no samples which had not received biosolids) however no significant changes in ARG - antibiotic resistance genes) were found in soils having received biosolids, neither before nor after the 2017 biosolids application. Also, bacterial cultivation also revealed no sign of antibiotic resistance related to biosolids application. Bioavailable copper and zinc levels found in biosolids amended soils were considered too low to exert antibiotic resistance selection pressure. The authors conclude that, under the conditions tested, there is no indication of risks of antibiotic resistance development in soils due to sewage biosolids application.

"Long-term application of Swedish sewage sludge on farmland does not cause clear changes in the soil bacterial resistome", C. Rutgersson et al., Environment International 137 (2020) 105339 DOI.

Review: climate change – eutrophication feedback

Review of nearly 200 scientific publications summarises how climate change enhances eutrophication and how eutrophied aquatic systems contribute to greenhouse emissions. See also SCOPE Newsletter n°137 on climate change and eutrophication. Climate change can both increase nutrient inputs to surface waters and weaken resilience to eutrophication:

- Droughts and increased temperature (which accelerates evaporation) reduce river flow and dilution, and so make water bodies more susceptible to eutrophication, especially in subtropical and Mediterranean regions.
- Increased precipitation leads to increased phosphorus loads to surface waters, e.g. +30% higher P losses to water by 2050 in temperate watersheds.
- Ash loads to water bodies, following wildfires, accentuate eutrophication problems.
- Warming can accelerate internal nutrient release in lakes, with increased decomposition of organic matter and stratification.
- Warming can decrease resilience of water bodies to eutrophication by damaging riparian vegetation and by modifying fish, invertebrate (algae grazers) and plant communities.

Eutrophication feeds back to climate change, because it leads to water browning or anoxia, causing release of carbon dioxide and methane (see SCOPE Newsletter n°135).

A number of studies are cited which show that climate warming increases cyanobacteria (blue green algae), including experimental warming trials, sediment analysis and modelling. Also, warming and eutrophication together can increase release of toxins by cyanobacteria.

The authors conclude by underlining the importance of reducing nutrient losses to surface waters, and of developing ecosystem reliance mechanisms, such as buffer vegetation and landscape connectivity with water bodies, and of maintaining and restoring biodiversity.

"Feedbacks between climate change and eutrophication: revisiting the allied attack concept and how to strike back", M. Meerhoff et al., Inland Waters, 2022, DOI.

Chronic drought reduces soil P storage

16 year field trial in natural Mediterranean forest shows that 30% reduction of rainfall resulted in significant reductions of soil microbe biomass C and N, and even greater and more chronic (less seasonal) reduction in biomass P. Previous work shows that drought – flooding alternations cause reduced P storage and increased P losses from soils (Khan in ESPP eNews n°62 and Bi in eNews n°63). This study used eight 10x15m plots in Mediterranean natural holm oak forest in Catalonia, Spain. For 16 years, half the plots received natural rainfall, the remained -30% rainfall. This reduced soil moisture by mean -15%. After 16 years, soil microbial biomass was sampled four times over the year, showing considerable reductions in microbial carbon, nitrogen and phosphorus in all four seasons, with carbon particularly reduced in summer, nitrogen particularly reduced in winter and phosphorus very considerably reduced (more than 4x reduction in winter, more than 2x reduction in summer). Microbial biomass P was sensitive to the long-term drought conditions, whereas C and N were more related to seasonal changes in water availability. The drought conditions resulted in N tending to be present in carbon-rich organic compounds, not mineralised, so less plant available, during the growing season, meaning potentially higher risks of nitrogen losses from soil.

"Seasonal drought in Mediterranean soils mainly changes microbial C and N contents whereas chronic drought mainly impairs the capacity of microbes to retain P", S. Mara˜n´on-Jim´enez et al., Soil Biology and Biochemistry 165 (2022) 108515, DOI.

Phosphorus and health

Phosphorus is essential for human health but studies continue to show that high levels of blood P are linked to heart disease, but without evidence that high food P intake is the cause, rather than body metabolism factors. Xia et al. 2022 analysis of UK data on 296 415 participants, free of prior heart disease, showed that higher levels of initial serum P (measured one time) were associated with increased risk of diagnosed aortic stenosis (narrowing of heart valve), within an average 8 year follow-up and after adjustment for cofounders, irrespective of kidney function. No association was found for serum calcium or vitamin D. The authors note that the results of this very large cohort study are coherent withy previous studies* showing a statistical link between blood phosphorus levels and risk of CVD (cardio vascular disease) and that the mechanism may be precipitation of calcium phosphate in arteries and valves.

The human body needs around 0.7gP/person/day to stay healthy US Recommended Daily Allowance). The European Food Safety Agency estimates average EU P intake in diet at c. 1.6 gP/person/day (see ESPPeNews n°34) and has fixed an Acceptable Daily Intake (ADI) of c. 2.8 gP/day.

To ESPP's understanding, there is no clear evidence today that increased P in diet leads to increased baseline blood phosphorus (fasting serum P = before breakfast in the morning). Phosphorus ingested in meals will increase serum P for up to 6 hours after the meal (e.g. Hazim 2014 and Anderson 2013 review).

** recently e.g. Lv 2021, Poudel 2020, and Cozzolino 2019 review*
"Association of serum levels of calcium phosphate and vitamin D with risk of developing aortic stenosis: the UK Biobank cohort", C. Xia et al., European Journal of Preventive Cardiology, zwac016, 2022 DOI.

High phosphorus diet does not show glucose impairment in mouse trial

A fourteen-week trial with mice showed impaired glucose tolerance and increased body fat with a high-fat diet but no such negative impacts with a high-phosphorus diet. The impacts of the high-fat diet were mitigated by exercise. The high-P diet had twice the normal diet P level, the high fat diet had five times the normal diet fat calory level. The high-fat diet mice showed significantly increased body fat and impaired glucose and insulin tolerance, whereas the high-P diet had no effect on these parameters. The high-P diet mice showed increased RER (respiratory exchange ratio = CO_2 out / O_2 in), indicative of consuming more carbohydrate than fat, after feeding, but not after fasting. Overall, the authors conclude that in this study high-P diet did not negatively impact glucose metabolism in sedentary or exercise conditions.

"Distinct Effects of High-Fat and High-Phosphate Diet on Glucose Metabolism and the Response to Voluntary Exercise in Male Mice", P. Vidal et al., Nutrients 2022, 14, 1201. https://doi.org/10.3390/nu14061201

Identifying key flows for P-stewardship action in Germany

A study of phosphorus flows in Germany identifies key points for improving the P cycle as reducing farm run-off, manure processing, phytate enzyme use in animal feed and P-recovery from slaughterhouse wastes. Such savings could on paper approximately replace all import of phosphorus into Germany which is around 300 ktP/y (around 120 ktP/y as mineral P in fertilisers or other products, around 180 ktP/y in imported food or in animal feed materials). Around 180 ktP/y is estimated to be lost annually in Germany in run-off to surface waters, mainly from agriculture and for a small amount from sewage works. The authors estimated that around 49 ktP/y can potentially be recovered and recycled from sewage sludge and 70 – 80 ktP/y from slaughterhouse wastes (animal by-products, in particular meat and bone meal ash). The authors suggest that current P losses from agriculture (180 ktP/y) could be reduced to 65 ktP/y by improved soil management, slow-release fertilisers and targeted fertiliser application, but this is an estimate not based on data or modelling. They also suggest that over 120 ktP/y could be recycled by processing manure to improve manure nutrient application and crop use, based on 90% of P in manure. This assumes that manure nutrients are today not recycled: a significant part of manure does today go back to land but often not in a place or time or form adapted to crop needs. The authors also suggest that P use efficiency of vegetable materials used to feed livestock could be increased from 40% to 80% by enzyme (phytate) and other pre-treatments (see below), so saving 65 ktP/y use in animal feed, and also reducing P content of manure. They suggest that this lower P content and more plant-available forms of phosphorus in manure will result in improved fertiliser efficiency (ESPP note: Toor & Sims suggest that manure with lower P:carbon ratio increases P losses). Overall the paper identifies as the key action points to improve phosphorus use in Germany and reduce dependency on imports: agricultural management to reduce field losses, manure processing to improve crop phosphorus use efficiency, animal feed P use efficiency and P-recovery from animal by-products.

"Closing the phosphorus cycle: Current P balance and future prospects in Germany", N. Mayer & M. Kaltschmitt, Journal of Cleaner Production 347 (2022) 131272, DOI.

Enzyme pre-conditioning of pig and poultry feed

A review on phosphorus in animal feeds suggests that phytase enzyme pre-treatment of cereal-based animal feeds, combined with acid treatment or germination, could significantly increase phosphorus use efficiency in livestock. The paper overviews the question of phosphorus in inositol phosphates (phytate) in animal feeds (see SCOPE Newsletter n°74), noting that 20% – 80% of P in seeds and cereals is in the form of phytate, which is poorly digestible for monogastrics (which include humans, pigs, poultry). The paper notes that phytase enzymes are already today widely added to livestock diets to improve gut uptake of P contained in phytate, but do not specify how effective this is in improving P uptake. In ESPP eNews n°47, Olsen reported trials showing 12% - 50% increases in feed P digestibility with addition of phytase to feed. In order to avoid loss of effectiveness of phytase enzyme resulting from breakdown or deactivation in the digestive tract, the authors suggest pre-conditioning of cereal-based livestock feeds, for example by mechanical separation of different parts of seeds or debranning, germination of seeds, treatment with phytase enzymes, chemical or temperature hydrolysis. No data is given as to relative effectiveness of enzymatic pre-treatment compared to enzyme addition in feed, whereas chemical / pH / heat treatment, with or without enzymes, can render >90% of phytate digestible.

"Review. Conditioning of Feed Material Prior to Feeding: Approaches for a Sustainable Phosphorus Utilization", N. Widderich et al., Sustainability 2022, 14, 3998, DOI.

Anaerobic digestion and pharmaceuticals in manures

Anaerobic digestion of manures showed highly variable effectiveness in degrading different pharmaceuticals and different antibiotic resistance genes (ARGs). Higher temperatures (thermophilic 55°C compared to mesophilic 35°C, 10-day bottle tests) generally resulted in significantly better removal of pharmaceuticals, but this was not always the case for ARGs. 9 out of 24 pharmaceuticals analysed were found in the poultry manure: one anthelmintic drug (i.e. against worms) and eight antibiotics, in particular fluoroquinolones and tetracyclines. 14 of the 24 pharmaceuticals analysed were found in cattle manure: 1 analgesic (painkiller), 1 anthelmintic and 12 antibiotics. The most present pharmaceutical in poultry manure and second-most in cattle manure was chlortetracycline, with concentrations in the solid fractions of manures of nearly 9 000 and nearly 1 000 µg/kg respectively. This pharmaceutical is recognised as problematic because it is widely used and has a relatively long environmental remanence. Removal in the anaerobic digestion was 40-50% at 35°C and around 80% at 55°C. Certain antibiotic resistance genes were largely removed in the digestion (e.g. qnrS) whereas levels of others were not significantly between digester input and output.

"Occurrence of veterinary drugs and resistance genes during anaerobic digestion of poultry and cattle manures", S. Zahadi et al., Science of The Total Environment, Volume 822, 20 May 2022, 153477 DOI.

Stay informed

SCOPE Newsletter: www.phosphorusplatform.eu/SCOPEnewsletter *eNews newsletter: www.phosphorusplatform.eu/eNewshome*

If you do not already receive ESPP's SCOPE Newsletter and eNews (same emailing list), subscribe at www.phosphorusplatform.eu/subscribe

LinkedIn: https://www.linkedin.com/company/european-sustainable-phosphorus-platform/

Slideshare presentations: www.slideshare.net/NutrientPlatform *Twitter: @phosphorusfacts*

ESPP members