

ESPP dates 2024		1
ESPP workshops		1
Join us: Market policy tools to support pull for recycled nutrients – 13 <sup>th</sup> March	1	
Join us: Defining targets for nutrient reuse and recycling from waste water – 14 <sup>th</sup> March	2	
Summary of ESPP workshop on Nitrates Directive and Safemanure / Renure	2	
ESPP members		3
ESPP new member: TTBS Belgium	3	
SNB announces P-recovery from ash project with SusPhos	3	
ICL commercialises first CE-mark recycled sewage sludge ash fertiliser	4	
Study concludes negligible pathogen risk in ash-recycled calcium phosphate	4	
N2-Applied plasma N-enrichment prevent methane formation in manure	4	
EU consultations and calls		5
EU public consultation on National Emission Reduction Commitments Directive (NERCD)	5	
EU public consultation on the Nitrates Directive	5	
DG Agriculture call to sign "Soil Manifesto"	5	
Policy		5
EU Fertilising Products Regulation (FPR) evaluation and interpretation	5	
Urban Waste Water Treatment Directive revision final text published	5	
Critical Raw Materials (CRM) Act adopted by European Parliament	6	
UK water industry Resource Recovery Working Group	7	
German Phosphorus Platform (DPP) regulatory proposals	7	
Federal Environment Agency joins German "Clean Phosphorus 2029" initiative	8	
ESPP founding participant of circular feed platform	8	
BlueBio Policy Brief: waste to resource	8	
Event summaries		9
Regulatory barriers to aquaculture and marine Circular Economy	9	
Fertilizers Europe Forum on Plant Nutrition	10	
Research and innovation		11
Phosphorus and nitrogen losses, climate change, impacts on Adriatic eutrophication	11	
Climate change will deteriorate eutrophication of Mediterranean river Júcar, Spain	11	
P fertilisation improves water use efficiency (WUE) in Mediterranean tree-grass system	12	
Stay informed		12
ESPP members		12

# ESPP dates 2024

- 13-14 March 2024: Brussels & online ESPP workshops on Nutrient recycling policy
  - 13<sup>th</sup> March: market policy tools to support pull for recycled nutrients (optional networking dinner)
     14<sup>th</sup> March: targets for nutrient recovery under the Urban Waste Water Treatment Directive revision
- **16-17 April 2024**: Brussels & online <u>NERM</u> Nutrients in Europe Research Meeting (with Fertimanure, Lex4Bio, Walnut, Sea2Land, Rustica)
- 8-10 October 2024: Lleida, Spain ESPC5 (5th European Sustainable Phosphorus Conference)

# **ESPP** workshops

# Join us: Market policy tools to support pull for recycled nutrients – 13<sup>th</sup> March

Identifying policy tools to support market pull for recycled nutrients, which could achieve consensus across industry and users. Speakers from waste and water industries, fertiliser industries, circular economy policy experts. Proposals to be discussed will include targets, quotas, border tariffs, recycling credits, fiscal incentives, public purchasing, labelling ... Industry and user positions can differ: The meeting aims to identify policies which could achieve consensus across recycled product producers (waste companies, recycling technology suppliers), industry and users (fertilisers industries, distributers, farmers), and to discuss ESPP proposals to submit to policy makers.

13th March Brussels & online. Registration is open www.phosphorusplatform.eu/nutrientevents2024



### Join us: Defining targets for nutrient reuse and recycling from waste water – 14<sup>th</sup> March

The proposed UWWTD revision text (art. 20) states: "The Commission is empowered to adopt delegated acts ... setting out the minimum reuse and recycling rates for phosphorus and nitrogen", see eNews n°80. This workshop will define ESPP proposals for these targets: How to define "reuse" and "recycling"? What % rate? What criteria for products ? What rates for different sizes waste water treatment works or type of sewage treatment ? ...

<u>14<sup>th</sup> March</u>: Brussels & online. Registration is open <u>www.phosphorusplatform.eu/nutrientevents2024</u> To present your ideas in Brussels 14<sup>th</sup> March, contact: <u>info@phosphorusplatform.eu</u>.

### Summary of ESPP workshop on Nitrates Directive and Safemanure / Renure

Over 100 online participants discussed evaluation of the Nitrates Directive and proposals for facilitating recycling of manure nutrients in Nitrate Vulnerable Zones. The aim was to develop ESPP input to the currently open EU <u>public consultation</u> to 8<sup>th</sup> March on the evaluation of the Nitrates Directive. The discussion showed a range of differing opinions of participants concerning the objectives of the Nitrates Directive, its implementation, changes needed, and concerning limits to use of manure-recovered nutrients:

- What is the objective of the Nitrates Directive? To reduce eutrophication of surface water ? To limit nitrates in groundwater for health reasons ? To limit concentration of livestock production and regional nutrient excesses ?
- Should the Nitrates Directive also address phosphorus ? This would add complexity and duplicate the obligation to
  engage actions to achieve water Quality Status under the Water Framework Directive. On the other hand, it would be
  coherent with addressing eutrophication, with the Green Deal / COP15 target to reduce nutrient losses by 50%, and
  phosphorus is already included in some Nitrates Directive national/regional Action Plans for Nitrate Vulnerable Zones
  (NVZs).
- How to better take into account nitrogen use efficiency in limiting manure and fertiliser application under the Directive, whilst ensuring clear and enforceable requirements ? The Directive already includes mandatory implementation of a Code of Good Agricultural Practice including farm fertiliser plans (art. 5.4, art. 4 and Annex II, in NVZs).
- Is the limit to 170 kgN/ha/year for use of manure in NVZs justified including manure in a "processed form"? This limit represents a significant obstacle to nutrient circularity, creating an unlevel playing field compared to synthetic fertilisers, and market obstacles. There is no agronomic justification for treating digestate / compost from manure differently than from that from e.g. food-waste. How to take into account the importance of returning organic carbon to soil ? Is this limit needed given that Annex III (3) of the Directive also specifies that NVZ Action Plans must limit application of all fertilisers, based on balancing crop needs and nitrogen supply ? Or is this limit somehow an 'indirect' way of limiting livestock density ?
- Under what conditions should manure-recovered nitrogen (recycled nutrient products) be exempted from this 170 kgN/ha/y limit? The JRC Renure report 2020, based on an agronomic science assessment, has not received unanimous support, and has not progressed towards implementation to date. This JRC report suggests as criteria: TOC:TN ratio ≤ 3 or a mineral N:TN ratio ≥ 90%, with such materials remaining subject to specific management and use constraints to be fixed for each NVZ. ESPP notes that these criteria penalise organic carbon input to soil, do not take account of the stability in soil of the TOC (total organic carbon), and would cover materials such as 90% raw manure spiked with 10% urea (impossible to detect by administrative control testing), some raw manures and also most liquid fractions of manures.

Given the widely ranging opinions expressed, ESPP will

- In the EU public consultation, underline that this is a consultation on the questions to be considered in an evaluation of the Nitrates Directive, not on how to modify the Directive. ESPP will suggest that evaluation questions include:
  - Should phosphorus be included into the Directive, given the impacts of agricultural phosphorus losses on eutrophication, and if so how ? Or is this unnecessary given limits to phosphorus losses implied by Water Framework Directive quality status obligations ?
  - Should the Directive be widened to cover atmospheric emissions of N pollutants N<sub>2</sub>O, NO<sub>x</sub>, ammonia (currently art. 1 limits to water pollution) ?
  - How should soil organic carbon be taken into account ?
  - Should the Directive specifically address livestock concentration and resulting regional nutrient misbalances ?
  - Need to update knowledge on eutrophication and health impacts of nitrates ?
  - How to better take into account Nitrogen Use Efficiency and organic nitrogen storage in soil ?
  - How to prevent the 170 kgN/ha/y limit from inhibiting nutrient recycling, but ensure environmental protection ?
  - The JRC Renure report proposals are scientifically justified, but are they consistent with the Nitrates Directive objectives, the need to reduce regional nutrient misbalances, the Green Deal / COP15 target to reduce nutrient loses by 50% ?



- How to better harmonise implementation, monitoring, definitions across Member States, in order to facilitate European transfer of knowledge and technologies ?
- Propose that manure-recovered nutrient products which are "Mineral Fertilisers" should be not considered manure "in a processed form" : Mineral Fertiliser: as defined in the EU Fertilising Products Regulation Annex III part II, that is < 1% organic carbon. ESPP will request a lawyer's opinion on whether the current Nitrates Directive text could be interpreted to enable this without modification of the Directive text.

Public consultation on evaluation of the EU Nitrates Directive (91/676/EEC). **Open to 8<sup>th</sup> March 2024.** <u>HERE</u> ESPP proposed consultation input, proposals on manure-recycled nutrient: <u>www.phosphorusplatform.eu/regulatory</u>

# **ESPP** members

### **ESPP** new member: TTBS Belgium



TTBS is a Belgian company focused on phosphate technology and located in Wavre (Belgium), founded by Mohamed Takhim who has over 25 years' experience as a phosphate industry process developer and industrial project manager. The objective of TTBS is to supply the phosphate market with efficient technical and business solutions. TTBS has developed a new patented process RubiPhos® for phosphate recovery, currently being pilot tested (12.5 kg/h input) with sewage sludge incineration ash, using digestion by hydrochloric or sulfuric acid. The company indicates that the technology can also be applied to other P-sources (vivianite, struvite, meal bones ashes, ...). Together with its partners, TTBS can supply a complete plug-and-play production unit for phosphoric acid and/or its salt derivatives. TTBS can install its mobile P-recovery pilot onsite, to generate data for the design and supply of an industrial full-scale P-recovery unit.

TTBS - Takhim for Technology and Business Services - https://ttbs.be - Photo TTBS 2-container mobile pilot P-recovery unit.

### SNB announces P-recovery from ash project with SusPhos



Slibverwerking Noord-Brabant (SNB, an ESPP member) has announced a contract with startup SusPhos to design and plan phosphorus recovery from sewage sludge incineration ash at Moerdijk, The Netherlands. SNB is Europe's largest sewage sludge mono-incinerator, burning 410 000 - 430 000 t/y of dewatered sewage sludge (> 90 000 t/y DM). The contract with <u>SusPhos</u>, following a European tender, aims to design a full-scale P-recovery from ash plant, establish the business plan and define cooperation with SusPhos within one year, allowing a decision on investment in a full-scale plant to then be taken. The objective is for the full-scale plant to be operational by 2027. SusPhos is presented as a robust process: sulphuric acid is reacted with the ash (similar to existing industry Single Super Phosphate type processes) then a proprietary solvent is used to extract



phosphoric acid. Purified phosphoric acid can then be stripped out of the solvent, or reacted to phosphate chemicals which can be separated from the solvent. The solvent is then recycled back to the process. The SusPhos solvent extraction leaves a residual mineral stream, containing gypsum (calcium sulphate from the sulphuric acid reaction), sand from silicates in ash, aluminium and iron. Heavy metals in the sewage sludge (copper, lead ...) are 95% removed from the phosphoric acid and immobilised in the residual mineral stream. Susphos intends that this mineral stream can be valorised in e.g. building materials. This SusPhos technology has to date been tested at pilot scale: a 25 kg/day pilot plant has been operated for over 2 years using various ashes and other phosphate rich waste streams. SNB Managing Director, Silvester Bombeeck, says "This all fits with our circular vision and mission to recover raw materials from sewage sludge".

"SNB and SusPhos join forces to recover phosphate in a circular way", 27th February 2024, HERE.

#### ICL commercialises first CE-mark recycled sewage sludge ash fertiliser

ICL Fertilizers (ESPP member), has launched the first fertiliser recovered from sewage sludge incineration ash to have obtained the CE-mark (EU Fertilising Products Regulation FPR certified). REACH declaration (EU chemicals regulation) and FPR Conformity Assessment (Module D1) were successfully completed in 2023. A first batch of over a thousand tonnes has been produced and commercialised at ICL's existing phosphate rock processing plant in Amsterdam, using ash supplied by Netherlands sewage sludge incinerators, with further production planned. The product is based on acidulation then granulation of ash, with or without other nutrients.. ICL's German production site in Ludwigshafen will also start this new process in coming months. ICL notes that the recycled fertiliser has specific characteristics different from synthetic mineral fertilisers, achieves EU FPR phosphorus crop availability criteria (>80% NAC solubility of P) and has shown good results in agronomic trials. The sewage sludge ash offers advantages over phosphate rock (no cadmium, no fluorine, no odour) but requires specific adaptations to the industrial chemistry, processes and handling, necessitating significant R&D and specific installations. Recycling is a strategic objective for ICL Fertilizers and the company now aims to progressively increase production.

https://www.icl-group.com/

#### Study concludes negligible pathogen risk in ash-recycled calcium phosphate

Assessment by the Swedish National Veterinary Authority (SVA) concludes that pathogen risk is negligible in calcium phosphates recovered from sewage sludge incineration ash by the EasyMining Ash2Phos process (ESPP member). The study assessed the risk of pathogens (probability of presence of infectious pathogens) in the recycled phosphate product, based on risk in sewage sludge and reduction of pathogen infectivity in the different processing stages: sewage treatment, sludge incineration, Ash2Phos processing (which uses sequential precipitation: acid, alkali, filtration, lime). The SVA study concludes "There is a clear scientific basis to support that no bacteria, viruses or parasites can survive the incineration step, making sewage sludge ash a safe substrate in terms of these pathogens". The study further concludes "The overall probability that phosphorus recovered from sewage sludge using the Ash2Phos process contains infectious prions was also assessed to be negligible". This results from the negligible/very low prevalence of TSE (transmissible spongiform encephalitis) in Europe and evidence that both incineration and the Ash2Phos process steps can significantly reduce prion infectivity. Knowledge gaps are noted concerning prions in sewage/sludge, inactivation of prions in incineration and effects on prions of sequential acid/alkali. The study concludes overall that, assuming operating procedures are appropriately respected, that "the probability that phosphorus recovered from sewage sludge ashes using the Ash2Phos process contains infectious animal pathogens is assessed to be negligible". Trials with chickens and pigs have shown that the Ash2Phos process contains infectious animal pathogens is assessed to be negligible". Trials with chickens and pigs have shown that the Ash2Phos recovered phosphate is digestible, safe and performs as well as commercial animal feed phosphates (see <u>ESPP eNews n°82</u>).

"Negligible risk of pathogens in our recycled phosphate", EasyMining 10<sup>th</sup> January 2024 <u>here</u> and SVA Risk Assessment Report "Assessment of the risk for pathogens in phosphorus recovered from sewage sludge ash", Sweden National Veterinary Institute, SVA report 92:2023, ISSN 1654-7098.<u>here</u>.

#### N2-Applied plasma N-enrichment prevent methane formation in manure

A three-year trial at Norwegian University of Life Sciences (NMBU) shows that the N2-Applied process prevents methane formation without accentuating NO<sub>x</sub> or ammonia emissions. The study compared methane production in four closed 2 m<sup>3</sup> tanks of manure over 70-80 days in three summers. Two tanks contained raw cattle manure (after screw press filtration) and two contained N2-Applied plasma treated manure (nitrogen enriched, NEO). The untreated manure generated 60 – 1500 gCH<sub>4</sub>/m<sup>3</sup> (cumulative after 70 days), whereas the NEO treated manure showed slight net methane uptake (0 – 0.3 gCH<sub>4</sub>/m<sup>3</sup>). Laboratory studies of methane production from manure showed that neither the pH decrease, nor the increase in nitrate or nitrite, nor combination of these, could explain the complete inhibition of methane production achieved by the N2-Applied process, suggesting that it is the elimination of methanogenic bacteria by the plasma treatment which is the key factor.

"Complete elimination of methane formation in stored livestock manure using plasma technology", M. Nyvold, P. Dörsch, 2023, DOI.



# **EU consultations and calls**

# EU public consultation on National Emission Reduction Commitments Directive (NERCD)

Consultation on EU Directive limiting emissions of ammonia, nitrogen oxides, sulphur dioxide, particulates and (non methane) volatile organic carbons (VOC). Open to 14<sup>th</sup> March. Organisations and individuals are invited to submit evidence and comments.

ESPP will underline that announced evaluation of this Directive should address recovery/recycling of nitrogen and sulphur (coherence with EU Circular Economy policy). ESPP suggests that this Directive is important in limiting emissions of the five targeted pollutant gases across Europe, and is necessary to achieve EU reduction targets, to avoid transboundary pollution and to ensure a level playing field across Europe for concerned activities. ESPP suggests that NERCD should, for coherence, also cover the climate gases N<sub>2</sub>O and methane, for which emissions can be related to NO<sub>x</sub> and NH<sub>3</sub> emissions (e.g. livestock, digestates). Coherence should be ensured with revision of the Industrial Emissions Directive, which increases emphasis on material efficiency and reuse. NERCD emissions limits should ensure protection from eutrophication of sensitive terrestrial and aquatic ecosystems (Habitats Directive, Water Framework Directive, Nitrates Directive) and also impacts on soil (proposed Directive on Soil Monitoring and Resilience) and should be supported by EU agriculture policy (CAP farm funding and CAP National Action Plans) and Nitrates Directive NVZ Action Programmes.

EU public consultation "National Emission Reduction Commitments Directive – evaluation", open to 14<sup>th</sup> March 2024, input 4000 characters plain text plus possibility to submit pdf documents <u>here</u>.

# EU public consultation on the Nitrates Directive

Consultation for evaluation of the Nitrates Directive. Open to 8th March. See ESPP eNews nº81.

"The protection of waters against pollution caused by nitrates from agricultural sources – Evaluation", public consultation preparatory to evaluation of the EU Nitrates Directive (91/676/EEC) and Call for Evidence. Input requested from the public, farmers, stakeholders. **Open to 8<sup>th</sup> March 2024.** In all EU languages. <u>HERE</u>

# DG Agriculture call to sign "Soil Manifesto"

**European Commission call for signatures for a "Soil Manifesto", recognising the need to protect and restore soils, current soil degradation, support the Soil R&D Mission objectives and commit to soil protection and awareness actions.** The Soil Manifesto was launched by the European Commission and the European Regions Research and Innovation Network (ERRIN) in April 2023, has today over 2 600 signatures, and remains open for signatures. Signatories recognise the importance of soil for food and for environmental and social functions as "the basis of our well-being", recognise that more than 60% of EU soils are in an unhealthy state and that pressure will increase with climate change, call to embed soil protection and restoration in all human activities, support the Soil R&D Mission goal to establish 100 test-demonstration sites ("living labs", "lighthouses") and commit to contribute to the protection and restoration of soil, to raise awareness and to enlarge the active community.

"The EU Mission Soil launches its Manifesto", April 2023, <u>link</u>. "Update on the Mission Soil Manifesto" European Commission, 28 February 2024, <u>here</u>. Sign the Manifesto <u>here</u>.

# Policy

# EU Fertilising Products Regulation (FPR) evaluation and interpretation

The next EU Fertilisers Expert Group is fixed 15-16 April. ESPP will participate. So if you have points you consider should be taken into account in the FAQ regulation guidance or aspects to consider in the upcoming regulation evaluation: please email us ASAP (before end March latest). The existing FAQ is <u>HERE</u> (Frequently Asked Questions = in effect, FPR guidance). Please indicate interpretation or implementation questions which are NOT already addressed or are not resolved in this existing FAQ, if possible with real case examples. The evaluation of the FPR will be launched by the European Commission in coming months, as required in art. 49 of the Regulation, with the aim of identifying if certain aspects of the Regulatory text should be modified. Please indicate aspects of the Regulation which you suggest should be evaluated, other than points already specified in art. 49 (contaminants including cadmium and uranium, functioning of the internal market, conformity assessment, market surveillance, optional harmonisation) and other than specifications and materials in CMCs and biostimulants (studies already underway, see <u>ESPP eNews n°81</u>).

EU Fertilisers Expert Group documents (CIRCABC public) <u>HERE</u>.

# **Urban Waste Water Treatment Directive revision final text published**

Final text validated by Council specifies that EU "combined reuse and recycling rates" for P from sewage and sludge will be fixed within 3 years, and a feasibility study on N reuse and recovery will be engaged. The P reuse & recycling rates



requirements are detailed in art. 20: these rates should take into account technical and economic viability, P content of sludge, other organic P sources on national markets, impacts on health and the environment. The N reuse & recycling study is specified in art. 30. This final text now goes to the European Parliament for endorsement and then legal verification before publication. The revised Directive also tightens sewage works discharge limits for P and N, requires that urban wastewater systems achieve "energy neutrality" (without increasing methane or nitrous oxide emissions, preamble 16), quaternary treatment (end-of-pipe removal of organic contaminants), extended producer responsibility to cover costs of this 4<sup>ry</sup> treatment (for pharmaceuticals and cosmetics only, extension to industrial chemicals to be studied), promotes water use, microplastic measurement methodology, "integrated urban wastewater management plans", and specifies new definitions (e.g. of "sludge"). For details, see summary of the Commission's initial proposal in <u>ESPP eNews n°74</u>. ESPP will provide a full summary of the final text when it is promulgated in the EU Official Journal.

ESPP will start work defining consensus proposals for defining these new "combined reuse and recycling rates" for phosphorus (from sewage and sewage sludge) at our **meeting of 14<sup>th</sup> March** (<u>Brussels & online – register now</u>): what % rates from different sewage works (size, configuration), definitions of "reuse" and "recycling", requirements for recovered materials (quality, safety, plant P availability ...).

Final validated compromise text for revised Urban Waste Water Treatment Directive 1st March 2024 HERE.

Working meeting, defining "combined reuse and recycling rates" for phosphorus from municipal waste water, 14<sup>th</sup> March (Brussels & online) <u>http://www.phosphorusplatform.eu/nutrientevents2024</u>

# Critical Raw Materials (CRM) Act adopted by European Parliament

European Parliament plenary has validated the CRM final text, following 'trilogue' finalisation, and pending final formal validation by Council. "Phosphate rock" and "Phosphorus" (meaning P<sub>4</sub>) are in the Critical Raw Materials List, but not in the "Strategic" sub-list.

ESPP considers that this Act should support phosphorus stewardship and recycling by requiring monitoring, inciting national circularity measures and facilitating permitting of recycling projects. ESPP regrets that  $P_4$  is not included in the "Strategic" sub-list despite being essential for the specified "strategic" industry sectors (renewable energy, e.g. solar panels; batteries; data and electronics fire safety) and despite the EU's 100% dependency on supply from three countries (China, Vietnam, Kazakhstan) – see joint industry declaration.

The finalised text adjusts the initial Commission proposal (see <u>ESPP eNews n°74</u>) by underlining materials efficiency and recycling of CRMs in art.1. The original text is also modified (art. 4.1) to specify that a CRM "at any stage of processing and when occurring as a by-product of other extraction, processing or recycling processes, be considered critical raw materials". The interpretation of this for "Phosphate rock" could be interesting (!).

Many points of the Act address "Strategic" raw materials only (not all CRMs) – in particular definition of recycling objectives, possibilities for "Strategic Projects". However, the following concern all CRMs:

- Art. 5.2: "incentivise technological progress and resource efficiency" of CRMs,
- Art. 9 and art. 2.16, 2.20 (definitions): Member States must establish "*Points of Single Contact*" (can be more than one!) to facilitate and coordinate permitting of installations for extraction, processing or recycling of CRMs,
- Art. 13, art. 18: certain CRM project planning simplifications,
- Art. 19: national exploration programmes for CRM resources,
- Art. 20: EU monitoring of CRM supply risks and stress testing,
- Art. 21: identification and monitoring of key CRM value chain operators,
- Art. 26.1: national programmes for circularity of CRMs, including incentivising resource and materials efficiency, "collection, sorting and processing of waste with high critical raw materials recovery potential ..." and "increase the use of secondary critical raw materials including through measures such as taking recycled content into account in award criteria related to public procurement or financial incentives for the use of secondary critical raw materials", "increase the technological maturity of recycling technologies", "support the use of Union quality standards for recycling processes of waste streams containing critical raw materials", workforce upskilling ...
- Art. 26.7: The Commission will define a "list of products ... and waste streams ... considered as having a relevant critical raw materials recovery potential",
- Art. 30 and art. 31: possible sustainability certification and environmental footprint schemes for CRMs.

The above are ESPP's understanding of the amended text published by the European Parliament and remain to be confirmed when the final Act is published.

European Parliament "Consolidated legislative document" <u>EP-PE\_TC1-COD(2023)0079</u> 12<sup>th</sup> December 2023



# **UK water industry Resource Recovery Working Group**

The third meeting (12<sup>th</sup> January 2024) of this informal UK group, led by Thames Water, discussed actions needed to develop markets for resources recovered from wastewater, with six UK water companies, waste/water engineering companies, the fertilisers industry, researchers and regulators.

User drivers for resource recovery were discussed. Leading food companies and fertiliser producers are looking to reduce carbon footprint, and recycling nutrients contribute this. Industry will drive interest in recovered resources as companies seek sustainable feedstocks to reduce supply chain greenhouse gas emissions, rather than agriculture itself. Discussions suggested that market forces alone are unlikely to deliver sufficiently rapid change: intervention and collaboration across the value chain are needed.

Joe Gilbertson, UK Agricultural Industries Confederation, explained that the UK is updating its (1991) fertilisers regulations, probably towards a matrix aligned with the EU Fertilising Products Regulation. Fertiliser blenders and companies manufacturing compound and liquid fertilisers in the UK can integrate recycled nutrient materials into their products. Recycled phosphates with low cadmium would be welcome. Sulphur is today needed in fertilisers, because no longer provided by atmospheric sulphur dioxide pollution ('acid rain'). A challenge to uptake of recycled nutrient materials is perception of possible risks in wastes, with possible unknown contaminants and fear of contamination the food chain. Price is also important. She underlined that food processors, retailers and the public will determine demand for recycled nutrients, irrespective of fertiliser industry or government wishes.

Discussion underlined the need for dialogue between the fertiliser industry - distributors and waste - wastewater companies, on how to deliver nutrients in a form useful to industry, and on quality and safety. A key challenge is scale and logistics. Recycled nutrients are available in small, diffuse quantities. In the short term, an answer is to target recycled products to niche markets, but the longer aim should be to generalise nutrient recycling to deliver a significant proportion of fertiliser nutrient needs.

Nutrient platforms can enable dialogue, between waste and user industries, and with researchers. An important role of platforms is on policy and regulation. Other tools are needed to directly develop markets, ranging from industry joint ventures to take recycled materials to market (e.g. AquaMinerals Netherlands) to market matchmaking apps and websites.

The UK water industry Resource Recovery

Working Group is open to participation of all concerned companies and competent persons. Contact: Robert Naylor <u>Robert.Naylor@thameswater.co.uk</u>

# German Phosphorus Platform (DPP) regulatory proposals

DPP's January 2024 'Political Memorandum' calls for changes to German national fertiliser regulations, to ensure coherence and facilitate phosphorus recycling from sewage. This 2024 DPP Memorandum follows from, and updates, the DPP's 2020 Memorandum (see <u>ESPP eNews n°49</u>). DPP reminds that Europe is largely dependent on imports for phosphorus, which is essential for food production, and increasingly for batteries and electromobility and calls for a national phosphorus circular economy strategy. German legislation (Sewage Sludge Ordinance 2017 AbfKlärV, see <u>ESPP SCOPE Newsletter n°129</u>) requires phosphorus recovery from sewage sludge from 2029 (except for small sewage works < 50 000 p.e. where sludge is used in agriculture, and with a transitional delay to 2032 for sewage works < 100 000 p.e.). DPP requests adjustments of German regulations to enable implementation of this:

- The current German fertiliser regulation (DüMV) currently specifies that only sewage sludge compatible with national criteria for agricultural valorisation (AbfKlärV) can be used as an input material for production of recovered phosphate fertilisers. This should not apply, for organic contaminants, in P-recycling processes which ensure elimination of these (e.g. incineration) subject to respecting fertiliser regulation heavy contaminant limits in the final product. The DüMV fertiliser regulation also specifies that only sewage sludge / ash respecting the DüMV fertiliser contaminant limits can be used as input material: this excludes P-recycling routes which simply dilute contaminants by combining with other materials, but it also excludes processes which remove or eliminate contaminants in order to achieve fertiliser contaminant limits.
- AbfKlärV (see <u>ESPP SCOPE Newsletter n°129</u>) currently requires phosphorus recovery ensuring reduction of sludge P-content by at least 50%, or reduction of sludge P content to < 2 %P/DM, or recovery of at least 80% of P from sewage sludge incineration ash. DPP requests clarification of how these requirements should be verified (e.g. P-flow balances: P-input, P-output, P in recovered product).</li>
- Phosphate solubility requirements in recovered fertilisers: DüMV requires at least 2.5% solubility in water of P<sub>total</sub>, 5% in NAC (neutral ammonium citrate-soluble) and 2% in mineral acid-soluble phosphate (it is unclear how these three different criteria fit together). DPP propose to modify this to 60% solubility (of P<sub>total</sub>) in NAC or 60% solubility in 2% citric acid. This differs from the EU Fertilising Product Regulation (FPR) which requires 40% solubility in water or 75% in NAC.
- End-of-waste status. Unlike under the EU FPR, the German national fertiliser regulation DüMV does not automatically confer end-of-waste status to fertilisers recovered from sewage. DPP requests clarification of this.
- DPP underlines the need for stable and appropriate support for phosphorus recovery, without which the German regulatory AbfKlärV 2029 deadline will not be met. Current municipal sewage management tenders often cover periods too short for investment in recovery installations. Currently not all federal states have the option of including P recovery in the wastewater



fee before 2029. DPP requests application, as of today, of the "polluter pays" principle to ensure adequate funding of phosphorus recovery, with a national cost approach (most sewage phosphorus comes from human excreta).

- DPP proposes a review of policies to pull market uptake of recycled phosphates:
- a quota for recycled phosphates in fertilisers (related to distributor sales),
- pricing of environmental costs (externalities),
- taxation, e.g. of resource consumption,
- support for early starter municipalities, for example through an incentive system,
- financial benefit / penalty for municipalities implementing / not implementing phosphorus recovery.

"Politikmemorandum zur Phosphorrückgewinnung 2023/2024 der Deutschen phosphor-Plattform DPP", 31<sup>st</sup> January 2024 <u>HERE</u>.

### Federal Environment Agency joins German "Clean Phosphorus 2029" initiative

This initiative, launched June 2022, aims to achieve the German regulatory P-recovery obligations with processes which explicitly remove contaminants and produce clean, marketable phosphorus products. The initiative currently brings together <u>Gelsenwasser</u> (waste and water utility employing 6 400 people - group), Ragn-Sells EasyMining (ESPP member), Remondis, MSE Mobile, Parforce, and several other sewage services, recycling and lime companies. The initiative promotes seven points for phosphorus recovery processes: achieve the P-recovery requirements of the German Sewage Sludge Ordinance AbfKlärV (see ESPP <u>SCOPE Newsletter n°129</u>), not accumulate pollutants to agriculture, remove pollutants in input materials, produce clean and marketable phosphorus products of quality irrespective of composition and pollutant load of input material, separate and recover other materials where possible and not only phosphorus. The Federal Environment Agency (UBA) is also a member of the German Phosphorus Platform (<u>DPP</u>), as is the Swiss Federal Office for the Environment (BAFU) and several German Land (regional) authorities.

"Umweltbundesamt schließt sich der Initiative Sauberer Phosphor 2029 an" (the Federal Environment Agency joins the Clean Phosphorus 2029 Initiative)., Gelsenwasser, 1<sup>st</sup> March 2024, <u>HERE</u> and "Sauberer Phosphor", seven point outline for P-recovery processes, EasyMining, 2 June 2022 <u>HERE</u>.

### ESPP founding participant of circular feed platform

New initiative, led by FEFAC (animal feed industry federation), will bring industry organisations together to develop circularity in animal feed. Discussions are underway with industry federations in chemicals, animal by products and several food and bio-based materials processing sectors. Aims could include a mapping to identify and quantify secondary materials with potential as animal feed inputs (which are not currently being used), analysis of these resources (safety questions, nutrient digestibility, transport distances and logistics, food versus feed status, waste hierarchy, land use), supporting different sectoral organisations' proposals for feed circularity within an overall strategy, possible definition of principles for feed circularity, analysis of regulatory and other obstacles, proposals to EU decision makers.

Industry federations and sectoral organisations wishing to engage with the proposed feed circularity platform should contact ESPP <u>info@phosphorusplatform.eu</u>.

### **BlueBio Policy Brief: waste to resource**

Policy Brief identifies three areas of regulatory barriers to circularity in the blue economy, including barriers to nutrient recycling from aquaculture sludge and by use of algae to treat wastewaters. The Policy Brief, from the Blue Bio Cofund (an initiative of the R&D platform <u>JPI Oceans</u> and the EU-funded R&D network Horizon2020 <u>ERA-NET Cofund</u>) accompanying the European Parliament event summarised below identifies:

- Regulatory complexity for use of algae in human food, animal feed and health products:
  - Cost and time needed for authorisations under the Novel Food 2015/2283, Animal Nutrition 1831/2003 and Animal Feed Hygiene 183/2005 Regulations
  - Varying heavy metal limits between different EU Member States for food / food ingredient uses
  - Process for validating nutrition and health claims under 1924/2006, 432/201
- Lack of European legislation concerning algae cultivation, leading to delays and uncertainties in production site licensing.
- Moving from "waste to resource" for fisheries and aquaculture:
  - Need to revisit the outdated Animal By-Product Regulations, in particular to resolve the current exclusion of fish excrement (and so fish aquaculture slurry) from the definition of manure
  - Clarify the exclusions of wastewaters and manures from animal feeds (767/2009), irrespective of processing, subject to fully ensuring food chain safety
  - Assess food chain safety risks for the use of aquaculture sludge as input for production of insects or aquatic invertebrates for use as animal feed (request an EFSA Opinion)

BlueBio "Policy Brief On identified regulatory barriers to more circularity in the blue bioeconomy", 5 pages, January 2024, <a href="https://bluebioeconomy.eu/wp-content/uploads/2024/01/BlueBio-policy-brief-Jan-2024.pdf">https://bluebioeconomy.eu/wp-content/uploads/2024/01/BlueBio-policy-brief-Jan-2024.pdf</a>



# **Event summaries**

### **Regulatory barriers to aquaculture and marine Circular Economy**

European Parliament meeting underlines the need to better identify and address obstacles to nutrient recycling from fish slurry, aquaculture and in algae production. The meeting had 43 participants in Brussels and 75 online and was organised by BlueBio Era-Net, with Clara Aguilera and Catherine Chabaud, MEPs.

Alex Obach, European Aquaculture Technology and Innovation Platform and FEFAC (animal feed industry federation), underlined that EU aquaculture is one of the most sustainable in the world. 40% of today's fish meal used in aquaculture feed comes from marine food production co-products and over half of the ingredients used are co-products of marine, vegetable and animal origin (e.g. from maize or soja processing). However, 70% of aquaculture food products consumed in the EU are imported, resulting in a 25 billion € trade deficit. Regulation needs to ensure both safety and flexibility to allow innovation in the EU to support a sustainable and ambitious growth of the industry. Market policies and promotions campaigns of aquaculture technology and innovation across the value chain, putting the EU at a competitive advantage in terms of RTDI transfer.

Anne Mette Baek, EFFOP (European Fishmeal and Oil Producers Federation), noted regulatory obstacles to producing foodgrade products and processing animal by-products on the same site, which is however important for industry efficiency and integration. The 2009 Animal By-Product Regulation needs to be revisited to address the circular economy and food sustainability, whilst continuing to ensure safety, in today's context.

**Ingeborg Korme, BlueBio Era-Net**, underlined that EU-funded R&D projects on aquaculture conclude that regulatory obstacles are important and are limiting innovation, investment and development of aquaculture in Europe, both concerning input of aquaculture products into applications such as animal feed, and concerning recycling of nutrients.

Ann-Cecilie Hansen, Norwegian Food Safety Authority. Norway uses around 2 million tonnes/year of fish feed for salmon aquaculture. The government has launched a mission into sustainable fish feed. Fish slurry from aquaculture, which contains mainly fish excrement and unconsumed feed, is authorised for use in fertilisers in Norway under national regulations, but is currently excluded from the EU Fertilising Products Regulation – but this is currently being studied. Challenges for recycling of fish sludge to agriculture include food-chain and environmental safety: heavy metals (zinc, copper, cadmium), organic contaminants (such as plant protection chemicals and pharmaceuticals), pathogens. Processing can ensure hygienisation and drying, which is important for transport from coastal to arable regions. Another possible route for valorisation is as food for insect farming, possibly for feed production, but this poses the risk of recirculating pathogens and contaminants. This route is currently excluded by feed regulations and requires more research into safety.

**Oana Parvulescu, NUST Polytechnic Bucharest**, summarised work on aquaculture and marine harvesting circularity. Fish processing wastes (heads, bones ...) and aquaculture sludge (fish slurry) are both rich in nutrients and offer valuable potential as inputs to agriculture, as fertilisers and biostimulants. However, their use is currently blocked by EU regulations as fish excreta are not animal by-products under the Animal By-Product Regulation (2009/1069, art. 3.20), so are not considered in the EU Fertilising Products Regulation. There are also obstacles in the EU Organic Farming regulations.

Panagiotis Kougias, Hellenic Agriculture Organisation, noted the challenges facing use of food processing wastewaters to produce (micro)algae for applications such as cosmetics or human foods. Data is needed to prove safety. Barriers include the absence of regulatory standards, leading to lack of clarity and predictability for investment.

Kerstin Kuchta, Hamburg University of Technology, also indicated the complexity of the regulatory context. For example, if mixed algal biomass is cultivated, authorisation is difficult in product regulations which are based on individual algae species.

Efthalia Arvaniti, SUBMARINER Network, showed some Seamark project results concluding that the costs of obtaining approval for health and nutrition claims are an obstacle to marketing new algae-based products, highlighting that while the commercial communication of non-authorised health claims is not possible in the EU, this is allowed in US and Japan, where qualified health claims supported by a less demanding level of scientific evidence, are allowed to be communicated to the consumers. Furthermore, Seamark concluded that the EU has more demanding harmful contaminant limits than in equivalents in US or Japan. The Seamark report "Assessment of EU regulatory landscape in a global context" will be published in April at the Seamark project website here: <a href="https://seamark.eu">https://seamark.eu</a>

Lorella De La Cruz Iglesias, European Commission DG MARE (Directorate General for Maritime Affairs and Fisheries) explained that the Commission is working with stakeholders and industry to identify regulatory obstacles and bring the Circular Economy into MARE strategies. The Strategic Guidelines for EU Aquaculture adopted in 2021 and the EU Algae Initiative adopted in 2022 look into circularity approaches and cover many of the issues presented by participants in the event. She noted the importance to keep a connection/dialogue between researchers and innovators (especially those part of EU-funded projects) and policy makers in order to ensure, to the greatest extent possible, that EU policy and regulation is adaptable to future societal and technological developments, whilst continuing to ensure high levels of safety and consumer confidence. This is the approach followed in the implementation of both the EU Aquaculture Strategic Guidelines and the EU Algae Initiative.



Paolo Caricato, European Commission DG SANTE, also underlined the importance of cooperation and communication with stakeholders. The Commission fully understands that current EU regulations may pose barriers, but at present no Member States are pressing for changes. The political input of Member States is fundamental at this regard.

**Round table conclusions** noted that the EU is a world leader in research and innovation, and in aquaculture sustainability. There is need to improve coordination between researchers, industry and regulators, to promote implementation. R&D projects are today asked to deliver policy recommendations. A key question is to define policies to support market pull for the circular blue economy.

Catherine Chabaud, MEP, underlined the need for a Blue Deal within the Green Deal, and that algae are a key link between the marine economy and Green Deal (circular economy).

**Clara Aguilera, MEP,** indicated that implementation of the Green Deal is not yet today finished, and hopes that Green Deal objectives, including for marine and algae, will be taken forward under the new European Parliament and Commission after the June 2024 European elections.

JPI Oceans – Blue Bio event at the European Parliament and online, 30<sup>th</sup> January 2024 "Connecting the dots for a Circular Blue Bioeconomy: From Science to Policy and Regulatory solutions" <u>https://www.jpi-oceans.eu/en/connecting-dots-circular-blue-bioeconomy-science-policy-and-regulatory-solutions</u> and <u>meeting report</u>.

# Fertilizers Europe Forum on Plant Nutrition

The forum underscores the central roles of nutrient use efficiency, decarbonisation of the fertilisers industry, and recycling of nutrients in Europe's path towards sustainable agriculture. The Forum on Plant Nutrition "Sustainable food production: From nutrient management to decarbonization" was hosted by MEP Peter Jahr and organised by Fertilizers Europe, and brought together policy makers, professionals and stakeholders in the food production value chain to discuss challenges of the agricultural and environmental sectors, with the ambition of guaranteeing food security, moving from current practices to a sustainable and decarbonised food production system.

Professor Wim de Vries, Wageningen University, shared main results from the study "Assessment of spatially explicit actual, required and critical nitrogen inputs in EU-27 agriculture", funded by Fertilizers Europe, the International Fertilizer Association and the European Environmental Agency. The study arose from the interest in an accurate calculation of N boundaries, accounting for the spatial variation in the sensitivity of terrestrial and aquatic ecosystems and in climate, land use and soil properties at the EU level. Downscaling of planetary boundaries to regions, as often applied, in fact neglects this variation and flat rate reductions in N losses and inputs as in the 'From Farm to Fork' strategy appear inappropriate, since N concentrations in air and water vary depending on application rate, climate, crop and soil type. The study quantified and compared current inputs and losses of N with required N inputs for crop production and N inputs/losses in view of adverse environmental effects, with a focus on ammonia emissions to air and nitrate leaching and runoff to groundwater and surface water. The required Nitrogen Use Efficiency (NUE) at which the current or target crop yield can be reached by improved management was also quantified. Required overall reductions in ammonia emissions and N runoff at EU level to protect terrestrial and aquatic ecosystems were calculated as 38% and 50%, respectively, the latter value being equal to the mentioned reduction in nutrient losses by the Green Deal's Farm to Fork strategy. At current NUE, the required reduction in N inputs to protect terrestrial and aquatic ecosystems, is 31% and 43%, respectively. Critical N inputs are most strongly exceeded in regions with high livestock density, such as Ireland, the Netherlands, Belgium, Luxembourg, Brittany in France and the Po valley in Italy. At increased NUE, a given crop yield can be obtained with less N input, while the critical N input increases since a lower fraction of N is lost to the environment. The NUE increase that is required to attain actual or target crop yields at acceptable N losses varies strongly, but a mean +22% of variation was calculated. Prof. de Vries then highlighted the need to develop region-specific mitigation policies based on regional information on critical N inputs and their exceedances with related environmental and health impacts, and wrapped up by linking sustainable food production to enhanced waste and nutrient recycling, decreased food waste and the adoption of efficient practices to fertilization and farm management, notably the 4R principle: right product, rate, time, and place.

A panel discussed the link between sustainable nutrient management and food security. Mónica Andrés Enríquez, Yara International, highlighted how the fertiliser industry is committed to transform the food value chain, through increased nutrient use efficiency, decarbonisation of fertilisers production and recycling of nutrients (as a solution to food waste as well). This is possible only through a collective effort, including fertilisers producers, food companies, regulators, consumers and farmers. In fact, to shift from "grey" (obtained from fossil fuels) to "green" fertilisers (obtained with renewable energy) and to reduce the carbon footprint of fertilisers of between 80 and 90%. The whole value chain needs to be involved, as this shift will be costly, requiring huge investments. Farmers are pivotal in this change, but they must be supported with digital tools to control nutrients and convinced by business cases for green fertiliser.

Max Schulman, Central Union of Agricultural Producers and Forest Owners (MTK), highlighted the important role of advisors, including farmers' associations, local cooperatives, fertilisers manufacturers, in helping farmers selecting the right type of fertiliser and use management according to soil type, crop variety and required quality of the product. He agreed that communication within the value chain is pivotal, as well as giving farmers the proper time to put in place the required changes but at the same time provide long term certainty that the targets will remain consistent and will not change in the short term.

Fabien Santini, European Commission; DG Agriculture, specified that the EU Fertilising Products Regulation introduced the possibility to create a single market for organic fertilisers, to increase the possibility of recycling nutrients from manure and waste



streams and to facilitate the movement and reuse of organic fertilisers in excess in one region. He announced that a report on the implementation of the CAP strategic plans is soon to be published, reporting Member States' interventions related to nutrient management. He reiterated that communication and clarity are crucial for innovation and for implementation of change.

Peter Jahr, MEP, concluded the meeting remarking that a combination of policy and technology solutions are needed to guarantee availability of fertilisers in Europe, and highlighted how farmers are the most important part of the solution, as long as they are advised in the correct way.

"Assessment of spatially explicit actual, required and critical nitrogen inputs in EU-27 agriculture" de Wries et al. (2022) <u>DOI</u> "Forum on plant nutrition: from food security to carbon farming", online, hosted by Peter Jahr, Member of the European Parliament, 9<sup>th</sup> February 2024, <u>HERE</u>.

# **Research and innovation**

### Phosphorus and nitrogen losses, climate change, impacts on Adriatic eutrophication

Review summarises changes in P and N discharges and concentrations in the Po river and the Adriatic coastal Mediterranean Sea, showing reduced algal blooms with lower P inputs, higher N/P ratios and impacts on fisheries. The Adriatic coastal Mediterranean is shallow with limited water exchange and high nutrient-rich river input. The Adriatic receives one third of freshwater flowing into the Mediterranean, of which over 50% from the Po river, which has a population of 16 million (including Milan, Turin) and is agriculturally intensive. These nutrient inputs make the Northern Adriatic one of the most productive fisheries of the Mediterranean, but also susceptible to eutrophication. Phosphorus inputs to the Adriatic were reduced from 1985 with the Italy ban on detergent phosphates (1988). Phosphorus inputs continued to reduce through to the 2020's (ESPP comment: probably because of improved sewage treatment: over 70% of phosphorus and 60% of nitrogen are removed from Lombardy's sewage <u>SCOPE Newsletter 124</u>) but this trend was not observed for nitrogen. Over past decades, climate change has also led to reductions in nutrient levels in the Adriatic, with low-nutrient waters from the central Adriatic. Algal growth fell, as shown by chlorophyll-a data 1978-2020. This led to lower fish populations and consequent overfishing. The authors note that questions are raised by the continuing high N levels in river input (largely from agriculture), leading to increased N/P ratios in the Adriatic, and that there is a need to further reduce nutrient losses to the Adriatic, to monitor impacts of climate change and to move towards more sustainable fisheries and aquaculture.

Cozzi et al. (2020), studying the Gulf of Trieste, Italian Mediterranean coast, showed similar results, with decreasing phosphorus inputs resulting in decreasing algal development through to around 2010, but then recurrence of algal blooms and changes in seasonal algal growth patterns as a result of climatic changes modifying water temperature, winds (water mixing).

Rubini et al. (2021), analysed occurrences of toxic microalgae in the Adriatic, releasing yessotoxins which can accumulate in shellfish, leading to stoppage of harvesting to avoid human health risks. These releases are considered to be linked to climate change (increasing water temperatures, changes in river freshwater discharge or in marine water mixing).

Soana et al. (2024) recently analysed the long-term trends (1992–2020) of N and P export from the Po river basin to the Adriatic sea, investigating annual and seasonal patterns and their relationship with water temperature and precipitation patterns. Diffuse plus point N sources in the basin did not significantly decrease over this period, yet a marked decrease (-20%) in N<sub>-total</sub> export, mostly as nitrate, was recorded in the last decade compared to the 1990s. This is likely related to the water temperature warming, especially during summer (+0.13°C/year) and autumn (+0.16°C/year)), to the increased number of warm days (+70%–80%), and to the persistence of low flow periods, that may enhance the rates of microbial processes and sustain favourable conditions for the denitrification and nitrate removal. On the other hand, despite a significant reduction in both agricultural diffuse P sources in the basin (manure, synthetic fertiliser) and point P sources (sewage works, but these are c. 20x lower than agriculture), the annual export of P-total in the river displayed a high inter-annual variability and no significant downward trend. In large turbid rivers, such as the Po, P cycling is less sensitive to temperature warming. The only negative relationship found between water temperature and soluble P loads in the river final section was observed in summer and attributed to increased P uptake by phytoplankton.

"The Role of Nitrogen and Phosphorus in Eutrophication of the Northern Adriatic Sea: History and Future Scenarios", M. Marini & F. Grilli, Appl. Sci. 2023, 13, 9267, <u>DOI</u>.

"Climatic and Anthropogenic Impacts on Environmental Conditions and Phytoplankton Community in the Gulf of Trieste (Northern Adriatic Sea)", S. Cozzi et al., Water 2020, 12, 2652, <u>DOI</u>.

"New Trends in the Occurrence of Yessotoxins in the Northwestern Adriatic Sea", S. Rubini et al., Toxins 2021, 13, 634. DOI.

"Climate change impacts on eutrophication in the Po River (Italy): temperature-mediated reduction in nitrogen export but no effect on phosphorus", E. Soana et al., J. Environ. Sci. 2024, 143, <u>DOI</u>.

### Climate change will deteriorate eutrophication of Mediterranean river Júcar, Spain

**Modelling suggests that climate change will multiply water in the Júcar basin with poor quality status by x4, requiring a 50% reduction in P losses**. The Júcar basin, 43 km<sup>2</sup>, drains into the Mediterranean and includes the cities of Valencia, Albacete and Ribera Alta. Two models (PATRICAL, RREA) were applied with climate scenario RCP8.5 for period to 2100. Surface water



area impacted by nitrates is estimated to increase by x1.3 as a result of climate change by 2100. Other Mediterranean studies have estimated decreases in nitrate loadings with climate change (Serpa et al., 2017; Buonocore et al., 2021). Nitrates runoff from agriculture will be reduced with lower precipitation and run off and with increased denitrification. Water area impacted by ammonia is estimated to increase by x1.9 and that by BOD (biological oxygen demand) and by phosphorus by x4. Median ammonium and phosphorus concentrations in the river and tributaries may double in low flow periods, because lower precipitation leads to reduced dilution of point sources and agricultural runoff. To maintain current water quality status, reductions of -25% for nitrates and -50% for ammonia, BOD and phosphorus will be required.

"Effect of climate change on the water quality of Mediterranean rivers and alternatives to improve its status", D. Doradao-Guerra et al., J. Environmental Management 348 (2023) 119069 <u>DOI</u>.

### P fertilisation improves water use efficiency (WUE) in Mediterranean tree-grass system

6-year field trial in central Spain extensive 'dehesa' agri-ecosystem shows that N or P+N fertilisation improves WUE and prevents carbon loss, with P+N showing the best WUE and lowest evaporation. The site studied, at Madajas de Tiétar, has 20-25 trees/ha, grass and extensive grazing (<0.3 cattle/ha). Annual rainfall was 440 - 970 mm/y (85% October – April). Three c. 20 ha plots received N fertiliser (100 kgN/ha/y) in 2015 and 2016, P+N fertiliser (50 kgP/ha/y) or no fertiliser (control), and were then monitored for further four years. Data was collected from three eddy covariance towers (one in each plot), CO<sub>2</sub> emissions, airborne spectral measurements, meteorological and Landsat data, vegetation sampling. The two plots receiving N fertilisation showed 40% increased leaf area index (LAI) in spring, resulting in reduced evaporation. Evapotranspiration increased in the N-only fertilised plot, but was similar to the control in the P+N plot. The higher leaf water loss with N-only fertilisation may be due to increased root development or root activity required for uptake of limited P. In both fertilised plots (N, P+N), annual net ecosystem CO<sub>2</sub> loss was reduced to net zero (from c. 75 gC/m<sup>2</sup>/y in control). The best water use efficiency was achieved in the P+N fertilised plot.

"How Nitrogen and Phosphorus Availability Change Water Use Efficiency in a Mediterranean Savanna Ecosystem", T. El-Madany et al., J. Geophysical Research Biogeosciences, 126, 2021, e2020JG006005, <u>DOI</u>.

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