Events, calls, job offers

5th European Sustainable Phosphorus Conference
8-10 October 2024, Lleida, Spain

120 abstracts received. With three European Commission services, United Nations, industry & experts from Europe and worldwide. Site visits to industrial nutrient recycling, digestate processing (Fertilizantes del Ebro, biogas installations). ESPC5 follows on from ESPC4 Vienna, 2022 which, with 320 participants onsite and 80 online, was the biggest conference on phosphorus ever worldwide. Join us for this unique networking, industry, policy and science event. *Updated programme, registration, site visit details:* https://www.phosphorusplatform.eu/espc5

Birdwatching in Spain after ESPC5. Some of us will be taking a long weekend birding on the Spanish steppes around Lleida after ESPC5. Anyone interested in joining, contact info@phosphorusplatform.eu

Upcoming call for projects on water circular economy

The European Water4All partnership has announced a Joint Transnational Call (c. 36 M€) for research and innovation projects to improve long-term water security, including resource recovery and valorisation.

The "Water for Circular Economy" call, backed by 36 funding agencies from Europe and outside, will be announced on September 12, 2024, with a total budget of c. 36 M€. The deadline for submitting pre-proposals is November 2024, and the projects will have a duration of 36 months. Research proposals must address at least one of the following themes: enhancement of water circularity in industries; urban water circularity; resource recovery and valorisation; economic, environmental and social implications of water reuse and recovered products. Project outcomes should contribute to the development of evidence-based water management policies and strategies at global, EU, and national levels, within the frameworks of the Green Deal, Water Framework Directive, Just Transition and UN Sustainable Development Goals.

Water4All 2024 Joint Transnational Call Pre-announcement.

Phosphates 2025 conference to include potash

CRU have announced that Phosphates 2025 (31/3/25 – 2/4/25, Orlando) will also cover potash. A call for abstracts is opened to 27th September 2024. Themes will cover all aspects of the potash industry (as is the case for phosphates, for which CRU Phosphates is "the" annual industry & technology meeting place): mining and resources, beneficiation, fertilisers, environmental aspects of production management, sustainability.

Abstracts of 200-400 words should be sent to Ava.Blagoeva@crugroup.com

Phosphates 2025 website: https://events.crugroup.com/phosphates/home

Job offer – BETA Technological Center

BETA Technological Center, Vic (Barcelona), Spain, is recruiting: "Senior Technician for the management of competitive projects in the field of governance". Application deadline 1st September. The selected person will be responsible for the implementation and technical management of the Horizon Europe CSSBOOST project.

Information: https://utalent.uvic.cat/index.php/Sollicituds/Vista/index/AD/11328

DPP P-recycling German thesis prize

DPP, the German Phosphorus Platform, is for the second year offering a 1000 € prize for a German bachelors or masters thesis on phosphorus recycling. The degree must have been obtained in Germany. The prize will be attributed at DPP's annual meeting (DPP Forum), Frankfurt-am-Main, 23rd October 2024. The first (2023) DPP thesis prize was awarded to Jannik Mühlbauer (TU Dresden) for his thesis "Laboratory studies on thermochemical sewage sludge treatment".

Application (letter of motivation, CV, diploma, supervisor's report, in one pdf file) plus the final thesis, must be sent by 1st September to info@deutsche-phosphor-plattform.de

DPP Forum, 23rd October 2024 https://www.deutsche-phosphor-plattform.de/aktuelles-forum/

ESPP new member

ReLEAF

The four year 2024-2028 ReLEAF project is funded by the Circular Bio-Based Europe Joint Undertaking (CBE JU) to test efficient, safe, and sustainable bio-based controlled release fertilisers. The project has 17 partners from 9 countries, 6.5 M€ allocated EU funding, and is coordinated by Leitat technological centre, Spain. The project aims to valorise several bio-wastes widely available in Europe (sewage sludge, fish processing wastewaters and sludge, mixed food wastes, and agri-food wastes) to obtain fertilising ingredients, biostimulants, and bioplastics that will allow to obtain 100% bio-based controlled release fertilisers and fertiliser-functionalised horticulture elements (mulching films and planting pots). The ReLEAF products will be tested on different soil and climate conditions to demonstrate their efficiency and safety. ReLEAF aims to close the nutrient cycle, while promoting a sustainable agriculture in Europe, fully aligning with the ESPP's objectives. ESPP membership will facilitate knowledge sharing, clustering and networking, to accelerate uptake of ReLEAF solutions and widen the project impact.

More information: https://www.linkedin.com/company/releaf-project-eu/

http://releafproject.eu/ (under construction)

Circular Bio-Based Europe Joint Undertaking https://www.cbe.europa.eu/cbe-ju-2023-call-projects

Animal By-Products nutrient recycling in fertilisers

Webinar: including Animal By-Products into the EU Fertilising Products Regulation (FPR)

17th September, 14h – 16h (CEST, Brussels time). Recycling animal by-products to fertilisers: nutrient circularity, food chain safety and consumer confidence. Jointly organised by ECOFI, Eurofema, EBIC and ESPP. With participation of the European Commission (DG SANTE, DG GROW Fertilisers). This webinar will address several key questions: Which Animal By-Product (ABP) materials can currently be used in EU fertilising products? Under what processing conditions? How do the EU ABP Regulations and the Fertilising Products Regulation (FPR) fit together? What other materials could be considered? What logic and procedures should be followed to consider additional materials?

Secondary materials and fertiliser industry operators are invited to submit examples of ABPs with significant recycling potential as fertilisers. These should be safe, higher uses in the waste hierarchy (food, animal feed) should not be feasible, and they should currently not be authorised under the EU FPR.

This first webinar will present the current regulatory context, discuss several examples of potentially valuable ABPs that are currently excluded from the FPR, and propose ways to advance the inclusion of different types of ABP materials.

Registration open (free) https://us02web.zoom.us/meeting/register/tZUrce6sqz0qGdD1o9cwY3u7GaJ4oo1gn5cA#/registration Please send industry examples of ABP materials for consideration: short text indicating origin of material (from which industries, type of by-product), processing, agronomic value, potential (tonnes/year EU), health and environmental safety, industry contacts (emails) – to info@phosphorusplatform.eu

Safety and agronomic value of Animal By-Products as fertilisers

QLab webinar presents conclusions proposed as input for pathogen safety, contaminants and agronomy for studied Cat.2 and Cat.3 ABPs for the Fertilising Products Regulation CMC10. **Further input is still possible.** The webinar included participation of the European Commission (DG GROW) and industry stakeholders. The study covers: processed insect frass, glycerine, by-products from production of fuels from ABPs, other Cat.3 materials, Processed Animal Protein (PAP), hydrolysed proteins, Meat and Bone Meal (MBM), Di- and Tri-Calcium Phosphate from bones, blood products, horn and hoof products, feathers and down, wet blue leather. Proposed conclusions are that in all cases, the processing required under the Animal By-Product Regulation are sufficient to ensure pathogen safety, when correctly applied (this includes BSE/TSE prion safety, given that Cat.1 materials are excluded). Pharmaceutical contaminants, including antibiotics or antibiotic resistance, could be an issue in some materials, and for these should be monitored and if possible reduced at source. In some materials, some contaminants could require specific limits on a case-by-case basis: methanol in glycerine; heavy metals in glycerine, horns & hoofs, hides & skins; arsenic in feathers & down; heavy metals and chromium in wet blue leather (chemicals used in tanning); possibly dioxins in feathers or horns where they may biologically accumulate. For processed insect frass, there are questions about protein allergens (in handling). Another question raised is possible deterioration of materials during storage, potentially resulting in mycotoxins.

The materials considered, based on available publications, show positive fertilising value, bringing organic material and/or nutrients (nitrogen, phosphorus, potassium, micronutrients) and can stimulate soil biology.

After any further input, the QLab report to the European Commission will be finalised, including proposed regulatory wording for inclusion of these materials into the FPR CMC10 (processing, contaminant and other criteria).

Webinar participants suggested that heavy metal levels are already fixed by FPR PFCs and need not be otherwise limited. ESPP commented that heavy metal limits in PFCs are adequate if these come only from heavy metals already present in the animal. However, for wet blue leather or skins/hides from tanning and leather processing, where chemicals including chromium, and arsenic are used, then specific limits in the CMC will ensure consumer and farmer confidence and environmental safety, and avoid "dilution" of such industrial pollutants into fertilisers and so onto fields.

Participants underlined that testing of e.g. allergens, pharmaceuticals, would be prohibitively expensive for organic fertiliser producers, and that these costs should be born by the livestock production and ABP processing sectors, so inciting to reduce at source.

Input and comments on the questions and conclusions proposed in these slides are invited to fertilizers@q-lab.fr

Watch the replay: webinar on use of 'Processed Manure' in EU fertilising products

Organised by CERTrust, with Theodora Nikolakopoulou of DG GROW. 'Processed Manure' is now authorised under CMC10 of the FPR under specific conditions (see ESPP eNews n°88) and manure can also be used as input to CMC3 (composts), CMC5 (digestates), CMC14 (pyrolysis materials) under conditions. This webinar discusses the regulatory mechanism of these authorisations, ABP 'End Points', interactions with national fertiliser regulations and other regulations, sterilisation and hygienisation conditions, temperature-time conditions, use conditions, post-processing, packaging and storage obligations, certification documentation, how manure-derived recovered nutrients are in some cases authorised under other CMCs (e.g. recovered ammonia salts from offgases under CMC15).

Webinar 1st July 2024 - watch replay and read transcript https://www.youtube.com/watch?v=HsUrwXJB_4w

"Processed Manure" in consolidated EU Fertilising Products Regulation (FPR)

The online consolidated version of the FPR has been updated to include "Processed Manure" in CMC10, as specified in the Delegated Regulation 2024/1682 (4 March 2024), see ESPP eNews n°88. The first batch of other materials which will hopefully be soon added to CMC10 are still under assessment (see QLab webinar above). ESPP recommends to users to always refer to the "consolidated" version of the FPR, in order to avoid working with outdated texts which do not take into account recent amendments (despite the consolidated version is only for guidance and does not include the recitals of the amending regulations). Note that CMC11 (By-Products) Regulation 2022/973 is NOT (and will not be) integrated into the consolidated FPR (for legal reasons) so should be consulted separately for CMC11. Also note that the link below to the consolidated FPR is to the CURRENT version: on opening this link, you should verify if there is not a more recent version (under "Hide all versions" on left hand side of page).

Consolidated EU Fertilising Products Regulation, consolidation of 3/7/2024 HERE.

Policy and regulations

European Commission further actions for failure to implement water policies

The EU continues to engage new infringement procedures against Member States for not fully implementing EU water policies, allowing pollution and deterioration of water bodies, including by phosphorus and nitrogen.

Failures to adequately collect and treat sewage or reduce agricultural nitrogen pollution are progressively being resolved, although this has in some cases only been after the European Commission engaged legal action at the European Court of Justice (ECJ): e.g. Belgium - ECJ C-395/13, France, Hungary - ESPP eNews n°56, Spain, Italy, Poland - ESPP eNews n°25, Germany – Euractiv 1/6/2023.

Implementation of the 1991 Urban Waste Water Treatment Directive (that is before the recently decided revision) and the 1991 Nitrates Directive both still remain incomplete. Over the last year, the Commission has engaged actions against:

- Slovakia: insufficient sewage collection for six agglomerations – INFR(2021)2147
- Belgium (referral to ECJ): nitrate pollution in the Flanders region "*successive Flemish nitrate action programmes [Nitrates Directive] have failed to deliver results and, to date, pollution levels remain excessively high, posing a risk to humans and the environment*".- INFR(2022)2051
- Greece (referral to ECJ): inadequate sewage collection in 153 agglomerations, inadequate secondary treatment in 143 of these, failure to remove phosphorus before discharge into a Sensitive Area in one agglomeration – INF(2020)2021
- France (referral to ECJ): drinking water exceeding legal nitrate concentration in 107 water supply zones in seven regions (Drinking Water Directive) - INFR(2020)2273
- Cyprus: insufficient sewage collection and/or treatment for 31 agglomerations – INFR(2017)2046
- Estonia: inadequate regulation of industrial wastewater – INFR(2023)2180
- Ireland: failure to adequately treat wastewater from 8 agglomerations, failure to remove phosphorus before discharge into a Sensitive Area in a further three agglomerations – INFR(2023)2180
- Spain (referral to ECJ): continuation of infringement procedures for inadequate collection of wastewater from 29 agglomerations and inadequate treatment of wastewater from 225 agglomerations – INFR(2012)2100 updated 21/12/2023
- Portugal: inadequate secondary treatment in 15 agglomerations, failure to remove phosphorus before discharge into a Sensitive Area in three agglomerations INFR(2022)2028

The Commission has also engaged actions towards a number of Member States for inadequate implementation of the EU Water Framework Directive (2000/60) and/or the Marine Strategy Framework Directive (2008/56), concerning reporting and definition of water basin management plans, river basin action programmes and flood risk maps.

Although there remain significant failure in EU water policy implementation by Member States, the situation is worse for EU waste policy: the Commission announced in July 2024 initial opening of infringement procedures against 27 Member States for failure to meet the 2020 target to prepare 50% of municipal waste for reuse and recycling (EU Waste Framework Directive 94/62 amended by 2018/852).

'Polluter Pays' lacks implementation in EU farming and industry policies

OECD paper indicates the need to improve coherence between EU agriculture and industry policies and the 'Polluter Pays' principle set by the Water Framework Directive. The 'Polluter Pays' principle was established by the OECD in 1972 and then as one of the 27 guiding principles of the UN 'Rio Declaration' 1992. The EU Water Framework Directive (WFD 2000/60) art. 9 fixes the "principle of recovery of the costs of water services, including environmental and resource costs, … in accordance in particular with the polluter pays principle". The OECD's 50-page analysis discusses challenges to implementation, including the distinction between water service users (paying water fees) and polluters. In particular, farmers using fertilisers or phytochemicals (diffuse pollution) will not pay environmental or depollution costs via water use fees. The OECD paper identifies pesticide taxes in place in Sweden and Denmark, a nitrate fertiliser tax in France only and a tradable phosphates quota system in The Netherlands. However, diffuse pollution is causing WFD quality status failure in nearly 40% of EU surface waters. In France, removal of nitrates and phytochemicals from drinking water costs 0.5 – 1 billion €/year (not considering environmental costs of water body quality degradation) whereas the nitrates tax revenue is <0.2 billion €/y. A study in Denmark estimated that a 150% tax on nitrates fertilisers would be needed to reduce losses by -30% (water quality target). The paper notes that cross-compliance introduced into the EU Common Agricultural Policy (that is, farmers must respect environmental legislation such as the Nitrates Directive or Water Framework Directive) to receive farm subsidies face difficulties of implementation, in particular identification of individual farmer responsibility in diffuse pollution. Also, CAP penalties are considered inadequate to ensure compliance. Measures such as obligatory balanced farm fertiliser plans and soil monitoring can contribute to ensuring application of 'Polluter Pays' to diffuse agricultural pollution. Nutrient credit trading programmes are noted, e.g. Great Miami River Watershed, Ohio. Identified challenges include Extended Producer Responsibility to implement

'Polluter Pays' for industrial chemicals (e.g. pharmaceuticals under the revised EU Urban Waste Water Treatment Directive, see ESPP eNews n°83) costs of 'legacy' pollution, the absence of an EU legal framework to apply 'Polluter Pays' to soil pollution.

"The implementation of the Polluter Pays principle in the context of the Wate Framework Directive", D. Sanchez Trancon, X. Leflaive, an output of the OECD Environment Policy Committee (EPOC) Working Party on Biodiversity, Water and Ecosystems (WPBWE), OECD Environment Working Papers No. 238, 23 May 2024, https://dx.doi.org/10.1787/699601fc-en

Increasing EU biomethane and digestate production

2024 "Biomethane Map" from European Biogas Association shows nearly 40% increase in EU biomethane production capacity since 2022-2023 producing nearly a million tonnes of digestate. EBA's updated map identifies over 1 500 biomethane plants across Europe, of which 80% are connected to methane compression, either for injection into the natural gas distribution network or for transport fuel. 25 billion € of private investment is already identified as secured for further plant investment, and will result in nearly 1 000 new plants by 2030. The EU objective to increase biomethane production by x10 by 2030 will be fed mainly by manure, as well as agricultural by-products and sequential crops. This will result in high-nutrient digestates. EBA estimates that by 2030 digestates in Europe will contain 4.1 Mt of nitrogen, 0.7 Mt of phosphorus and 0.4 Mt of potassium, that is around 60% of phosphorus currently used in mineral fertilisers. Today around 2/3 of digestate is used locally on fields and only around 16% is processed to fertiliser products. (See Giulia Cancian, EBA, in SCOPE Newsletter n°146 and EBA digestate report in ESPP eNews n°86).

"New edition of the Biomethane Map shows 37% increase in biomethane capacity in the EU compared to the previous map", European Biogas Association (EBA), 5th July 2024.

EU Industrial Emissions Directive (IED) – revision published

The revised IED was published on 24th April 2024, setting mandatory emissions and environmental criteria across industry, increasing emphasis on material efficiency and covering around three quarters of pig and poultry farms. The Directive is implemented by BAT (Best Available Technology BREFs, established under a JRC process, and formally adopted by the European Commission. Emission limits, environmental technologies and other standards defined in these BAT BREFs then become mandatory for all installations of the relevant industry sector across Europe (above specified size). Under the new title "Industrial and Livestock Rearing Emissions Directive", intensive pig and poultry farms (as defined in Annex Ia) will be covered from 280 – 380 LSU(livestock units). This is expected to increase the number of pig and poultry farms covered from around 35% under the current IED to 75 – 80% by 2030. Intensive cattle farms are not yet covered, but the Commission must assess this possibility by 2026. The revised Directive also increases the emphasis on materials and resource efficiency.

JRC BAT BREFs https://eippcb.jrc.ec.europa.eu/reference

Industrial and Livestock Rearing Emissions Directive (IED 2.0) 2024/1785 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AL_202401785

European Commission IED2.0 page: https://environment.ec.europa.eu/topics/industrial-emissions-and-safety/industrial-and-livestock-rearing-emissions-directive-ied-20_en

Research

Phosphorus-based superconductor material

Research shows that lead – phosphorus based material can be superconductor (zero electrical resistance) at room temperature and pressure. The "LK-99" material was synthesised from copper phosphide (CuP, a derivate of elemental phosphorus P_4) and lanarkite (a lead sulphate – lead oxide mineral). The superconductivity is considered to result from structural distortion as copper ions substitute lead ions in the phosphate lattice, enabling electron movement. This research paper provides another example of possible applications of P_4- derived chemicals in electronics developments.

"The First Room-Temperature Ambient-Pressure Superconductor", S. Lee et al., 2023. arXiv:2307.12008, DOI

Waterlogging of soil can increase plant availability of iron phosphates

In pot trials, iron II and III phosphates were not effective P-fertilisers for rice, but the P-availability was increased by 60-day waterlogging of the soil and addition of organic matter (glutamate). Three iron II (vivianite) and three iron III phosphates were pot-trialled with rice in three P-deficient soils (pH: 4.5 limed to 6.1, 6.0, 7.9, iron 0.9, 2.6, 2.9 gFe/kg). The vivianites were provided by Wetsus (recovered from wastewater), Fertiberia and laboratory synthesis. The iron III phosphates were phosphorus-loaded iron materials from drinking water treatment (two Aquaminerals, one from NeReDrain agricultural drainage P-trap). In the pot trials, the iron phosphates were compared to triple super phosphate (TSP) at the same P application rate plus a control (no added P). N, K and micronutrients were added in all cases. The rice pot trials (21 days) showed in all cases plant P uptake considerably lower than with TSP and generally not higher than for the control (no added P), in all three soils for all the iron phosphate materials tested, both in pot trials with waterlogged and non-waterlogged soil. In longer soil incubation tests (60 days), with waterlogged soil, the different iron phosphates did show P-release (increased soil $CaCl_2$ extractable P) compared to the control, in two of the three soils (not in the limed acidic soil), in particular when organic matter was also added (glutamate).

"Increasing phosphorus fertilizer value of recycled iron phosphates by prolonged flooding and organic matter addition", R. Saracanlao et al., Pedosphere 34(3), 2022, pp 631-640. DOI

Nutrient flows studies

Landfilled P in Rimini province (Italy) could meet 96% of crop demand

Of nearly 240 tP/y entering the system, c. 80 tP/y accumulate in soils or are lost to water bodies. Recovery of P from digested sewage sludge would meet up to 96% of the annual P demand for crops, but this flow is currently landfilled.

Material flow analysis has been applied to characterise the 2020 phosphorous cycle in the seven municipalities of the Rimini province (Italy) and the State of San Marino. The area is served by the Santa Giustina wastewater treatment plant (560 000 p.e.), where sewage sludge undergoes anaerobic digestion. Two phosphorus flow analysis studies from the literature were used as archetypes for the modelling of the system (van Dijk et al., 2016 and Koppelaar and Weikard, 2013), and data were gathered from databases, inventories and statistics (from EEA, ISPRA, ARPA, USDA, …), and complemented with literature searches including ESPP Fact Sheet. The model showed that 236 ± 23 t P enter the system annually, of which 122 ± 12 t P/y from fertilisers applied to agricultural soils (producing wheat, lettuce, alfalfa, and grapes), and the remainder from imported food products, animal feed supplements for livestock, and household chemicals. The greatest P flow within the system (158 ± 31 t P/y) is from the agricultural soils to the harvested crops, even though a net accumulation in soils of 15 ± 23 t P/y was estimated by the model. The P consumed by the population is excreted into the sewage system, along with P from household chemicals, for a total of 142 ± 3 t P annually, corresponding to the recovery P potential at theoretical 100% efficiency rate. In 2021, current treatment technologies at the WWTP allowed the removal of about 117 ± 2 t P/year from wastewater (removal efficiency rate of 82%). This amount of P could theoretically meet up to 96% of the annual demand of mineral fertilisers in the system, but currently goes to landfill. The P discharge after water treatment is 25 ± 3 t P/y and adds to P leached flow from crop production (45 ± 8 t P/y). The resulting net P input to water bodies of 66 ± 8 t P/y and runs off to natural water bodies.

"Phosphorous flow analysis and resource circularity at the province level in north Italy", C.M. Duque Torres et al., Sustain. Chem. Pharm. 33 (2023) 101133 DOI

Low nutrient use efficiency in Flanders (Belgium)

Detailed N and P flow analysis for the livestock-intensive region of Flanders shows low nutrient use efficiency (11% N, 18% P). Recycling/reuse could be increased from 35% N and 37% P of system inputs to 45% N and 48% P.

A recent study (Vingerhoets et al., 2023) modelled 40 sectors and processes, examining over 1 800 nutrient flows within the Flanders region. This included the fate of nutrients post-consumption, using data from various sources like government agencies, farming industries, treatment facilities, and households. The study builds on Coppens et al. (2016), which analysed nutrient flows in the same region for 2009, quantifying 160 N and P flows across 21 compartments. The 2016 study found 20 kgN/cap/y and 0.53 kgP/cap/y were emitted to the environment, lower than the EU averages. Crop and livestock production were the main contributors to emissions. In crop production, animal manure supplied 55% of the N and 87% of the P demand for fertilisers, contributing significantly to environmental nutrient losses. Inorganic fertilizers accounted for 32% of N and 6% of P. Despite advancements in waste management, only a small fraction of nutrients in waste streams were recycled (17% N and 12% P).

Vingerhoets et al. (2023) estimated a total system input of 87.9 ± 2.4 kgN/cap/y and 13.9 ± 0.4 kgP/cap/y, mainly from imports of plant and animal products (50% and 53% of N and P inputs), mineral fertilizers (21% N, 4% P), and animal feeds (18% N, 20% P). Compared to 2009, N and P inputs decreased (87.9 vs. 130 kgN/cap/y and 13.9 vs. 19 kgP/cap/y). Nutrient inputs were exported in food products (19% N, 20% P), feed (8% N, 11% P), side streams (including manure, 27% N, 61% P), lost to the environment (39% N, 4% P), or accumulated in soils (7% N, 4% P). Feed flows were dominant due to intensive livestock production. About one-third of consumed nutrients were assimilated into animal products, with the remainder in animal manure, reused for crop production, processed, or exported. The model showed a low nutrient use efficiency of 11% for N and 18% for P. Currently, 55% of 59.6 kgN/cap/y and 56% of 10.0 kgP/cap/y in recoverable streams are recycled or reused, providing 35% and 37% of total N and P input, respectively. Implementing recovery technologies for untapped recoverable streams (e.g., treated municipal wastewater, dried and exported poultry manure, activated-sludge treated pig and cattle manure, and point source NH_3 emissions) could increase recovery efficiency by 22.7% for N and 17.6% for P, enhance reuse efficiency by 14.6% for N and 24.4% for P, and replace 45% of external N input and 48% of external P input.

"Detailed nitrogen and phosphorus flow analysis, nutrient use efficiency and circularity in the agri-food system of a livestock-intensive region", R. Vingerhoets et al., J. Clean. Prod. 410 (2023) 137278 DOI

"Follow the N and P road: High-resolution nutrient flow analysis of the Flanders region as precursor for sustainable resource management", J. Coppens et al., Resour. Consev. Recycl. 115 (2016) 9-21 DOI

Potential to recycle P will increase in Montreal (Canada) by 2050

Over 80% of imported P is landfilled, 17% flows to the Saint Lawrence River, and less than 3% is available for recycling. There is potential to recover P from wastewater and solid organic waste and to reduce P flows to landfill by up to 95%.

The study presented a P flow analysis in the island of Montreal (Canada) in the year 2014, and explored possible flow modifications in the 2008-2050 period following potential policy changes and shifts in social behaviour. The study focussed on the food, wastewater, and waste management sectors, not calculating inputs and flows related to pet food and pet waste, household products containing P, and other flows. The geographical system boundary for the analysis was the island of Montreal, therefore flows associated with food systems operating exclusively off-island were not considered. P concentrations, quantities, and flow rates were based on peer-reviewed literature and published government reports. Site-specific data were used when possible, supplemented by provincial or national values. Results showed that approximately 3% of imported P (from food, feed and fertilisers) is being recovered in compost, with only 0.2% being recycled to urban food production. The majority of P is accumulating in landfills (c. 85%, mostly as sewage sludge), while 17% is exported to the river. At present, there is c. 1.7 ktP/y in organic waste streams, of which c. 2/3 is in sewage and c. 1/3 is in organic wastes. The amount of organic solid waste (food, leaves, and yard waste) being collected is expected to increase. The amount of compost produced from these solid wastes is predicted to eventually exceed the needs of on-island agriculture, resulting in available P for off-island markets.

"Dynamic simulation of phosphorus flows through Montreal's food and waste systems", Treadwell et al., Resour. Conserv. Recy. 131 (2018) 122–133, DOI

Phosphorus management in Spain could increase efficiency and reduce losses

P flow analysis (PFA) suggests that Spain's current P cycle is not efficient with significant losses and soil accumulation. However, data incoherences mean that precise conclusions cannot be drawn.

A phosphorus flow analysis conducted for Spain (19 autonomous regions plus Baleares and Canarias islands) for the year 2012 suggests that a net total of 215 kP/y was imported by Spain (imports – exported products). The numbers given suggest that one third of this is accumulating in stockpiled food and animal feed products. This would mean* that around a quarter of Spain's food and animal feed production was being stockpiled, which seems unlikely. The PFA also suggests that over half of compost production was stockpiled (13 ktP/y accumulation in compost), also unlikely, as well as accumulations in industrial chemicals and fertiliser stocks. As indicated by the authors, these apparent accumulations are probably due to "partial information" rather than reflecting reality. This suggests that the PFA estimates for losses of phosphorus to water (45 ktP/y, of which 32 ktP/y from sewage works and 13 ktP/y from agricultural land) and for accumulation in soils (42 ktP/y) are probably too low.

These incoherences mean that the authors' conclusions concerning efficiency of crop and animal production P use, and comparisons with efficiency in other countries, are not meaningful: it seems likely that much of the apparent "accumulation" of P is in reality P being lost to water or accumulated in soils.

The PFA numbers indicate that input to agricultural land (340 ktP/y) consisted of mineral fertilisers (48%), animal manure (39%), urban sewage sludge (10%), compost and others (3%). Fertiliser use data (kgP/ha applied) indicated an overdosing trend in Spain, up to 4 times the average for EU-27, with a ratio of applied mineral fertilisers to total fertiliser application close to the EU-27 average. 60% of the P received by wastewater treatment plants is removed in sewage sludge and around 69% of the sewage sludge was recycled to agriculture.

** comparing P shown as stockpiled to P shown as input to "Food and feed" in fig. 1.*

"A Phosphorous Flow Analysis in Spain", J. Álvarez et al., Sci. Tot. Env. 612 (2018) 995-1006 DOI

High P inflow and storage in Gippsland's agricultural system (Australia)

A six-year (2008–2013) P flow analysis in Gippsland, Australia, found that c. 70% of annual P inflow was stored within the region, and that the per capita P inflow (60 kg P/y) was remarkably higher than other regions (1.6-20.7 kg P/y).

In Gippsland, an intensive agricultural food-producing region of Australia, most of the annual inflow, outflow, and storage of P in the region is associated with the livestock farming system. The annual inflow of P primarily comes from commercial fertilisers for pastures (66% of the 15 ktP/y total input) and livestock feed (29%), while livestock products account for 94% of the mean annual total outflow (c. 4 ktP/year). The majority of P storage (66%, c. 7 ktP/year) is in livestock farm soils, where cattle excreta accumulate. These findings are consistent with previous flow studies (summarised in SCOPE Newsletter n° 77 and 95), indicating that Australia is a significant P importer, with livestock production accounting for a large share of the country's P consumption, including fertilised pastures and animal feeds, and that P in animal manures mostly accumulates in the soils of pastures. Over the study period, over 65 ktP accumulated in the region, and c. 3 ktP were lost through soil erosion and runoff. Both the annual inflow and storage of P in the Gippsland region and the livestock farming system showed a decreasing trend over the study period, while the annual outflow remained nearly the same. This suggests improved P management, coinciding with several initiatives for sustainable nutrient management in the region's dairy farms. Despite these improvements, c. 0.5 ktP annually entered water bodies from different subsystems, negatively impacting the aquatic environment. Additionally, nearly half of the annual total P inflow in the waste management system remains unrecovered or unutilised, ending up in landfill or the environment as disposal of garbage (from solid waste streams), wastewater, and sewage sludge.

"A multi-year phosphorus flow analysis of a key agricultural region in Australia to identify options for sustainable management", R. B. Chowdhury et al., Agric. Sys. 161 (2018) 42-60 DOI

Phosphorus use efficiency trends across thirteen countries

Agricultural phosphorus use efficiency in thirteen countries averages c. 45%. It is higher in crops & pastures (c. 70%) and lower in the livestock sector (c. 20%).

The study reviewed national scale P flow analyses to compare the major key P inflows, outflows, and P use efficiency (PUE*) in the crop-pasture, livestock and overall agricultural production sectors across various nations**. National flow studies were selected among peer reviewed single- or multiple- years flow studies published between 2005 and 2020, considering agricultural flows including crop, pasture and livestock production, and from which quantitative data were available.

1. Crop-pasture sector: mineral fertilisers and livestock manure account for c. 90% of the annual total P inflow in all considered countries. PUE in this sector ranges from 25 to 85%, with European countries showing higher PUE (66-85%) due to significant P inflow from animal manure, and therefore higher P recovery and recycling. Countries like Japan, South Korea, Finland, Portugal and Norway exhibit high soil P storage (>50% of inflow) and lower PUE (25-50%).
2. Livestock sector: P inflows mainly come from livestock feed from pasture/crop production (e.g., France, Bangladesh) and feed industry (e.g., China, Netherlands, Portugal). Total P outflow (livestock manure and products) was almost equal to the inflow, indicating almost no or low storage (ESPP note: logically the only “losses” in livestock are in bones and other non-food parts of the animal). PUE ranged from 2% (Bangladesh) to 34% (Netherlands), averaging 18%. Higher PUE is noted in Pacific and European countries, attributed to higher P outflow as livestock products for food production. However, authors excluded this flow from the calculation due to the uncertain fate of P in manure, which can be wasted or lost.
3. Overall agricultural sector (including crop-pasture and livestock sector): P inflows are primarily from mineral fertilisers (China, India, Bangladesh) and imported feed (Germany, Netherlands, Switzerland and Norway), with major outflows being crop/plant and livestock products. PUE ranged from 22 to 76%, averaging 46%. Countries with higher PUE (i.e., EU countries) often recycle P from organic waste streams, and show high PUE in the crop-pasture subsystem.

Given the positive correlation between high PUE in the crop-pasture subsystem and high PUE in the overall agricultural sector, the authors conclude that applying P fertilisers for producing more plant-based food than animal feed/pasture for generating animal-based food could reduce P input and improve PUE in the overall agricultural production system. They also underline the potential for improving PUE in the agricultural system of Asian countries by reducing the use of mineral fertilisers and enhancing the use of livestock manure through recovery and recycling, following many EU-countries example.

** Definitions of P use efficiency (PUE), as reported by the authors for the sector of:*

- *crop production: conversion ratio of the total P input into useful plant exports (e.g., harvested crops)*
- *animal/livestock production: conversion ratio of the total P input into useful animal/ livestock products (e.g., milk and meat)*

*** Selected national P flow studies: Bangladesh, China (summarised in ESPP Scope Newsletter 128), India, Japan, South Corea, Australia (see Scope Newsletter 95), New Zealand, Austria (see Scope Newsletter 143), Finland, France (see Scope Newsletter 104) , Germany, Netherlands (see Scope Newsletter 105), Norway (see Scope Newsletter 123), Portugal, Spain (see summary above), Sweden, Switzerland (see Scope Newsletter 128), Turkey, UK (see Scope Newsletter 113) and USA. Only 13 countries were considered for PUE comparison in the overall agricultural sector.*

“Phosphorus use efficiency in agricultural systems: A comprehensive assessment through the review of national scale substance flow analyses”, R. B. Chowdhury et al., Ecol. Indic. 121 (2021) 107172 DOI

Phosphorus flow studies previously summarised by ESPP

State/Region/City	**eNews**	**SCOPE Newsletter**	**State/Region/City**	**eNews**	**SCOPE Newsletter**
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