ESPC4 and PERM5, Vienna, 20-22 June 2022

VIENNA 20 - 22 June 2022 ESPC4 European Sustainable Phosphorus Conference

The 4th European Sustainable Phosphorus Conference (ESPC4) will be the biggest phosphorus stakeholder meeting globally for 4 years (since ESPC3 Helsinki, which attracted 300 participants from 30 countries SCOPE Newsletter n°127).

ESPC4, Monday 20th and Tuesday 21st June 2022, will be followed by **PERM5, the 5th Phosphorus in Europe Research Meeting**, Wednesday 22nd June 2022 (summary of PERM4, June 2021, online, coming soon here).

ESPC4 will include a **Nutrient Recovery Technology Fair**, with stands, presentations and possibility to meet technology suppliers presented in the ESPP-DPP-NNP Catalogue of Nutrient Recovery Technologies, currently being updated (see below).

ESPC4 - PERM5 will be both in-person in Vienna and accessible online.
The updated outline programme of ESPC4 and a call for abstracts for presentations and posters for ESPC4 are now online https://phosphorusplatform.eu/espc4

EU consultation on "Taxonomy"

P-recovery in EU list of top-100 green activities … but clarifications needed

The EU Taxonomy will classify which economic activities, and when, are considered environmentally sustainable, so eligible for EU Green Deal investment. It may become a key tool for private investors, markets, other public policies. Phosphorus recovery from sewage is one of the 100 activities listed (at the same level as e.g. livestock production, crop production, hotels and accommodation …) but N-recovery or P-recovery from other streams is not cited.

Consultation open to 24th September 2021, 18h00 deadline (not midnight).

The unified EU-wide classification system ("EU Taxonomy") will establish an operational list of economic activities, with technical screening criteria (TSC), determining in which cases each economic activity makes a 'substantial contribution' to an environmental objective. The Taxonomy Regulation (2020/852) defines six eligible environmental objectives: Climate change mitigation, Climate change adaptation, Water and marine resources, Circular economy, Pollution prevention and control, Biodiversity and ecosystems.

The EU has now published a report (over 1 000 pages including the annex) proposing criteria for classifying when a wide range of different industries and activities can thus be considered environmentally friendly, covering (amongst many others) agriculture (both livestock and crop production), sewage treatment, waste management ... The report and its annex propose TSC (Technical Screening Criteria for "substantial contribution" to sustainability) and criteria for DNSH (Do No Significant Harm, under Pollution Prevention and Control).

The consultation, based on the published report draft Taxonomy categories and criteria, enables public comment, for each of the nearly one hundred activities / industries listed, to comment on the description/boundaries of the activity and the proposed criteria (TSC and DNSH): ambition level of criteria, key factors missing from criteria, feasibility of implementation, comparison to state of the art, scientific justification, possible improvements of wording or clarifications.

Phosphorus recovery from waste water is one of nearly one hundred activities for which Technical Screening Criteria are proposed (Annex B, pages 922-927).

However, the proposal is limited, somewhat imprecise and in places confused:

- It refers only to P-recovery from municipal wastewater (it is under $12: "Sewage")
- Only P-recovery, recovery of N or other nutrients or organic carbon are not considered
- Only two specific routes are considered:
  - P-recovery integrated into the wastewater treatment plant, with recovery of >10% of inflow sewage works P (e.g. struvite)
  - P-recovery from sewage sludge mono-incineration ash by chemical or thermal process, with recovery of > 80% of inflow
- The text inappropriately compares energy consumption in the above P-recovery routes to that in production of P_4
- It seems to be assumed that all recovered P materials will be used as fertiliser, whereas recovered phosphoric acid can be used in high added-value technical applications
- Close reference is made to the German P-recovery legislation, but no mention of the Swiss legislation, which is of interest as regards implementation and state-of-the-art even if not in the EU
- No requirements, or inappropriate, are proposed on contaminant separation in the recovery process, safety and quality of the recovered P product (it is stated that it will be "*a material with a real market demand ensuring its reasonable use*" but then conformity only to the old EU fertilisers regulation 2003/2003 is specified)

ESPP will input to this consultation addressing the questions above.

ESPP members and other stakeholders reading this eNews are recommended to reply to this EU public consultation, suggesting other technologies for inclusion in this section on "P-recovery", inclusion of technologies for N-recovery, or suggesting inclusion of nutrient recovery in other sections, e.g. 1.1 Agriculture – animal production; 2.19 – Manufacture of food & beverages – circular economy; 11 - Water supply / desalination; 13.5 – Recovery of bio-waste by AD and/or composting; 13.8 – Material recovery of non-hazardous waste.

For water, the proposed criteria are based on achieving good environmental status of fresh or marine waters (as defined under the Water Framework and Marine Strategy Framework Directives), or preventing deterioration of waters in good status.

For agriculture, proposed criteria for both animal and crop production include limiting nutrient losses, in particular by a farm-gate nitrogen balance and minimum nitrogen use efficiency (NUE). ESPP will input that these criteria should be widened to include phosphorus. A livestock feeding plan, specifying feed nutrient content, and an annual crop nutrient management plan, including soil testing every 3-5 years for N and every 5 years for P, are also indicated under DNSH.

*EU public consultation on "Taxonomy", **open to 24th September 18h00 CEST** (not midnight). This page includes overview, links to the report and annex with proposed categories and criteria, and link to the public consultation questionnaire: https://ec.europa.eu/info/publications/210803-sustainable-finance-platform-technical-screening-criteria-taxonomy-report_en With thanks to EBA for alerting ESPP to this consultation.*

Other events

DPP Forum (German Phosphorus Platform)

9th September Frankfurt-am-Main and online. Bringing recycled phosphates to the market. In German

Programme and registration here.

Hamburg Wasser – EWA – VSA online workshop on P-recovery

21st September 10h30-13h00, online broadcast from the Remondis P-recovery plant, Hamburg, Germany: first full-scale operational experience of P-recovery in Hamburg, update on P-recovery in Switzerland, etc. The event is organised by Hamburg Wasser (city-owned municipal water company), with EWA (European Water Association, a water profession association with members across much of Europe) and input from VSA (Swiss Association of Water Protection Professionals)

Registration here.

Phos4You Final Conference

22 – 23 September, presentation of Phos4You (InterReg) project outcomes, presentations of trials of P-recovery technologies, regulatory developments, LCA aspects. With European Commission DG GROW and DG AGRI and InterReg Secretariat. Technologies presented will be: EuPhoRe, bioacidification & STRUVIA struvite, PULSE (Liège University), Parforce, Filtraflo (crab carapace P-adsorption), micro-algae.

In-person capacity is now fully booked, but online registration is still open. Phos4You website for programme etc. Registration here.

CRU Sustainable Fertiliser Production

Online industry conference addressing fertiliser industry carbon footprint, emissions tax systems, Green and Blue Ammonia and Hydrogen, CO2 capture and (23rd September afternoon) phosphogypsum recycling and P-recovery

20-23 September, online https://events.crugroup.com/sustainableferttech

European Wastewater Management – full day on phosphorus

28-29 September, Birmingham UK and online, European Wastewater Management Conference (EWWM, AquaEnviro) with a full day (28 September) on P-removal and P-recycling. Updates on technologies to achieve low phosphorus discharge constraints and on catchment P management, from Welsh Water, United Utilites, Yorkshire Water, Severn Trent Water, Thames Water and from technology suppliers / deliverers Arvia, Stantec, Brightwork BV, Bluewater Bio, Evoqua, WPL.

EWWM, 28-29 September 2021 https://ewwmconference.com/

SPA "Legacy Phosphorus" webinar

30th September, 18h-19h30 CEST (Brussels/Paris summer time), organised by the US Sustainable Phosphorus Alliance. The webinar aims to describe the global magnitude of the "legacy P problem", where phosphorus from past applications overwhelms soil P storage capacity and leaks into surface waters, to discuss soil chemistry of "legacy P" and techniques for dealing with the resulting P losses to water bodies. With Dean Hesterberg, Brazilian Center for Research in Energy and Materials, Isis Scott, University of Maryland, and Jean-Olivier Goyette, University of Montreal.

Online, free, information and registration here:
https://asu.zoom.us/webinar/register/WN_I_KBf7BQSJeShoGrXskmIg

Calls for input

Update and new entries for Catalogue of Nutrient Recovery Technologies

ESPP, DPP and NNP are updating the Catalogue of Nutrient Recovery Technologies summarising processes for recovery of nutrients from sewage, manure or other sources. Information is invited on technologies to be added. To be included, technologies should be operational or demonstrated at full-scale or pilot scale, and should recover phosphorus, nitrogen, potassium and/or micro-nutrients. The catalogue provides practical data and information on: technology supplier(s) (website, contact), process input materials (sewage sludge, ash, manure …), output products (nutrient content, organic carbon content and other properties), process description (in particular indicating fate of contaminants), current operating status (number and capacity of plants operating, capacity of pilots and duration of continuous operation) and photos of installations.

To include further technologies in the Catalogue: *send information, as specified above and if possible in the format of (column titles) the Catalogue as currently online here to info@phosphorusplatform.eu*
ESPP - DPP - NNP Catalogue of Nutrient Recovery Technologies: http://www.phosphorusplatform.eu/p-recovery-technology-inventory

Call for abstracts: ESPC4, Vienna 2022

A new call for abstracts for presentations and posters is now open for the 4th European Sustainable Phosphorus Conference, Vienna 20-22 June 2022. Deadline 30th November 2021. Proposed presentations should address the conference parallel session themes (see updated outline programme here): Policy tools and business models, Climate change links to phosphorus management, New fertilisers for nutrient sustainability, P-recycling R&D and new technologies, Regions in action for phosphorus sustainability. Posters can address any theme relating to phosphorus sustainability. Abstract submission instructions are on the conference website here.

ESPC4 – PERM5 website: https://phosphorusplatform.eu/espc4

ESPP new Member

RecaP innovation training network (EU Marie Curie)

The RecaP project, an H2020 MSCA-ITN led by University of Southern Denmark (SDU), will train 15 PhD students with support from 23 industrial and research organizations in 10 countries. RecaP stands for "Capture, recycling and societal management of phosphorus in the environment" and aims to contribute to sustainable phosphorus changes across the globe. Our international collaboration addresses the world's changing Phosphorus needs by creating a new generation of Phosphorus specialists to become 'knowledge brokers' across disciplinary silos with their interdisciplinary skills, experience and networks, ensuring transformative changes in P sustainability in the EU. RecaP will not just explore the technical aspects of the global P challenge, but also where such solutions can be implemented in a way that is socially, economically, and environmentally acceptable. The 15 PhD projects fall into one of five themes: the capture and recycling of P from wastewater and freshwater systems, novel P recovery techniques, strategies to improve crop utilization of P, novel freshwater restoration techniques, and barriers and enablers to policy and economic transformation to support recycling. All activities are connected to one another in order to create novel insights that can help create new P governance.

By becoming a member of the ESPP, RecaP joins the strong collaboration of partners contributing to a long-term vision for phosphorus sustainability in Europe and the world.

The RecaP project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956454. Website.

Policy

EU consultation on water pollutants

The EU has opened a public consultation to 1st November 2021 on pollutants to surface and groundwaters, asking about types of chemical, sectors, types of regulation and possible sources of further information. The consultation, set in the context of the Green Deal and the Zero Pollution Action Plan, is open to both the general public and to stakeholder organisations, and is mainly general questions asking about defining priorities for concern. Chemicals and sectors mentioned include agriculture, fertilisers, pesticides, waste water treatment, pharmaceuticals, micro-plastics, household chemicals, chemicals released from household items (e.g. flame retardants). The 'Roadmap' prior to this consultation (10/2020) suggests that regulatory policy options after this consultation could include modifications of the current lists of chemicals designated as 'Priority Hazardous', 'Priority', 'Watch List' or Groundwater 'Pollutants' lists under the Water Framework, Environmental Quality Standards or Groundwater Directives. Currently the EU Water Framework Directive "Watch List" includes certain pharmaceuticals (e.g; Diclofenac (anti-inflammatory), Ethinylestradiol (contraceptive) …). Phosphorus is listed in the Groundwater Directive since 2014, so requiring Member States to define threshold values and monitor concentrations of phosphorus (P) in groundwater.

Water Framework Directive "Priority" and "Priority Hazardous" substances list as specified by Annex II of Directive 2008/105/EC and eight other substances for which environmental quality standards for these substances are included in the Environmental Quality Standards Directive 2008/105/EC: https://ec.europa.eu/environment/water/water-framework/priority_substances.htm
Surface water chemicals "Watch List" COM 2018/840 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018D0840
Groundwater Directive 2006/118/EC list of "Minimum list of pollutants and their indicators for which Member States have to consider establishing threshold values" (Annex II, Part B) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02006L0118-20140711
Directive on Environmental Quality Standards (Directive 2008/105/EC) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0105
***EU public consultation, open to 1st November 2021**: "Integrated water management – revised lists of surface and groundwater pollutants" LINK.*

EU call for experts for EGTOP (Organic Farming)

Call for applications for selection of members of EGTOP, the Expert Group for Technical Advice on Organic Production, open to 15th September 2021 here.

EU consultation on the Marine Strategy Framework Directive (MSFD)

The EU has opened a public and stakeholder consultation to 21st October 2021 for the review of the MSFD, noting that Member States were supposed to achieve marine Good Environmental Status by 2020. Questions address the state of Europe's marine environment, definition of Good Environmental State (GES) and is this definition clear and coherent, effectiveness of different policy actions, obstacles to achieving GES, benefits of the Directive, resources allocated by Member States for MSFD actions, coherence with other EU policies, added value of the Directive. Two questions specifically mention nutrients: proposed actions the public is ready to do (proposed option: eat less meat and fish, so reducing nutrient losses) and 'Descriptors' characterising Good Environmental Status for marine waters (one option: excess nutrients). ESPP will input underlining the need to reduce N and P inputs to coastal waters, with Marine Region nutrient reduction targets, coherent with the Farm-to-Fork -50% nutrient loss target 2030, and actions in EU agricultural and water policies. ESPP will also emphasise the links between coastal eutrophication and climate change.

*EU public consultation, **open to 21st October 2021**: "Protecting the marine environment – review of EU rules" LINK.*

Consultation on EU Ecolabel for Growing Media and Soil Improvers

Comments are open to 19/9/2021 on draft revised EU Ecolabel criteria for Growing Media and Soil Improvers. Resource-efficient use of nutrients is emphasised and some % recycled materials requirements are proposed. The proposals, however, in fact suggest a minimum 30% of "organic" components (not necessarily recycled) or alternatively a minimum 30% recycled content of mineral components. Furthermore, these requirements are proposed for Growing Media only, not for Soil Improvers. ESPP will input suggesting that the proposed 30% minimum content of recycled or secondary materials should apply to both organic and mineral components, and also specifically to nutrients (P and N) where significant in the product. ESPP will also comment regarding definitions of phosphorus content, definition of "organic" and "biological origin" (exclude "fossil" materials) and coherence of specifications with the EU Fertilising Products Regulation.

*Draft revised EU Ecolabel criteria for Growing Media and Soil Improvers (download the document titled "ANNEX_Stakeholders consultation July – September. Draft proposal of the Commission Decision that establishes EU Ecolabel criteria for growing media and soil improvers" and the document "Table for comments" necessary to submit your comments). **Deadline 19th September 2021** https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/450/documents*

European Commission "MSA" for P_4

The EU (JRC) has published the Material System Analysis ("MSA") for elemental phosphorus (P_4 / white phosphorus), using the JRC Critical Raw Materials common methodology and drawing on the workshop co-organised with ESPP (2020, full summary, see SCOPE Newsletter n°136). The MSA for P_4 is published along with those of eight other materials added to the EU Critical Raw Materials List (CRM) in 2017 (as was P_4). The EU MSA methodology was developed by Deloitte in 2015 (see critique of the MSA for phosphate rock in SCOPE Newsletter n°119) and updated by JRC (Torres de Matos et al. 2020). It aims to provide a data set for each material for flows and stocks in the EU, so highlighting hotspots, bottlenecks and possibilities for circularity.

The elemental phosphorus (P_4) MSA identifies that although this represents only 2-3% of total phosphate rock use, P_4 and its derivatives are essential for a wide range of end-uses including fire safety, water treatment, catalysts, lubricants, electronics, pharmaceuticals … P_4 is produced from phosphate rock in specific high-temperature furnaces, with high energy consumption. Europe has today no P_4 furnace, and is dependent on imports, principally from Kazakhstan, Vietnam and China (not necessarily in this order of magnitude).

Many phosphorus chemicals, and also the extremely high-purity phosphoric acid needed in electronics, can only today be feasibly produced via P_4 (from P_4 or from P_4 derivatives). Because of the energy cost of P_4 production, phosphate fertilisers, animal feed phosphates, detergent phosphates (but not phosphonates) are today produced from phosphate rock via phosphoric acid ("wet acid route"), followed by purification, and this is increasingly also the case for (human) food phosphates and metal treatment. The MSA notes that use of P_4 derived chemicals in lithium-ion batteries, currently limited, may significantly increase in the future.

The MSA concludes that the EU is overall self-sufficient in manufacture of end-use chemicals reliant on P_4 / P_4 derivatives, but is entirely dependent on import of P_4 / P_4 derivatives for this manufacture.

Recycling of P_4 is today inexistent (the MSA concludes EOL-RIR and EOL-RR both zero), but JRC notes that recycling of P-based flame retardants may develop, and that several projects are looking at producing P_4 in the EU from phosphorus-rich wastes, in particular sewage sludge incineration ash.

Lastly, JRC underlines the difficulties in establishing quantitative data on P_4 flows, because currently significant uses can be based on either "wet-acid" or P_4 derivatives.

"Material System Analysis of Nine Raw Materials: Barytes, Bismuth, Hafnium, Helium, Natural Rubber, Phosphorus, Scandium, Tantalum and Vanadium", C. Torres de Matos et al., European Commission JRC, EUR 30704 EN, 2021 DOI

EU legislative proposals to further sewage circularity

Eureau, the European water sector federation, has proposed changes to EU water and waste regulations to facilitate recycling from sewage. Eureau says the objectives of sewage sludge recycling, stated in the Urban Waste Water Treatment (UWWTD) and the Sewage Sludge Directives should be grouped and clarified in one legal instrument. Industrial Emissions Directive (IED) obligations concerning emissions of industrial chemicals into municipal sewage networks should be tightened to ensure better upstream information of water operators and to exclude all risks of discharge of SVHC (Substances of Very High Concern). Regulatory status of anaerobic digesters treating a mixture of sewage sludge and other organic materials should be clarified. End-of-Waste criteria should be developed for materials recovered from sewage.

Eureau July 2021: Position paper "Enabling the circular potential of sewage sludge within the EU legislative framework. A critical analysis of the current urban waste water treatment sludge legislation with respect to the circular economy" www.eaureau.org and direct link HERE.

Global action on phosphorus

Status of development of the Irish Nutrient Sustainability Platform

Following stakeholder meetings, this all-Ireland platform aims to support nutrient circularity and expects an initial 20+ paying members. The all-Ireland Nutrient Sustainability Platform (INSP) project was initiated with an Ireland EPA study in 2014. This led to a "Founders Day" stakeholder meeting in 2019 with nineteen industry, governmental and academic organisations present. This Day validated a platform vision and mission, a proposed structure, budget and funding model. The aim is to employ a full-time platform manager. The budget, as now reviewed, aims for c. 50% funding from membership fees (approx.. 20 members), and the remainder from research grants or projects. Signature of members is now ongoing.

"An Irish Nutrient Sustainability Platform to underpin sustainable development", Ireland EPA Report n°381, June 2021, V. O'Flaherty et al., 51 pages HERE.

EU Environment Agency: nutrient and carbon recycling from sewage sludge

The Agency estimates that P-recovery from 50% of the sewage sludge currently not valorised to farmland could replace up to 10% of fertiliser P, with potential also for recovery of N and S. The study considers that the potential of sewage sludge to increase soil fertility by input of organic carbon cannot be calculated with available data. The study is based on Eurostat data for 2018 or 2017 full implementation of the Urban Waste Water Treatment Directive requirements for sewage collection and treatment (but does not take into account possible more stringent nutrient requirements resulting from the Water Framework Directive or other policies). It assumes 100% valorisation of phosphorus in sewage sludge applied to farmland (after composting and/or anaerobic digestion), mono-incineration of 50% of sewage sludge not applied to farmland and 90% P-recovery from mono-incineration ash.

In 2017-2018, some 10.4 million tonnes (DM/y) of sewage sludge were produced in the EU (17 gDM/capita/year), with 83% of the population connected to sewerage (sewage collection systems). Destination of sewage sludge is unclear, because different Member States have categories such as "other" or "compost", but probably 48% is used in agriculture, 23% incinerated and 28% is landfilled or otherwise disposed.

The study specifically looks at four countries (Estonia, Germany, Italy and Sweden) and at two case studies of contaminants (DEHP, a phthalate used widely in PVC and benzo(a)pyrene (BaP) and polycyclic aromatic carbon released in smoke (wood and other fuels, tobacco, barbecues …).

The European Environment Agency concludes that 1% - 10% of P fertiliser used in the EU (in 2018) could be replaced by P in sewage sludge, via agricultural use and application of P-recovery to half of the ash where sludge is incinerated.

There is also potential to recover and additional 3 500 GWh electricity (on top of current production) if sludge currently landfilled or composted is instead anaerobically digested (to produce biogas methane).

Currently agricultural use of sewage sludge represents nearly 1% of EU nitrogen fertiliser use, but this could be increased if N was recovered in sewage treatment rather than denitrified to N_2 released to the air.

The report recommends:

- Improvements to sewage sludge data in Europe, in particular concerning treatment and disposal routes;
- Further analysis of the energy, nutrient and organic carbon potential of sewage sludges;
- Action to reduce contaminant inputs upstream of sewage works, and also investigation of new solutions in sewage and sludge treatment to address contaminants.

"Sewage sludge and the circular economy", European Environment Agency, N. Anderson et al., 17th May 2021, 138 pages. Online here.

Nutrient recycling

N2 Applied field trials report

ESPP member, N2 Applied has published results showing that their process treating manure resulted in higher wheat protein yields, NUE comparable to mineral N fertiliser and reduced manure ammonia and methane emissions. N2 Applied supplies on-farm units which condition and nitrogen-enrich manure (or other organic materials) using only air and electricity (see ESPP eNews n°33). The resulting Nitrogen Enriched Organic Fertiliser (NEO) has a better N:P ratio than manure. Ammonia and methane emissions in manure storage and use are avoided. In 2020, field trials were carried out using the NEO fertiliser on wheat at ten locations in Scandinavia, the UK and South Africa. Results show that the N2 Applied NEO fertiliser led nearly always to higher wheat protein content (average +41%). The trials also showed NUE (nitrogen use efficiency) comparable to mineral nitrogen fertiliser and considerably better than for manure/slurry. The trials in Sweden and in the UK also showed near zero loss of ammonia and methane with N2 Applied, compared to 0.25 kg ammonia and 0.48 kg methane loss per tonne of untreated manure (over 108 summer days).

"Performance Report 2020. NEO by N2 Applied" here.

SusPhos pilot producing phosphoric acid from sludge incineration ash

A 25 kg ash/day pilot is being tested in Leeuwarden, The Netherlands, using sewage sludge incineration ash to produce phosphoric acid. The first step of the process is based on the same overall principles as others already operational or under development (EasyMining AshtoPhos, Remondis Tetraphos, ZAR/Técnicas Reunidas Phos4Life, …): attack of the ash using acid, but the subsequent processing does not use water, relying on solvent extraction to separate out purified phosphoric acid. By-products are iron/aluminium salts (for recycling to sewage works for P-removal). Heavy metals are fixed into inert an insoluble minerals stream, potentially valorisable in construction, and iron and aluminium are removed and recovered as recyclable salts. SusPhos claim that the proprietary organic solvent and extraction process used enable production of high quality phosphoric acid and >95% heavy metal removal in a cost-effective, simple system without ion exchange or membranes In addition, the process can produce high-purity ammonium phosphates in a simple add-on step. The SusPhos process has also been adapted to use struvite as input, with ongoing development for iron phosphate (vivianite) The developers will start a 4 000 kt/y pilot in October 2021 and indicate the aim to build a full-scale plant (50 000 t/y input) in the Netherlands in coming years.

"Recycling: SusPhos maakt de fosfaatcirkel rond", VNCI Royal Association of the Dutch Chemical industry, July 2021, LINK.

Quebec: agricultural application of sewage sludge incineration ash (SSIA)

SSIA from Montreal sewage works has been used directly as an agricultural amendment since 2016 with c. 8 000 tonnes of ash applied to farmland in 2020. The ashes are classed by agronomic value (P and lime contents). A report prepared on request of the Jean-R. Marcotte wastewater treatment plant, Montreal, presents in detail the use of the sewage sludge incineration ashes as an agricultural fertiliser. 15% of the 50 000 tonnes of sewage produced by the sewage works were spread on farmland in 2020. The ashes can be sorted into three categories:

- Fertil Cendres. Minimum 0.6% "available" phosphorus (as P), pH < 11.3. This material is registered by the Canada Food Inspection Agency (CFIA) and can be used as a fertiliser.
- Fertil Cendres PLUS. Minimum 1.3% "available" phosphorus (as P). A new registration is pending.
- Liming ash. pH > 11.3

"Available" phosphorus is defined as NAC (neutral ammonium citrate) soluble, generally considered to be a good indicator of plant availability

The wastewater treatment work's sewage sludge incineration ash contains an average of 3.7% total phosphorus (P), range 1.2% - 6.5%, and average 1.9%, range 0.4% - 7.4% plant "available" (as P). The ash contains nearly zero nitrogen and only 1.2% potassium (average, as K). Because the soluble potassium is lost to water in the sewage works, the remaining K is mostly not plant available. Heavy metal and dioxin levels meet the Canada CFIA regulation requirements. The liming ash can meet the requirements of BNQ 0419-090, Quebec Standard for "Liming materials from industrial processes".

The report notes that in 2020 the agricultural use of the ash costs more than landfill disposal, but that changes in landfill tax and a tax on incineration (resulting from the Quebec Organic Matter Recovery Strategy, see SCOPE Newsletter n°134) could make the agricultural use of sludge ash cost-effective in coming years.

Hébert, M. 2021. « Recyclage agricole des cendres de boues d'épuration municipales de Montréal - État des lieux et optimisation des pratiques ». In French, 71 pages, inc. 3-page English summary. http://marchebert.ca/publications/
The report will be presented in English at the NEBRA (US North East Biosolids and Residuals Association Conference, 7th October 2021.

Research

Phosphorus in global agricultural product trade

P in traded crops and livestock products (not including P traded in fertilisers, phosphoric acid, other chemicals, phosphate rock) is estimated to be c. 16% of that in harvested biomass. This means an estimate of 17.5 MtP/y in harvested biomass, which compares to the ESPP Phosphorus Factsheet estimate of 17 – 24 MtP/y in phosphate rock mined annually worldwide. The study estimates a global cropland soil P budget (inputs, outputs) assuming losses by leaching + runoff of 12.5% (based on Bouwman 2013). P in globally traded crops and livestock products is estimated at 2.8 million tonnes P / year (2014), of which 70% in soybean (0.71 MtP/y), wheat (0.66 MtP/y) and maize (0.54 MtP/y). Only 12 countries were net P exporters and the biggest net P-exporters were the USA and Brazil, the biggest net importer was China (note: this concerns only P in crops and livestock products traded). The authors estimate that global trade in agricultural products saves net c. 0.2 MtP/y (ESPP note: c. 1% of global fertiliser use) because of different P use efficiencies between countries. The authors underline that much larger savings could be made by global cooperation to improve PUE (phosphorus use efficiency). The paper includes eleven very visual diagrams illustrating P-flows between countries, by crop type, importing and exporting countries, fertiliser savings vs. wastage.

"Influences of international agricultural trade on the global phosphorus cycle and its associated issues", F. Lun et al., Global Environmental Change 69 (2021) 102282, DOI.

Phosphates concluded to be safe as used in cosmetics

A 52-page analysis of toxicology data on phosphoric acid and 30 inorganic phosphate salts, based on over 150 references, concludes that they are safe "as used" in cosmetics. The review covers phosphoric acid and calcium, sodium, magnesium, potassium phosphates, metaphosphates and pyrophosphates. The most widely used inorganic phosphates in cosmetics are indicated to be phosphoric acid (mostly in wash-off products) and dicalcium phosphates (mostly leave-on). Dicalcium phosphate is indicated to be used at up to 50% in toothpastes. The review considers skin irritation, oral toxicity, accidental inhalation and possible long-term effects. Phosphoric acid is irritating and corrosive at low pH. The analysis concludes that all of these inorganic phosphates are safe for use in cosmetics when formulated to be not irritating.

"Safety Assessment of Phosphoric Acid and Its Salts as Used in Cosmetics", W. Johnson et al., International Journal of Toxicology 2021, Vol. 40(Supplement 1) 34S-85S DOI.
The authors are all affiliated to the Expert Panel for Cosmetic Ingredient Safety, part of the "Cosmetic Ingredient Review". The organisation is financially supported by the US cosmetics industry (Personal Care Products Council) and supported by the U.S. Food and Drug Administration and the Consumer Federation of America and its reviews are "independent" of the industry trade body.

Book chapter: phosphorus in human health

This 88-page review includes some emerging human health research areas such as phytate, phosphate polymers and phosphorus action as a signalling molecule. The authors note that levels of P in human diets worldwide are on average twice that needed by the body, posing questions of possible health effects of high P intake, especially with phosphate food additives which are much more bio-assimilable than most P in foodstuffs. Phytate, a widespread form of P in plant materials (see SCOPE Newsletter n°109) is generally considered to be not digested by humans, so that its P content is not absorbed in the gut. However, recent research shows that some phytate may be available, especially if the diet is low in calcium. Dietary phytate has benefits of reducing absorption of fat and sugar from food, but can also reduce absorption of essential minerals such as Zn, Fe, Ca. Mechanisms of P homeostasis in the body are detailed, including the roles of calcitonin, vitamin D, PTH (parathyroid hormone), GFG23 and Klotho. Possible health effects of high blood phosphorus (serum orthophosphorus = Pi) are suggested including feedback on these signalling molecules, insulin secretion, bone health, calcification of arteries and modification of vascular smooth muscle cells (VSMC), brain health (possibly linked to Pi levels in CSF – cerebrospinal fluid), kidney health, cell autophagy (self-destruction) and ageing. Inorganic polyphosphate polymers, found in mammal cells at very low levels, are an emerging area of research. They appear to be involved in energy storage, would healing and inflammation, protection of protein structure, neuron health and vascular functions. The authors suggest that more research is needed into possible health impacts of high diet P, in particular on brain health, and into possible induced changes in polyphosphate levels.

"The emerging role of phosphorus in human health", P. Bird & N. Eskin, Advances in Food and Nutrition Research, Volume 96, 2021 DOI.

Harvesting marine biomass offers nutrient and climate benefits

Blue-green circular economy: LCA for seven examples of harvesting cultivated or spontaneous biomass from the sea shows benefits for climate and for eutrophication mitigation. All cases studied were in the Baltic or Kattegat Seas. Four aquaculture cases: mariculture of sugar kelp (*Saccharina latissimi*, used for production of fuels or chemicals), blue mussels (for food, at two sites), and ascidians (sea squirts, for food). Three cases of spontaneous biomass: invasive Pacific oysters (aquaculture of this species is forbidden, but it is harvested for control purposes and then sold as food), common reed (*Phragmites*) and harvest of mixed beach-cast seaweed. LCA analysis show that the emissions of $CO_{2\text{-equiv}}$ and of phosphorus to water related to harvesting and supply chain activities are low, compared to N, P and C contained in the harvested biomass, so that all seven cases contributed positively to mitigation of eutrophication and to net climate emissions reduction, as well as bringing benefits such as improved water quality and clean seafronts. Discussions with stakeholders underlined the need to improve science evidence of benefits of such blue-green economy activities, which are often locally specific, in order to support discussions with policy makers and investors. Stakeholders noted the challenges posed by complex and outdated regulatory landscapes.

"Marine biomass for a circular blue-green bioeconomy?: A life cycle perspective on closing nitrogen and phosphorus land-marine loops", J-B. Thomas et al., Journal of Industrial Ecology 2021;1–18 DOI.

P-footprint of food in Brussels

The phosphorus footprint for Brussels Capital Region is calculated as (average) 7.7 kgP/person/year, that is ten times higher than the actual food intake of 0.7 kgP/year (1.9 gP/day). The study is based on estimated consumption of 19 different food groups, derived from the Belgian Household Budget Survey 2014, average nutrient content for each food group and estimates of P-inputs to produce each foodstuff, based on feed consumption I livestock-producing regions and fertiliser use in crop-growing countries compared to food product outputs. 60% of the inputs to food production are from manure (ESPP comment: this could be considered as "recycled P", so not as "input" to the P-footprint) and 40% from mineral fertiliser). The study assumes 100% recycling of P in food waste and sewage sludge (this optimistic assumption leads to a conservative estimate of the P-footprint (underestimate).

Most of the P inputs are for livestock production, and a shift to vegetarian or vegan diets would reduce the P-footprint to 4.8 kgPperson//year –40%) or 0.9 kgP/person/year (-90%) respectively. The authors also conclude that consuming only food produced in Belgium would increase the P-footprint because of high manure use in Flanders.

"A resource-based phosphorus footprint for urban diets", A. Papangelou et al., Environ. Res. Lett. 16 (2021) 075002 DOI.

Pyrolysis of sewage sludge eliminates organic contaminants

An up-to-date review of published data on biochars shows that organic contaminants and microplastics in sewage sludge are largely destroyed, resulting in a safe product. This is a response to the EU's decision to exclude sewage sludge from inputs to "Pyrolysis and gasification materials" used in fertilising products (EU Fertilising Products Regulation STRUBIAS criteria) and the European Commission JRC STRUBIAS report (DOI see page 138) which "*recommends that the scientific knowledge base be further developed in order to demonstrate that the use of EU fertilising products derived from (specific) pyrolysis & gasification materials does not present an unacceptable risk*". The review identifies 20 studies with data on over 100 different organic pollutants: over 50 different pharmaceuticals, PFAS, several organic consumer chemicals, dioxins, PCBs, PAHs, hydrocarbons, hormones, antibiotic resistance genes (ABRs), microplastics. This data shows that pyrolysis at 500°C (and in some cases also at lower temperatures) reduces levels of nearly all of these contaminants by >99%. In many cases, such as for microplastics or PFAS, contaminants were reduced below detection limits. Pharmaceuticals were mostly reduced by >99% to non-detectable levels. The authors note that in some cases, the organic contaminants may be not eliminated but transferred to the vapor phase. However, modern pyrolysis installations include higher temperature post-combustion, to recover energy and this will eliminate such contaminants and prevent environmental contamination.

A previous paper (2020) shows that doping sewage sludge with potassium salts before pyrolysis significantly improves the plant availability of phosphorus in biochar, as well as providing potassium to plants.

"Unlocking the Fertilizer Potential of Waste-Derived Biochar", W. Buss et al., ACS Sustainable Chem. Eng. 2020, 8, 12295−12303, DOI.
"Pyrolysis Solves the Issue of Organic Contaminants in Sewage Sludge while Retaining Carbon ・Making the Case for Sewage Sludge Treatment via Pyrolysis", W. Buss, ACS Sustainable Chem. Eng. 2021 DOI.

Struvite effective fertiliser for alfalfa, Manitoba, Canada

Recovered struvite (Ostara) improved alfalfa productivity in the field (clay soil, low phosphorus Olsen P 2.6, pH 8.1). No nitrogen fertiliser was applied (alfalfa is a nitrogen-fixing legume) to simulate Organic Farming. In the 3-year field trial, struvite increased forage shoot growth biomass and shoot P concentration, with increased effect in the second and third years, despite application of struvite only in the first year. Fertiliser P-recovery was c. 26% after three years. Pot trials were also carried out with alfalfa, comparing struvite to mono ammonium phosphate (MAP) in soil with Olsen P 10 pH 7.1 and Olsen P 6 pH 8.0. In the pot trials, alfalfa response to both struvite and MAP only showed at the highest application rate in the neutral soil (in this case, struvite gave similar results to MAP) and not at all in the alkaline soil, suggesting that alfalfa had sufficient P available in these soils. The authors conclude that recovered struvite is an effective P source for Organically grown alfalfa and so could help alleviate P deficits in Organic Farm systems reliant on biological nitrogen fixation.

"Efficacy of struvite as a phosphorus source for alfalfa in organic cropping systems", J. Thiessen Martens et al., EGU21-8078 LINK. This study was supported by Ostara.

Recycled P for Canada's Organic farming

Review concludes that Organic farm systems are often P-deficient and recycled nutrients could help address this, e.g. insect frass (from processing food waste), struvite from municipal wastewater or food waste digestate. Several cited references show that Organic farms tend to be phosphorus deficient, especially when relying on BNF = Biological Nitrogen Fixation. (Welsh 2009, Reimer 2020 – see ESPP eNews n°49, Entz 2001, Knight 2010, Gosling 2005. ESPP note: also Ohm 2017). Insect frass (waste from insect production) from insects fed food waste and food waste digestate are both approved for Organic farming in Canada. Struvite from livestock manure or from plant wastes is approved, but not struvite from sewage. Several studies cited show that insect frass can be an effective fertiliser (although high doses may inhibit plants, possibly because of ammonium levels), but further research is needed into frass from insects fed other materials. Food waste digestates have also been shown to be effective fertilisers, with improvement possible by post-digestion processing. Many studies show the fertiliser effectiveness of struvite. The Canadian population generates c. 3 million tonnes P / year in human waste and food waste, i.e. only c. 8% of Canada's P-fertiliser imports (whereas sewage alone represents 50 – 60% of Europe's P-fertiliser imports). However, this potential for recycled P is considerably greater than current needs of Canada's Organic Farms, but with the need to redistribute from populated to agricultural regions. The authors conclude that incorporating recycled nutrients into agriculture is essential for food security and sustainability and could contribute to ameliorating phosphorus deficiencies in Organic Farming. Barriers to uptake by Organic farmers are likely to be supply availability of recycled fertilisers, logistics / transport and cost.

"Recycled Nutrients as a Phosphorus Source for Canadian Organic Agriculture: A perspective.", J. Nicksy & M. Entz, Canadian Journal of Soil Science, 2021, DOI.

Struvite tested for use in hydroponics

Lab tests show that struvite is an effective fertiliser for use in hydroponics, applied as granules in the perlite substrate for French beans. The struvite used was Suez PhosCare™ Phosphogreen™ from Aarhusvand A/S municipal sewage works, Denmark (see SCOPE Newsletter n°125), as granules 0.5 – 1.5 mm diameter. Because struvite has a low water solubility, it does not directly dissolve into the hydroponic nutrient solution, so it was mixed with perlite in a perforated plastic bag (holes < 1 mm), into which the beans were planted (as 14-day old seedlings) and grown for nearly 10 weeks. Prior validation tests showed that the perforated bag did not impact bean crop production. Struvite was tested at various rates ranging from 1 to 20 g of struvite per plant and compared to soluble mineral P fertilizer in the hydroponic nutrient solution. The pH of the hydroponic solution in the struvite tests was approximately 7. Results show that struvite at > 5 g/plant resulted in better initial plant growth than the dissolved mineral P fertilizer, as well as higher bean crop yield and considerably lower P losses to the hydroponic leachate (nearly 70% of the dissolved mineral P fertilizer was lost to leachate). The authors suggest that the higher initial growth may be related to the ammonia N content of the struvite (released as needed by the plants). The authors conclude that these tests show that struvite granules are a potentially effective P fertilizer for hydroponics.

In a previous study, also using struvite similarly for bean tests, nitrogen in the hydroponic nutrient solution was substituted by rhizobium inoculation. This led to a 50 – 60 % bean yield reduction although the combination of both struvite and rhizobium seemed to be compatible and promising for further research.

"Recovered phosphorus for a more resilient urban agriculture: Assessment of the fertilizer potential of struvite in hydroponics", V. Arcas-Pilz et al., Science of the Total Environment 799 (2021) 149424 DOI.
"Assessing the environmental behavior of alternative fertigation methods in soilless systems: The case of Phaseolus vulgaris with struvite and rhizobia inoculation", V. Arcas-Pilz et al., Science of the Total Environment 770 (2021) 144744 DOI.

Lab tests of sewage sludge incineration ash (SSIA) in fertiliser production

In lab tests, 25% of phosphate rock was substituted by SSIA in superphosphate production, showing no difference in fertiliser effectiveness in maize pot trials and no impact on heavy metal levels in the plant. The sludge ash was from the Sülzle Kopf gasification process and had total P of 9.9%, compared to 11.8% P in the phosphate rock used (sedimentary, Israel). The P in this SSIA was identified as (for the crystalline part) mainly $Ca_3Mg_3(PO_4)_2$, whereas the authors suggest that P in SSIA is generally mainly whitlockite $Ca_3(PO_4)_2$ or similar (based on Donatello et al. 2013). Superphosphate was produced by dissolving either 100% phosphate rock, or 75% rock + 25% SSIA, in 95% sulphuric acid. The superphosphate using 25% SSIA showed slightly higher cadmium and nickel levels compared to that from phosphate rock only, slightly lower chromium, significantly higher lead and very much higher (order of magnitude) copper and zinc. 10-week pot trials with maize, in a low-P soil, pH 5.2, tested the two superphosphates, struvite (Stuttgart process), the SSIA, the phosphate rock and a control (no P fertiliser). The pot trials showed the highest maize biomass production with struvite, high and the same between the two superphosphates, but significantly lower with rock phosphate and even lower with sewage sludge incineration ash (c. 25% of biomass produced with superphosphates or struvite). None of the heavy metals were significantly different with superphosphate using SSIA (or struvite) compared to superphosphate from rock. The authors hypothesise that significant inputs over the long term of SSIA replacing phosphate rock in fertiliser production could decrease the solid / soil solution partitioning of copper, nickel and lead.

"Producing Superphosphate with Sewage Sludge Ash: Assessment of Phosphorus Availability and Potential Toxic Element Contamination", Y. You et al., Agronomy 2021, 11, 1506, DOI.

Review of fertiliser value of sewage sludge incineration ash (SSIA)

Based on over 200 references, the authors conclude that SSIA offers significant potential for P-recovery but is highly variable, showing inconsistent results when used directly as a fertiliser, and contains contaminants. Useful collated data is provided on SSIA particle size, surface area, phosphorus content, chemical form of phosphorus in SSIA and contents of other elements and of contaminants. Variations confirm that SSIA is specific to each sewage treatment works. Fourteen studies of agricultural land application of SSIA are listed. Several of these studies showed that plant biomass or P uptake was higher with SSIA than with no added phosphorus (control), but this was often with P loadings higher than agronomic requirements. SSIA generally shows very considerably lower fertiliser effectiveness than mineral P fertiliser. Cases are recorded of crop uptake of copper and zinc when SSIA was applied. The authors conclude that more research is needed into possible fertiliser value of SSIA, untreated and after chemical / heat treatments.

"Land application of sewage sludge incinerator ash for phosphorus recovery: A review", P. Ma, C. Rosen, Chemosphere 274 (2021) 129609 DOI.

Pot trials of P-fertiliser from digestates

A precipitated phosphate salt from manure + energy crop digestate liquid fraction, and dried solid fraction (40°C, 120°C) were tested in 50-day pot trials with maize. Two different soils were tested: silty loam subsoil, nutrient poor, low biological activity, pH 7.3 and clay loam agricultural top soil, pH 7.4. The phosphate salt was recovered by acidification (sulphuric acid, to release phosphorus to soluble orthophosphate) then sodium hydroxide addition, and was a mixture of calcium and magnesium phosphates. In the top soil, the precipitated P salt showed fertiliser effectiveness (increased maize dry matter), slightly higher than with mineral P fertiliser (triple super phosphate TSP). In the biologically inactive subsoil, the P-salt alone was less effective than TSP, but P-salt plus dried digestate was in some cases as effective. The dried digestates alone showed lower fertiliser effectiveness than TSP in this short-duration pot trial.

"Efficiency of Recycled Biogas Digestates as Phosphorus Fertilizers for Maize", I-M. Bach et al., Agriculture 2021, 11, 553, DOI.

Possibilities for P-recycling from baby nappies

The quantity potential (case of Australia), possible technologies and needed changes to disposable nappy design and management for phosphorus recycling are reviewed. For Australia, with a population of just over 25 million, the study estimates that total P in human urine and excreta is around 13 million tonnes P / year, of which c. 3 MtP/y goes to disposable baby nappies and is currently lost in solid waste disposal. Nearly 25 publications on nappy recycling are assessed, including composting, pyrolysis, energy recovery, recovery of fibres or polymers or use as a fibre additive in concrete. Of these, only the composting routes (and potentially pyrolysis biochar production) reuse the phosphorus and nutrients, plus one study of nutrient solution extraction (Nobel & Han 2020, see below). The authors note that nutrient recovery from disposable nappies requires redesign for sustainability of the nappy product and the use cycle, for example nappies with two separable layers, with the absorbing layer biodegradable, separate collection and processing logistics.

Nobel & Han (2020) tested at the lab scale extraction of nutrients from used disposable nappies by shredding, then using sodium hydroxide to dissolve cellulose fibres (c. 15% of unused diaper weight) and super absorbent polymers (c. 30%) and release nutrients to solution, then neutralisation using nitric acid, and finally sterilisation to remove possible pathogens. This study notes that around 65% of mass of used diapers is water. A concentration of 1 molar or higher sodium hydroxide showed to be necessary.

"Phosphorus circular economy of disposable baby nappy waste: Quantification, assessment of recycling technologies and plan for sustainability", R. Chowdhury et al., Science of the Total Environment 799 (2021) 149339, DOI.
"Method for nutrient solution extraction from used diposed diapers.", B. Nobel & S. Han, SJ. Energy Eng. 29 (3), 34–41, 2020, DOI, PDF.

Climate change and plant P uptake

Meta-analysis suggests drought events may decrease soil phosphatase activity (needed for plant P uptake from organic molecules), CO_2 increase and N fertilisation may increase activity, with no significant effect noted for warming. Over 610 data measurements were analysed, in each case including sample sizes and standard deviations, and covering both acid and alkaline phosphatases (phosphomonoesterases), from 97 publications. 50 data pairs for nitrogen fertilisation showed that increased N led to increased phosphatase activity (to be expected, as phosphatase production consumes N) whereas increased P fertilisation decreased activity (24 pairs, also to be expected, as P-uptake from organic forms is less necessary). Also N fertilisation often reduces soil pH, so is likely to cause a shift from alkaline to acid phosphatases. Elevated CO_2 led to a small increase in soil phosphatase activity (105 data pairs), whereas warming had no significant impact (51 pairs). Drought episodes, an expected consequence of climate change in many regions, clearly reduced soil phosphatase activity (56 data pairs), particularly of acid phosphatase in Mediterranean regions, and also temperature and subtropical forests. Water content of soil is known to be a very important factor favouring plant P-uptake. Drying may however increase enzymatic activity in wetlands and organic soils. Presence of invasive species led to increased phosphatase activity (49 data pairs). Overall, this meta-analysis confirms that climate change is likely to significantly modify plant and crop P-uptake, in particular because of changes in soil humidity (see also SCOPE Newsletter n°137).

"The effect of global change on soil phosphatase activity", O. Margalef et al., Global Change Biology, 2021, DOI.

Plant phosphorus in diet causes health problems

Tests with rats and humans show that phytate, the main form of P in seeds (cereals, nuts, legumes …), is digestible (normal calcium diet), with high levels causing P-related health problems such as kidney crystals and bone loss. Phytate is often considered to be non-digestible by mono-gastric animals, because it binds to minerals such as Ca, Mg, Fe, Zn (see SCOPE Newsletter n°78). This means that high phytate diets can cause health problems by inhibiting uptake of these essential minerals. Dietary phytate can however also be beneficial because it inhibits hydrolysis (and so uptake) of lipids, proteins, sugars and starch. In this work, rats were fed for 12 weeks feed with 0% to 5% added phytate (i.e. 0 – 1.4 % added phosphorus. The standard AIN-93G rat diet used contains 0.5% phytate (and total 0.3 % phosphorus). Rats fed +5% phytate and standard diet level calcium showed decreased blood calcium levels and high blood phosphorus and magnesium and developed crystal nephropathies, kidney fibrosis and severe bone loss, both symptoms associated with excess diet P. However, increasing the diet calcium for the rats (+1% Ca) prevented these mineral unbalances and negative impacts. A 12-day pilot study was also carried out on six healthy women (23-34 years) with 4 days white rice (0.35% phytate), 4 days brown rice (1.07% phytate) and 4 days brown rice + bran (2.18% phytate). Blood P, Ca and Mg remained within normal levels for all three diets, but the higher phytate diet did result in slightly decreased blood phosphorus. The authors conclude that phytate is digestible by monogastric animals when the diet calcium/phytate ratio is low.

"High-phytate/low-calcium diet is a risk factor for crystal nephropathies, renal phosphate wasting, and bone loss", O-H. Kim et al., eLife 2020; 9:e52709, DOI.

Erratum

Global peatlands phosphorus and carbon

In our eNews n°56, We summarised an article by D. Schillereff et al., under the eNews title "*Will atmospheric P deposition significantly impact peat bog carbon storage?". In our summary, we stated "Mid-latitude peatlands are estimated to hold 0.23 Gt of carbon (1.7% of global soil carbon)*". This should read "**Mid-latitude peatlands are estimated to hold 0.23 Gt of phosphorus (1.7% of global soil phosphorus)**".

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