ESPP new members

PYREG

PYREG is the global lead manufacturer of pyrolysis installations, with over 50 biochar plants operating worldwide, stabilising carbon into biochar and producing renewable energy. PYREG was set up in 2009 as a spin-off from TH Bingen, University of Applied Sciences. Today, PYREG's installed biochar plants stabilise over 30 000 t/y of CO_2 from biomass or from wastes such as sewage sludge, food waste and biomass residues, binding the carbon long-term into biochar. The CO_2 bound into biochar can be certified and traded. The biochar can be used in technical applications or applied to soil. When phosphorus-containing substrates are pyrolysed (e.g. sewage sludge, food waste, food industry by-products), the phosphorus is retained in the biochar and can be returned to soil as a slowly plant-available nutrient. Six PYREG pyrolysis plants are today operating with dried sewage sludge as input, treating 1 300 – 3 900 t/y, and several others with various dry biomass residues as input, treating up to 3.300 t/y. The sewage sludge biochar contains 15 - 35% organic carbon, 6 - 7% P , around 1% N and more than 10% K (all as % of dry solids). PYREG sewage sludge biochar is registered as a fertiliser in Sweden (PYREGphos). By becoming a member of ESPP, PYREG will communicate with regulators, research, potential customers and companies offering technologies with potential synergies, and will promote pyrolysis as a route to fixing carbon in sewage sludge and to recycling phosphorus to agriculture.

https://www.pyreg.de/

NOAH AS

A waste management and recycling company, in minerals, stone and contaminated soils, as well as hazardous wastes and batteries, NOAH's aims are circularity and a non-toxic material cycle, including nutrient recovery from fly ash. NOAH, part of Gjelsten Holdning group, has today around 135 staff and 25 years proven expertise in safe chemical-technical treatment solutions to manage wastes safely for people and the environment. Examples are zinc, mercury, arsenic, lead, hydroxides, and reactive metals. At Langøya (photo), NOAH processes the wastes into a gypsum matrix that binds and stabilises pollutants, treating around 500 kt/y of hazardous waste and relandscaping an old lime quarry. NOAH is developing recovery of mineral salts using a purification system to remove remaining impurities (sulphates, heavy metals, other metals) then a concentration process where sodium and potassium chlorides precipitate from the calcium chloride rich mother brine. Sodium and potassium salts are separated, crystallised and dried. NOAH is also testing phosphorus recycling from calcium phosphate slag, using the nitro phosphate process to produce pure gypsum and phosphoric acid. NOAH believes policies should move away from landfilling to circularity. EU regulations need to be optimised to make the transition to the Circular Economy. NOAH is joining ESPP to work together for these transitions

https://en.noah.no

Consultations, calls & tenders

EU public consultation on Critical Raw Materials to 30th June

Consultation extended to 30h June 2023 on draft EU Critical Raw Materials Regulation, before discussion in EU Parliament and Council, covering Critical and Strategic Raw Materials Lists, with update of the EU Critical Raw Materials List. Elemental phosphorus (P_4) and phosphate rock are NOT included in the proposed list of "Strategic" Raw Materials (see ESPP eNews n°74).

ESPP has input to provide reasons why **Elemental Phosphorus (P_4 and derivates) and Purified Phosphoric Acid (PPA) should both be included in the "Strategic Raw Materials" List**.

ESPP also suggests that **materials critical for EU food security** should be assessed and defined Strategic.

ESPP's input to the public consultation is on the EU website here *and the full document submitted is at www.phosphorusplatform.eu/regulatory (see under "EU Critical Raw Materials")*

Individuals, companies and organisations can input to the EU public consultation until 30th June here (4000 characters free text plus optional document).

EU tender on new input materials and biostimulant micro-organisms for FPR

The European Commission has opened a tender for studies on microorganisms for inclusion as biostimulants and on possible other new materials as inputs for the EU Fertilising Products Regulation (FPR). The tender includes two lots. The first will develop methodology for assessing microorganism which are candidates for inclusion in EU FPR "biostimulants" (addition into CMC7), including their safety, agronomic effectiveness, legal status, production and processing, potential for significant trade, etc. The study will then use the methodology to assess a number of microorganisms proposed under the EU survey held in 2022 (see ESPP eNews n°69). The second study lot will assess candidate new input materials and treatments for possible inclusion into CMCs of the EU FPR, starting by screening submissions made under this 2022 survey. "Indicative examples" cited include materials from: human excreta; algae grown on waste waters; nutrients from battery recycling; from feed industry; sewage sludge; sludge from fish farming; seafood processing residues; and additional processing methods or input materials for a number of CMCs. This study will then assess potential for significant trade, environmental and health safety, agronomic efficiency, and will then make technical proposals for FPR Annex II amendments for materials identified as relevant. Estimated total tender value is 275 K€ (125 K€ for microorganisms, 150 K€ for new CMC materials).

DG GROW tender (TED), open to 17th July @ 9h00 GROW/2022/OP/0046 "Technical Studies to Support the Inclusion of New Materials and Microorganisms under the Fertilising Products Regulation" HERE

EU tender for study on Animal By-Products (ABPs) in fertilising products

The European Commission has pre-announced an upcoming tender for a study on agronomic value and environmental safety of certain Animal By-Products in fertilising products (CMC10). As indicated in ESPP eNews n°75, the authorisation of certain ABPs in CE-mark fertilising products (under the EU Fertilising Products Regulation FPR – CMC10) is very, very slowly progressing. It is our understanding that the DG SANTE Delegated Act amending the Animal By-Product Regulations to define "end points" allowing use of certain ABPs in EU fertilising products (that is, without traceability) is now finalised and will hopefully be published in the Official Journal within a few months (link below). However, these ABPs can only be added to the EU FPR (CMC10) after assessment by the European Commission (DG GROW) of their agronomic value and environmental safety. For "processed manure", this will be done by the Commission itself (JRC), see ESPP's input HERE. For ABPs other than "processed manure" cited in the SG SANTE Delegated Act, and possibly for other ABPs which could be considered for future integration into the FPR, the study of agronomic value and environmental safety will be contracted, and for this DG GROW has published a tender pre-announcement.

DG GROW CMC10 ABP agronomic and environmental safety study pre-announcement 5/6/2023: HERE

DG SANTE Delegated Act for "end points" for certain ABPs for use in fertilisers: HERE

EU Polluter Pays Policy consultation to 4th Aug. 2023

Consultation asks questions about Polluter Pays Policy implementation. At the same time, the Urban Waste Water Treatment Directive recast proposes PPP for costs of removing pharmaceuticals and cosmetics in sewage works. The public consultation on PPP **open to 4th August** asks about pollutant costs, which pollutants should be targeted, how PPP should be implemented including how the Polluter Pays Principle (PPP) should be integrated into prices of products and what impacts this could have. This consultation is open to input from the general public, companies and organisations. At the same time, the recast of the Urban Waste Water Treatment Directive, currently in discussion in European Parliament and Council, raises the question of PPP. The Commission's proposed text would introduce PPP (here called "Extended Producer Responsibility") for costs of removing pharmaceutical and cosmetics residues in sewage works (Recital 13, arts. 9, 10, 30 and Annex 3) and will evaluate for 2030 whether this should be enlarged to other chemicals found in wastewater.

Legislative dossier underway Urban Waste Water Treatment Directive recast https://oeil.secure.europarl.europa.eu/oeil/popups/ficheprocedure.do?reference=2022/0345(COD)&l=en

"Polluter Pays Principle – fitness check of its application to the environment", EU public consultation open to 4th August 2023 HERE

Nutrient Platforms

Italian Phosphorus Platform restarts its activities

A new two-year collaboration agreement has been signed between the Italian Ministry of the Environment and Energy Security (MASE) and ENEA for the resumption of the activities of the "Italian Phosphorus Platform". A webinar on the 15th March launched this second ENEA contract which covers two years. The meeting was opened by Carlo Zaghi (MASE), who emphasised the challenges and opportunities of circularity. Maria Grazia Verdura (MASE Technical Secretariat) introduced the Italian National Table on Critical Raw Material, which aims to enhance national coordination and generate proposals to establish regulatory, economic, and market conditions that promote a secure and sustainable supply of critical raw materials, including phosphorus. Claudia Brunori (ENEA) introduced the Italian Phosphorus Platform objectives of closing the loop in the phosphorus cycle to achieve long-term Italian self-sufficiency in phosphorus supply. Representatives from ENEA presented results achieved by the four thematic groups during the first two-year Platform programme (2018-2019, six published reports, in Italian, here) and planned activities for the 2023-2024 period. Alessandro Spagni (ENEA) presented the reports prepared in 2019 on phosphorus recovery technologies. At that time, only one full-scale P-recovery plant was operating in Italy (Colsen struvite recovery in Emilia-Romagna), but there was significant research interest and company pilot tests. The report emphasised that Italian phosphorus fluxes are primarily linked to agriculture and that there is a strong focus on recovery from liquid and solid organic fractions from wastewater treatment. The future activities include updating the "technology catalogue" (13 technology summaries) and assessing potential replicability of international technologies in Italy. Over 30 people, primarily from industries and sector associations, participated in the report on legislation (coordinated by Sergio Cappucci, ENEA), which analysed more than 90 legislations related to phosphorus at the European, Italian and regional levels. This report will now be updated. Francesca Ceruti (ENEA) presented a comparative study of other Member States' policies related to phosphorus and a market analysis on the phosphorus cycle in terms of supply and demand. The main critical issues in the sector, hindering the closure of the phosphorus cycle and market development, were identified as the lack of specific regulation on end-of-waste and recovery, as well as a lack of public awareness. The two reports will also be updated over the next two years, and a feasibility study will be conducted to establish a national database on phosphorus. This database will track the main users and sellers of phosphorus on the basis of stakeholder inputs, including those who recover it from secondary sources.

***The first meeting of the four thematic groups took place online on May 30th 2023**, 9h-16h, with around 2 hours per thematic group.*

To participate in future meetings contact: roberta.decarolis@enea.it

Italian Phosphorus Platform website: https://www.piattaformaitalianafosforo.it/en

Critical and Strategic Raw Materials

Joint Declaration supporting phosphorus to be a Strategic Raw Material

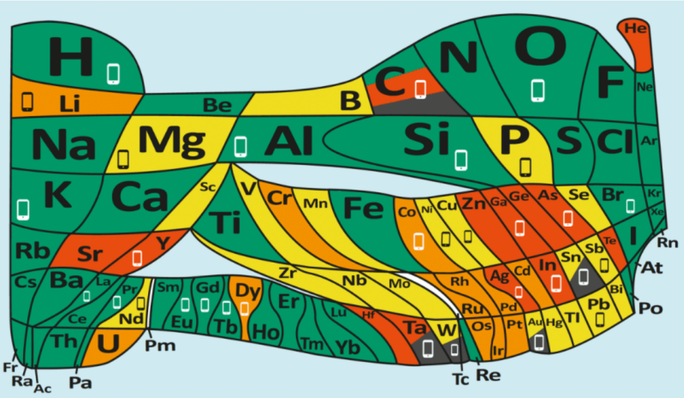
ESPP is coordinating a joint declaration, for signature by concerned companies and other organisations, calling for Elemental Phosphorus (P_4 and derivates) and Purified Phosphoric Acid (PPA) to be included in the "Strategic Raw Materials" List. The Declaration explains that phosphorus is necessary for the "Strategic" industry sectors defined in the draft Critical Raw Materials Act (batteries, renewable energies, electronics and data, aerospace) because it is needed for battery electrolytes and cathodes, photovoltaic panels, fuel cells, semiconductors, hydraulic fluids and for fire safety in all of these sectors. The objective is to input to the discussion of the draft Act in the European Parliament and Council. If you wish to include your company or organisation signature, please contact ESPP.

*You can input to the EU public consultation **to 30th June** here*

ESPP's input to the public consultation here

Joint Declaration calling for phosphorus to be included in the EU Strategic Raw Materials List www.phosphorusplatform.eu/regulatory

EuChemS webinar discusses why phosphorus (P) is essential to humanity



Nearly 200 participants at the EuChemS webinar organised from the European Parliament, discussing phosphorus uses, stewardship and recycling, and concluding that the element P should be identified as critical.

The webinar was opened by **Maria Spyraki, Member of the European Parliament**, and **Christos Vasilakos, Senior Policy Advisor** to Ms. Spyraki, who highlighted the essential role of the European Chemical Society and underlined that phosphorus is essential for both biological life and the human body, and for industry, but that it build ups in water and soils are problematic. P-recycling is necessary both to reduce losses and for the Circular Economy.

Evamarie Hey-Hawkins, Leipzig University and **Floris Rutjes, Radboud University** and **EuChemsS President**, underlined that P is essential for food production. Mineral nitrogen fertilisers ensure food for around half the world's population. For phosphorus, **ESPP estimates that mineral P fertilisers currently feed 4/5 of the world's population**, but this is an estimate, and better data from science would be welcome.

Nicola Armaroli, CNR Italy (National Research Council) explained that **EuChemS has developed a Periodic Table based on the abundance of elements on Earth and identifying by colours which elements are critical for humanity and subject to resource scarcity or conflicts** (latest version here): P is currently indicated as yellow (limited availability, future risk to supply). Participants at the webinar suggested that P should also be indicated as deep red (problems due to losses and over-use) and that specific forms of P should be included in the EU "Strategic" Raw Materials list, currently open to public consultation and to debate in the European Parliament and Council (see under public consultations, above).

Alessandra Quadrelli, CNRS France (National Research Council) outlined work on Planetary Boundaries and discussed challenges of resource sustainability, indicating that P use and losses show exceedance by a factor of more than 4x and that this prejudices food security. **Dana Cordell, University of Technology Sydney**, underlined the nature of **phosphorus vulnerability**, including geopolitical risks, short-term supply-chain disruptions that led to last year's 400% phosphate price spike, in addition to P losses, and that only around 20% of mined P applied to crops ends up consumed in food, as P is bound to soil and lost to water, causing eutrophication. She spoke of overcoming market barriers to scaling up circular phosphorus value chains and the need to improve P governance so that all farmers worldwide have access to sufficient phosphorus to ensure soil fertility and food security whilst avoiding eutrophication. **Chris Slootweg, University of Amsterdam**, underlined the need for systems thinking to develop phosphorus circularity and address losses and eutrophication. **Jan Weigand, Dresden Technical University**, summarised work underway to find routes to organophosphorus chemicals needed by industry without using the chlorinated vector chemical PCl_3.

Andreas Rak, Remondis, presented the company's TetraPhos process to recover phosphoric acid (brand name: REPACID) from sewage sludge incineration ash. A first full scale installation (20 000 t ash / year) is currently underway starting operation in Hamburg. The plant is owned and operated by HPHOR (Hamburger Phosphorrecyclinggesellschaft mbH), a public private partnership between REMONDIS and HAMBURG WASSER.

Robert van Spingelen, ESPP President, explained why **two specific forms of P, elemental phosphorus (P_4) and Purified Phosphoric Acid (PPA) are both essential for the "Strategic" industry sectors targeted by the proposed EU Critical Raw Materials Act** (batteries, renewable energies, electronics and data, aerospace). ESPP therefore considers that these two materials should be added to the EU "Strategic Raw Materials" list. The EU public consultation is open to 30th June (see above). ESPP also suggests that food security is "Strategic" for Europe and that raw materials essential for food security should be assessed for a second "Strategic" list.

Chris Lawson, CRU, summarised trends in P use. Today around 200 million tonnes/year of phosphate rock is mined, of which around 95% is sedimentary and nearly 5% igneous. **Prices spiked following Russia's attack on Ukraine, have since come down but are still currently around twice their year 2000 level,** with considerable differences between different grades of rock. Only around 2/3 of world mine capacity is currently utilised, so that there is little incentive to invest to increase production. Morocco and Saudi Arabia have significantly increased rock extraction over recent years. World trade in phosphate rock fell from 2000 to 2015 (more or less stable since) as mining countries tend to move to process rock to phosphoric acid, fertilisers or other products, trading these not rock. This means that the world's biggest exporter of phosphate rock is today Jordan. Lithium Iron Phosphate (LFP) batteries are expected to develop considerably in coming years, in particular for grid energy storage, and may require 9-10 million tonne/year of phosphate rock by 2035, but this remains small compared to total world phosphate rock production.

EuChemS Science-Policy Phosphorus Workshop "The role of chemicals in our daily life: the phosphorus element, feeding the world and beyond", online from the European Parliament, 25th May 2023 here.

EuChems periodic table (above) "The 90 natural elements that make up everything. How much is there? Is that enough? Is it sustainable?", 3rd version 2023 https://www.euchems.eu/euchems-periodic-table/

EU knowledge report on nutrient management

JRC study to support INMAP

The European Commission's Joint Research Centre has published a study to support the upcoming Integrated Nutrient Management Action Plan (INMAP) and Biodiversity Strategy and Farm-to-Fork target of reducing nutrient losses by 50% by 2030.

ESPP comment: this is a knowledge review and does not make regulatory/political proposals: these should be in the European Commission's INMAP proposal which is forthcoming. The report does however assess whether current policies can be expected to achieve this 2030 target.

The study reviews available literature and data to assess nutrient flows, divergences from environmental targets and measures to reduce nutrient losses, including spatial maps and summaries by EU country. The current relevant regulatory context applicable to waste management is summarised.

Annual input of P in the EU is estimated at 1 MtP/y and reactive nitrogen 8 MtN/y to air and 5 MtN/y to water. Planetary boundaries for the EU are estimated at c. 0.4 MtP/y and 4.4 MtN/y, so in both cases considerably lower than 50% of current inputs. Around 40% of P and 50% of N entering agricultural production is estimated to end up in waste.

Nutrient recycling is addressed in particular as a route to reduce losses, including assessing nutrient recycling potential, possible contribution to reducing nutrient losses, costs and economic benefits. A range of nutrient recycling routes and technologies are discussed in detail (pages (pages 49-62). Four nutrient recycling routes are considered in detail: mineral P and N fertilisers recovered from digestates by precipitation and scrubbing, P-recovery from ashes, mineral N recovery from offgases (from stables, manure storage, composting), use of digestate or compost in organic fertilisers (organic carbon containing fertilisers). The report notes that nitrogen recovery from combustion flue gases is not today operation, and that flue gas treatment often uses catalysis with ammonia or urea injection to convert N_2O/NO_x to N_2, so effectively consuming reactive nitrogen not recovering. JRC estimates that a maximum of around 0.3 MtP/y and 1 MtN/y could be recovered to mineral fertilisers from waste or losses plus 0.3 MtP/y and 0.7 MtN/y by using wastes in organic fertilising products.

ESPP comment: these JRC estimates do not necessarily mean replacing fertilisers, as the waste may currently be reused as an organic fertilising material, e.g. manure slurry / digestate or sewage biosolids. For P, this JRC compares to 0.3 – 0.4 MtP/y estimated without including manure by Van Dijk et al. 2015, see SCOPE Newsletter n°117).

JRC suggests (p. 128-129) that recovery of nutrients to concentrated nutrient products could substitute a maximum of 25% and 10% of EU P and N mineral fertiliser consumption. This is estimated to have a cost of c. 6 billion €/y (additional cost compared to virgin mineral fertilisers) compared to environmental benefits to society of > 7 bn€/y.

Impacts of possible measures are analysed for atmospheric nitrogen losses and nutrient deposition to land, balanced mineral N fertilisation, reduction measures on P and N losses to freshwater and the sea and for different scenarios for the EU agro-food system. Actions currently announced or planned for wastewater treatment (revision underway), under CAP or for atmospheric nitrogen emissions (e.g climate actions FitFor55) are estimated to reduce nutrient losses (reaching the sea) by around 17% for P and 32% for N. *ESPP comment: this is significantly less than the Biodiversity Strategy and Farm-to-Fork 50% reduction target.* The report suggests that achieving food and feed self-sufficiency in Europe within nutrient environmental constraints will require structural changes to agri-food production and to dietary patterns. Regional variations could enable specific opportunities for nutrient loss reduction.

The report concludes that the results are preliminary and not exhaustive with uncertainties in modelling and data.

ESPP recommends to consult the full report, in particular key findings and conclusions (pages 124-131).

European Commission JRC, Grizzetti et al., "Knowledge for Integrated Nutrient Management Action Plan (INMAP)", 184 pages, 200 references, ISBN 978-92-68-02654-0 DOI.

UK water industry collaborative research reports

Contaminants and biosolids

UK Water Industry Research (UKWIR) has published a number of reports into practical investigation of removal of contaminants in wastewater treatment and levels in treated sewage sludge (biosolids), including microplastics and antimicrobial resistance. See also summary of UKWIR report on sewage sludge biochar below and summaries of UKWIR phosphorus removal technology trials in ESPP SCOPE Newsletter n°129.

The UK **National Chemicals water industry's Investigation Programme (CIP)** is the UK water industry's response to current and emerging concerns about trace chemical substances in the water environment. It brings together the 10 water and wastewater companies in England and Wales, with their environmental regulators, to investigate a range of chemical substances often present in domestic products that find their way into wastewater and biosolids and ultimately rivers and streams.

One of the investigations **analysed 173 chemical contaminants in biosolids from eleven UK sewage sludge treatment centres** (waste water treatment plants (wwtps) treating their own and other sewage sludge), finding 128 of these chemicals (above detection limits in at least half of samples) at one or more works, with wide variations both within and between centres ("Biosolids Products Data Report"). Some chemicals showed consistent patterns in sludge across the different centres, whereas others varied widely. Chemicals tested include pharmaceuticals, industrial chemicals, flame retardants (halogenated, non-halogenated), AMPA (metabolite of particularly glyphosate), PCBs, cosmetics, detergent chemicals, heavy metals, PFAS chemicals, as well as ions such as calcium, chloride, phosphorus, iron …

This data feeds into the "**Biosolids Report**" which aims to assess how wastewater and sludge treatment processes influence the fate of these contaminants in biosolids. This report concludes that the data enables to identify which chemicals are likely to be introduced into the environment by use of sewage biosolids in agriculture, but does not enable risk assessment. The studies did not analyse directly how levels of chemicals were impacted by wastewater treatment and sludge processes but it is concluded that fate of PFAS (removal, partitioning) is particularly uncertain and that some pharmaceuticals may be broken down in wastewater treatment but further data is needed. Most of the organic contaminants considered are removed from effluent discharge in wastewater treatment works by sorption to sewage sludge, not by breakdown (table 3.6, pages 45-46).

Microplastics were specifically studied at ten wwtps operating different treatment systems (trickling filters, activated sludge, fixed film activated sludge, biobead biological aerated fixed film). Microplastic removal (from discharge water) was very high (>99% by mass and by number of microparticles). Mostly acrylate, polyethylene and polypropylene polymers found, with no significant fibre forms. Microplastics are transferred to sewage sludge, not broken down, resulting in around one million microplastic particles per kg sewage biosolids (dry weight), so a total over 8 000 t/y of microplastics going to land in the UK. (although potential weaknesses in the mass prediction method mean that these values should only be seen as a starting point and not definitive). Managing the microplastic load to wwtps would therefore seem to be a suitable candidate for source control.

Antimicrobial resistance (AMR) was also specifically studied concluding that wastewater treatment eliminates over 97% of ARG (antibacterial resistance genes). The treatment can however select for certain ARGs, this being related to metal concentrations not antibiotic pharmaceutical concentrations. Also, ammonia levels correlated to AMR in final effluent, suggesting that treatment conditions not favouring nitrification were related to lower ARG removal. No clear conclusions could be drawn concerning which wastewater treatments were more effective in reducing AMR, but anaerobic digestion of sewage sludge did reduce AMR. It is noted that further investigation is needed into AMR in sewage sludge and its fate in soils after land application of biosolids.

UKWIR National Chemical Investigations Programme 2020-2022:

"Biosolids Products Data Report", vol. 6, ref. No. 22/EQ/01/27 (60 pages)

"Biosolids Report", vol. 12, ref. No. 22/EQ/01/2339 (33 pages)

"Fate and behaviour of microplastics within wastewater treatment", vol. 2, ref. No. 22/EQ/01/23 (117 pages)

"Changes to antimicrobial resistance through wastewater and sludge treatment processes", vol. 1, ref. No. 22/EQ/01/22 (182 pages)

UKWIR research reports online https://ukwir.org/water-industry-research-reports

Review of sewage sludge biochar processes

UKWIR analysis suggests that pyrolysis can offer benefits for sewage sludge valorisation but raises questions on technology demonstration, fertiliser properties of sewage sludge biochars, regulatory and market aspects. The feasibility and options review of pyrolysis, gasification and HTC (hydro thermal carbonisation) is based on a literature search, contacts with technology suppliers (Green Waste Energy, Pyreg, Aqualia, Kobelco, Amey), technology scenarios and analysis by water industry operators. The report underlines that no one technology fits all, and that conclusions and implementation scenarios must be adapted to each water company's context. Potential benefits of sewage sludge pyrolysis are identified as reduction of quantities (reducing transport), energy recovery (heat, biofuels), potential reduced carbon footprint and long-term carbon sequestration, reduction in emerging contaminants, elimination of pathogens. Uncertainties identified concern the wide range of technologies and different implementation scenarios, resulting in limited references relevant to sewage sludge and lack of data concerning energy consumption, sludge drying, operating challenges, robustness, cost; lack of evidence on long-term stability of carbon and of pollutants in sewage sludge biochars; legal uncertainties regarding output products and questions on whether carbon accounting will credit sequestration in biochar. The report recommends installing a demonstration plant in a UK sewage works as a water industry collaborative trial, undertaking long-term trials on the agronomic benefits and impacts of sewage sludge biochar applied to land, testing of uses of sewage sludge biochars for example as adsorbents in sewage works as well as further research into energy balances, carbon benefits, integration into sewage sludge processing (e.g. solid-liquid separation) and costs.

UKWIR 2023 "Converting sewage sludge to biochar – a review of options & feasibility", ref. No. 23/SL/07/2 (254 pages).

UKWIR research reports online https://ukwir.org/water-industry-research-reports

Research and development

1st White Ammonia Research Meeting (WARM)

Brussels & hybrid, 7th June 2023

This first workshop on nitrogen recovery research attracted 70 participants in Brussels and 50 online. A wide range of routes for reusing N in organic waste streams were presented. A SCOPE Newsletter summary will be published soon. Different N recovery routes discussed included using waste streams to feed biomass production (algae, duckweed, microbial protein), N-recovery from separately collected urine, manure N stabilisation or local processing to organic fertilisers, recovery of ammonium sulphate solution, or production of ammonia gas for industry use (e.g. by adsorption from waste liquors or offgas followed by desorption as ammonia gas). Discussion suggested that ammonia sulphate solution is mainly adapted for local distribution to farmers (not economic to transport, even if concentrated, unless in specific use chains). Industry participants suggested that further R&D is needed on possible new technologies (adsorption/desorption by ionic liquids, geopolymers, recovery logistics for ammonia gas, recovery from NO_x/N_2O stripping) whereas researchers proposed more modelling studies.

https://www.phosphorusplatform.eu/nrecovery

Energy and phosphorus recovery from fish farm discharge

PwC says that the 1 Mt/y of sludge from Norway fish farms which will be produced by 2050 could provide energy for 600 000 households and over 33 000 t/y of phosphorus. A full scale pilot is planned in Norway. Currently the sludge of fish excrements and food remnants goes into fjords and the sea, with discharge today of some 16 000 t/y of phosphorus to the sea, expected to triple as aquaculture increases by 2050. A full scale solution developed by Framo LiftUP, AquaProp and Ragn-Sells Havbruk is underway at Eide Fjordbruk Hardangerfjorden, and will collect some 18 000 t/year wet weight of sludge and dead fish instead of their sinking to the seabed (= c. 1 800 t/year dry weight, containing 3 - 3.5 % phosphorus). The sludge is taken to anaerobic digestion, where energy is recovered as methane. Phosphorus can then be recycled as a fertilising material in the processed digestate and studies are underway into nitrogen recovery in the digestate processing. A report by PwC for Vestland County Norway and the business network ARAL estimates that implementation of this technology can recover around 70% of sludge from fish farms, so reducing environmental footprint and enabling increased production (+600 t fish/y for an average size fish farm), offering the potential to produce 350 – 950 billion m^3/y of biogas and recycle 33 500 t/y of phosphorus by 2050.

"Norwegian fish poo can power 600,000 households and supply entire countries with phosphorus", Ragn-Sells 27/2/2023 LINK

"Circular solution for sludge recycling in Norwegian fish farming", Ragn-Sells 31/8/2022 HERE.

27-year field trial of organic wastes as fertilisers

Long-term trial with sewage sludge and manures confirms the need to balance nutrients to crop needs not simply to nitrogen application rates. The 27-year trial at Cervený Újezd, Czech Republic, with maize each year, compared control (no added nutrients), mineral N-fertiliser (with or without also straw), sewage sludge and two manures, all at 120 kgN/ha/year. This resulted in c. 80 kgP/ha/y of phosphorus with sewage sludge (from a sewage works using iron and aluminium salts for chemical P removal) and 23-32 kgP/ha/y with manures. Above-ground maize biomass production was highest with N-fertiliser and wheat, followed by the two manures, then sewage sludge and N-fertiliser alone (these last two being around one third higher than control). Soil P decreased slightly in the control over the 17 years and decreased significantly with N-fertiliser (c. -10%) but increased nearly +50% with sewage sludge and c. +25% with the manures. Water soluble P was however 20-30% lower with sewage sludge than with manures, suggesting a lower risk of phosphorus losses despite higher soil P (presumably due to iron and aluminium).

"Side effect of organic fertilizing on the phosphorus transformation and balance over 27 years of maize monoculture", D. Asrade et al., Field Crops Research 295 (2023) 108902, https://doi.org/10.1016/j.fcr.2023.108902

Cerium for P-removal and hypothetical recovery

Cerium oxides are widely used in glass polishing. Lab study recovered cerium chloride from glass polishing slurry, tested for phosphate precipitation from brewery wastewater, then cerium recovery. The brewery wastewater had 630 mg/l suspended solids, 20 mgP/l, 46 mgN_{-total}/l, and significant levels of other ions including sulphur, calcium, potassium, magnesium. Cerium chloride crystals were recovered from the glass grinding slurry (which contained 82% CeO_2) by leaching with HCl and H_2O_2. This cerium solution was added as 0.05 mol/l to the wastewater in beakers to precipitate phosphorus (stirring 10-20 minutes with pH adjustment, settling for 5 minutes, tested Ce:P ratio of 1 to 2). Total P removal was >99% and suspended solids removal of >96%. Cerium recovery from the precipitated sludge was tested by leaching cerium with 15% hydrochloric acid, then precipitating with sodium hydroxide. Over 70% cerium recovery was achieved. The authors suggest that the remaining leached precipitation sludge enable phosphorus recovery but this was not demonstrated. This leached sludge contained nearly 25% P but also >12% cerium which could be an obstacle to use in fertilising products (cerium is both mildly toxic and also a plant micronutrient), and if the process was used on municipal wastewater the sludge would likely contain other heavy metals and contaminants.

"Removal of phosphate from brewery wastewater by cerium(III) chloride originating from spent polishing agent: Recovery and optimization studies", P. Lejwoda et al., Science of the Total Environment 875 (2023) 162643 DOI.

Iron-loaded plastic fibre lab tested for P removal – recovery by adsorption

Plastic fibres loaded with iron were tested at lab-scale for phosphorus removal from synthetic solutions and for P-recovery by desorption with fibre reuse for P-removal. 99% P-removal was achieved. 5 reuse cycles were tested. Polypropylene fibres were aminated then loaded with iron by 3-step reaction with acrylamide, ammonium iron sulphate, benzoyl peroxide, toluene and iron chloride. An iron loading of 13.5% was identified as optimal. The iron-loaded fibres (PPFFe) were tested for P-removal from synthetic solutions of potassium sulphate, with also chloride, nitrate, carbonate and sulphate ions. The PPFFe fibres removed over 99% of soluble phosphate in continuous flow conditions, with good ion selectivity, reducing phosphate from 2 mgP/l to <0.2 mgP/l. P adsorption capacity of the PPFFe fibres was 3%P. The P-loaded PPFFe fibres were regenerated using 0.1 mol/l EDTA (chelating agent) showing 99% desorption over five PPFFe reuse cycles. The authors note that waste polypropylene fibres could be used. ESPP notes that testing in real wastewater, with other competing ions and suspended solids / organic carbon is needed, as is demonstration of how to recover a useable phosphorus material from the EDTA regeneration solution, to enable application for phosphorus recycling.

"Fabrication of recyclable Fe^{3+} chelated aminated polypropylene fiber for efficient clean-up of phosphate wastewater", S. Zhao et al., Front. Chem. Sci. Eng. (2023) DOI.

Pharmaceuticals and heavy metals release from sewage sludge biochar

Pyrolysis of sewage sludge can reduce the content of pharmaceuticals and heavy metals in the resulting biochar and their availability to plants, depending on pyrolysis temperature and duration. Sludge from the municipal sewage treatment plant in Binhai District, Tianjin, China, was hydrothermally treated (2 litre reactor) at 180 and 240°C for 6 and 15 h. The sludge contained c. 50 µg/kg caffeine and c. 100 µg/kg acetaminophen (a pharmaceutical). The resulting sludge biochars were characterised in terms of elemental composition, surface properties, PPCPs and heavy metals (Cr, Pb, Cu and Zn), and added to a hydroponic solution at doses of zero to 0.8 g/l to test their toxicity for wheat growth. For all of the contaminants tested (caffeine, acetaminophen and the heavy metals) concentrations in the sludge biochars were of similar magnitude to those in the sewage sludge (from c. 4x lower to c. 2x higher), with no general relation to the two tested temperatures or times. Lower doses of the biochars in the hydroponic solution had benefits for wheat growth or health, but higher doses showed toxicity and damage to plants. Caffeine, acetaminophen and heavy metals from the biochars were taken up and accumulated in the wheat, but with levels in wheat shoots below China drug and food additive standard limits.

"PPCPs and heavy metals from hydrothermal sewage sludge-derived biochar: migration in wheat and physiological response", K. Zhen et al., Environmental Science and Pollution Research 29, 83234–83246 (2022), DOI

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