EU consultations

EU consultation on nutrient management (INMAP) – *open to 26th August 2022*

Public consultation, open to individuals and to organisations, to 26th August 2022, asks for opinions and proposals on nutrient policies, fiscal and regulatory tools, and on nutrient recycling. In addition to the questionnaire, supporting documents or proposals can be submitted.

ESPP has input stating that the key pillars of INMAP should be:

- reducing nutrient losses (Farm-to-Fork target)
- nutrient recycling (Circular Economy)
- R&I to support these objectives and to understand nutrient planetary boundaries and nutrient flows
- INMAP should ensure synergy between nutrients and other key EU strategies: climate change, sustainable and healthy diet (Farm-to-Fork strategy), water policy, including integrating nutrient recycling into the Sewage Sludge Directive, Critical Raw Materials (phosphate rock, phosphorus), Specific policies: Methane Strategy (biogas), Emissions Ceilings Directive (ammonia), Algae Initiative, Aquaculture, Soil Strategy, chemicals and pharmaceuticals policies (reducing contaminants), etc.

ESPP noted in comments:

- Facilitate Need for coherent policy and EU legislation on phosphorus.
- Fiscal and market tools to monetarise the environmental and social impacts of nutrient consumption and support nutrient recycling.
- Dietary shift. Healthier, more sustainable diets will have lower climate impact and reduce nutrient use in fertilisers and animal feed.
- Climate change. Address links between climate change and increasing nutrient losses and eutrophication; between nutrient losses and climate emissions.
- Implementation of Green Deal nutrient loss reduction targets and Water Framework Directive Quality Status obligations, and resulting water basin catchment plan actions, in CAP.
- Recycling of other nutrients should be considered.
- Absence of regulatory tools for nutrient recycling in most EU countries (only in Germany)
- Inadequate tools for nutrient recycling in Common Agricultural Policy
- Importance to implement EU ban on PFAS - a problematic contaminant for nutrient recycling
- Need for full-scale nutrient recycling demonstration projects
- Absence of EU End-of-Waste status for non-fertiliser uses of recycled nutrients and for materials recovered from wastewaters

- Obstacles from local regulators to factories wishing to take in waste materials (secondary nutrients) for recycling to partially replace virgin nutrient materials (operating permit)

ESPP's detailed input on INMAP can be found on our website actions -> regulatory page
EU public consultation on INMAP, "Nutrients – action plan for better management", open to 26th August 2022, HERE.

EU seeks input on Fertilising Products Regulation (FPR) CMCs

The European Commission has opened a survey, to 16th September 2022, on possible additional waste or recycled materials for the EU FPR (Annex II CMCs), on possible additional biostimulants micro-organisms, or other amendments to existing CMCs. Input will be considered for a planned Commission study to identify potential new 'CMC' materials or biostimulants micro-organisms which offer significant trade potential, agronomic value and safety. Proposals for materials can either be materials falling outside existing CMCs (possible new CMCs to add into Annex II), modifications of input specifications for existing CMCs, or other processing methods for existing CMCs. Existing CMCs cover (with limitations) composts, mechanically-processed plant materials, food industry by-products (limited list), precipitated phosphates, ash-derived materials, pyrolysis/hydrocarbonisation materials, some by-products and recovered minerals (see consolidated Fertilising Products Regulation and Commission information sources document 23/5/2022 here). Before submitting input, you should verify the texts of existing CMCs 1-15. The survey asks to justify Circular Economy, environmental and resource aspects, agronomic efficiency, and to provide supporting data on regulatory aspects, scientific studies, market data, including estimating existing and potential use and trade volumes. The EU FPR states (art. 42) that the Commission can only modify the FPR Annexes to enable market access for products which "have the potential" (for) significant trade" at the European (not local) level and for which there is "scientific evidence" of safety to health and the environment and of agronomic efficiency. Submissions should therefore justify such potential. Proposals for modifications of Annexes I (PFCs), III (labelling) or IV (certification) can also be submitted.

EU survey on materials for CE-mark fertilisers "EU survey on possible future development of the FPR", responses by 16th September 2022 will be considered for upcoming EU study: https://ec.europa.eu/eusurvey/runner/possible_future_development_of_the_FPR

EU consultation on Soil Health

EU public consultation, to 24th October 2022, to support preparation of a future EU Soil Health Regulation. This general public questionnaire asks for opinions of individual citizens and organisations on the need for EU action on soil, causes of soil degradation, contaminated sites and soils, possible legal obligations requiring Member States to improve soil health and to stop net "land take" (loss of natural or agricultural land to urbanisation or infrastructure). A second part of the questionnaire (you will only access this if you tick "YES" after Q13) questions which parameters should be taken into consideration for soil health and at what level. Q17 (only accessible by ticking YES after Q13) specifically addresses the EU Green Deal target to reduce nutrient losses by 50% by 2030. ESPP will input underlining the importance of nutrient and organic carbon retention in and losses from soils – soil erosion, and the need to Integrate the EU Green Deal nutrient loss reduction target (halving of nutrient losses by 2030) into CAP Strategic Plans and conditionality of CAP farm subsidies, and into Water Framework Directive River Basin Management Plans

EU consultation, open the general public, companies, organisations, to 24th October 2022, "Soil health – protecting, sustainably managing and restoring EU soils", on development of EU policy on Soil Health LINK.

Policy

Massive increase in biowaste recycling needed

ECN (European Compost Network) "Data Report 2022" shows that today only 17% of the EU's municipal solid waste (MSW) is separately collected and organically recycled as compost or in anaerobic digestion (AD), and that this must increase to 35% by 2035 to meet the EU's overall target of 65% recycling of MSW. Already Member States must, by end 2023, separately collect biowaste at source. ECN estimates that the increase to 35% MSW organic recycling will increase employment in composting and AD from 7 – 12 000 full-time equivalent jobs today to 14 – 25 000 by 2035 (around 80% of this employment in anaerobic digestion). Currently around twice as much (tonnes) biowaste goes to composting as to AD. In 2035, biowaste compost could be applied at 10 t/ha/y to one third of eroded land in Europe (4% of EU arable land) to increase soil organic carbon (digestate not included).

ECN Data Report 2022 here.

EurEau calls for resources reuse from waste water

The European water industry federation, EurEau, has published a statement calling for policy changes to enable recovery of resources, in particular nutrients, and energy from waste water, in order to address geopolitical challenges and climate emission reduction objectives. The statement highlights phosphorus, potential nitrogen recovery, energy recovery, carbon reuse, cellulose, algae, polymers and carbon dioxide. The statement calls for six policy changes:

- Facilitate placing on the market of wastewater-recovered materials by aligning environmental legislation and circularity policy: REACH, End-of-Waste, Urban Waste Water Treatment Directive, EU Fertilising Products Regulation …
- Control-at-source for polluting contaminants
- Research and innovation

- Funding of energy and nutrient recovery by waste water operators
- Energy and climate audits for wastewater treatment plants
- Incite economic and public demand for recovered materials

"Call for a European commitment to better reuse resources and energy from waste water. Public statement", Eureau (European Federation of National Associations of Water Services.), 24th June 2022 LINK.

Organic Farming

EGTOP approves struvite (again)

The EU's "Expert Group for Technical Advice on Organic Production" (EGTOP) has confirmed its positive opinion (2016) that "recovered struvite" should be authorised in Organic Farming, but now widens this to other recovered precipitated phosphate salts (coherent with the EU Fertilising Products Regulation CMC12 definition - here). EGTOP recommend that for precipitated salts from animal manure, this shall not be of "factory farming" origin. This new EGTOP Opinion thus recommends a wider and simpler inclusion of recovered precipitated phosphate salts into Organic Farming than did the EGTOP 2016 Opinion, which covered only struvite from municipal wastewater. The new Opinion effectively recommends that any recovered phosphate salt corresponding to the criteria of the EU Fertilising Products Regulation 2019/1009 CMC12. However, it is NOT clear to ESPP whether EGTOP recommends (a) that also "derivates" (as defined in CMC12) should be included and (b) that the product must have obtained the CE-Mark (i.e. undergone Conformity Assessment as defined in 2019/1009 Annex IV. ESPP hopes that the European Commission (DG AGRI) will now move rapidly to add recovered precipitated phosphate salts to Annex II of the EU Organic Farming Regulation. ESPP does not understand why recovered "calcined phosphates" are not included in this new EGTOP Opinion, despite they were positively approved by EGTOP in 2016 at the same time and under the same conditions as recovered struvite

EGTOP "Final Report on Plant Protection (VII) and Fertilisers (V)", adopted 8-10 June 2022 https://agriculture.ec.europa.eu/farming/organic-farming/co-operation-and-expert-advice/egtop-reports_en

EGTOP on nutrient recycling, biowaste, bone char, phosphogypsum

EGTOP underline that recycling of organic wastes is important for agri-food chain sustainability and that the "circular economy should be widely adopted in Organic Production" but underlines concerns about possible contaminants. EGTOP's report on fertilisers (V) recommends approval of recovered struvite and phosphate salts in Organic Farming, and also provides various general and specific positions on nutrient recycling in Organic Farming. In discussion of struvite, EGTOP notes that if soils contain stores of phosphorus, it is preferable to increase soil P availability rather than adding P in fertiliser, but also notes (in discussion of "bio-waste) that there is a lack of sources of phosphorus and nitrogen for Organic Farming. EGTOP underlines however that recycled materials may include contaminants "such as microplastics, heavy metals, veterinary drugs or pesticides"

Bio-waste: EGTOP recommends modifying current wording of the Organic Farming Regulation (2021/1165) Annex II which allows use of "Composted or fermented mixture of household waste" to become conform with the Waste Framework vocabulary and read "Composted or fermented bio-waste". "This effectively widens to organic wastes from gardens and parks and food wastes from restaurants, caterers, retailers (as well as households) and "comparable waste from food processing plants". The term "bio-waste" is already used in the EU Fertilising Products Regulation (CMCs 3 compost and 5 digestate).

Bone char: EGTOP recommends that "bone charcoal" (Animal Bone Char ABC from Hungary) be NOT authorised for Organic Farming. EGTOP note concerns about levels of PAH in this material, underline that bone meal is already authorised in Organic Farming and conclude "no clear advantage of using bone charcoal, but a certain (not precisely quantifiable) risk" and that "non-pyrolysed bone meal and other permitted alternative P-fertilisers should be used in preference". EGTOP note that nitrogen is lost in pyrolysing bone meal, PAH are formed and that there are no concerns about pathogens if bone meal is used correctly, meaning that pyrolysis is not useful.

Phosphogypsum: EGTOP recommends that phosphogypsum be NOT authorised as a liming material in Organic Farming. EGTOP recognises the environmental interest of phosphogypsum use in Finland (locally available from phosphate rock processing, alternative minerals must be imported) but considers that phosphogypsum does not "strictly" meet the Organic definition of "plant, animal, microbial or mineral origin" because sulphuric acid is used in its production. EGTOP considers that use of industrial by-products can support the circular economy, but that phosphogypsum should be excluded because it is a by-product of mineral fertiliser production, and these fertilisers are not authorised in Organic Farming.

Iron phosphates: EGTOP recommended that ferric pyrophosphate be authorised for use in Organic Farming, as a plant production substance, not as a fertiliser. Ferric phosphate (iron (III) phosphate) is already authorised as a plant production product (Annex I, part 2). Both ferric phosphate and ferric pyrophosphate are used against slugs and snails.

EGTOP "Final Report on Plant Protection (VII) and Fertilisers (V)", adopted 8-10 June 2022 here.
List of EGTOP committee members here.

Action on other recycled nutrient materials in Organic Farming

Companies wishing to see other recycled nutrient products considered for authorisation in EU Organic Farming need to propose a dossier to the European Commission via a Member State (national authority). ESPP has prepared outline proposals for the following:

- Calcined phosphates

- Recovered elemental sulphur
- Bio-sourced adsorbents used to treat wastewater
- Phosphorus-rich pyrolysis and gasification materials (inc. biochars)
- Algae and algae products grown to treat wastewater
- Vivianite
- Recovered nitrogen from off-gases.

See attached to DG AGRI reply of 9/8/22 to ESPP letter of 12/7/22 under 'Organic Farming' at www.phosphorusplatform.eu/regulatory

However, the European Commission (DG AGRI) will only move forward when a request is submitted by a Member State.

If you are interested to submit a request via a Member State, for one of the above or for other recycled nutrient products for authorisation in Organic Farming, ESPP can provide support.

Documents on ESPP website here.

Nutrient recycling

Kemira and Veolia to pilot test vivianite recovery from sewage

ViviMag® is a Kemira patented technology to recover clean Vivianite (iron (II) phosphate) by magnetic separation from sewage sludge or sewage sludge digestate. The technology was developed by WETSUS and Delft University, in cooperation with Kemira and the water industry The industrial automated pilot is installed at Schönebeck municipal wastewater treatment plant in Germany, by Veolia, since July 2022, and will process 1 m^3/h of digested sludge, that is c. 15% of the sewage works' total sludge production. The objective is to recover at least 50% of the total P inflow to the sewage works (proportional to the 15% of sludge treated). Dosing with iron salts is the most widely used and operationally reliable way to remove phosphorus from sewage and so prevent discharges into the environment, which is necessary to respect EU water quality legislation and to prevent eutrophication. Iron dosing is often used even with biological P-removal, to ensure very low P discharge consents. Anaerobic conditions (e.g. in sludge to biogas digesters) tend to convert iron (III) to iron(II), resulting in significant presence of Vivianite, which can be separated and recovered because of its magnetic properties. Vivianite has shown to be effective as an iron-providing fertiliser (see ESPP SCOPE Newsletter n°138), useful in calcareous soils with iron deficiency in parts of Europe. Phosphorus in Vivianite shows better plant availability than in iron (III) phosphate, but in soils Vivianite may tend to oxidise within hours to iron (III) phosphate. The success of the ViviMag project will therefore depend not only on the pilot-scale recovery trial at Schönebeck, and at other municipal wastewater treatment plants already planned, but also on identifying a viable industrial market and logistics for the recovered Vivianite.

Kemira – Veolia press release 16th June 2022.

European Commission policy brief on "next-generation fertilisers"

A 2-page (plus references) "Science for policy brief" issued by the EC Joint Research Centre (JRC) says recycled and organic fertilisers show smaller carbon footprints and reduce nutrient losses. The briefing says that the European Commission has set a goal of 30% reduction of non-renewable resources in fertiliser production. This refers to a Commission press release of December 2018 (IP_18_6161) which estimated that 30% of EU phosphorus imports could be replaced by recycling from sewage sludge, organic wastes or manure. The JRC policy brief underlines that nitrogen, phosphorus and potassium all face surging costs and supply disruption as a result of the war in Ukraine and international trade restrictions. Organic fertilising materials are indicated to have 78% lower greenhouse emissions (for N) and 41% lower (for P) than mineral fertilisers (based on digestate and compost in Havukainen et al. 2018, DOI). The brief notes that various promising technologies for nutrient recovery and novel fertiliser products are already being developed, but that further investment is needed in technical improvement, including for recovering both energy and nutrients from manures.

"The next-generation of sustainable fertilisers: a win-win solution", European Commission JRC Science for Policy Brief, JRC130293, 2022 HERE.

Climate change

Climate change and lake eutrophication

Review paper shows that climate change is likely to accentuate lake eutrophication and algal bloom problems worldwide. Based on some forty references, this paper provides a summary of how increased nutrient inputs (eutrophication) can negatively impact lake ecosystems: decreasing water transparency, oxygen depletion, excess phytoplankton growth, accumulation of organic matter and phosphorus in sediments, loss of biodiversity. It is emphasised, as is well recognised, that the accumulation of phosphorus in sediments can render lake recovery very slow (decades) even after P inputs are reduced. Recent studies suggest that combined phosphorus and nitrogen can stimulate harmful algal blooms (HABs), so that reducing N inputs is also important. Studies show that climate change has already started to impact lakes, including increased surface water temperatures (increases of up to 1°C per decade found), increased water evaporation, reduced ice cover and changes of stratification and mixing. Surface water warming can extend the stratification season (when a layer of cooler, deep water does not mix with surface water). This can reduce nutrient upwelling, so in some cases reducing algal blooms, but can also lead to anoxic deep waters and reduced fish production. Offshore surface waters may also warm faster than near-shore waters, leading to ecosystem dysfunction. Climate change will also result in increased frequency and magnitude of exceptional events, such as high rainfall events and summer droughts which can lead to higher nutrient releases. Increases in wildfires also cause P and N losses to lakes.

"A global problem: trends in nutrient loadings of lakes with climate change and increasing human developments", 4 pages, C. Marti, Hydrolink 2021/1, LINK.

Swiss lakes: climate change, nutrients and biodiversity resilience

Decades of data from five peri-alpine lakes show that climate warming reduces plankton food web connections, particularly under phosphorus loading. 24 – 43 years of monthly data from Lakes Baldegg, Sempach, Halwil, Freifensee and Surichsee covered, at different depths, abundance and taxa of phytoplankton and zooplankton (grazers of phytoplankton), phosphate (DIP) and water temperature. Over this period, these lakes have undergone significant re-oligotrophication (reduction of anthropogenic phosphorus inputs) whereas water temperature has risen by 0.6 – 2°C. The authors conclude from the data that water temperature increases cause non-linear changes to taxa interactions, modifying in particular populations of small grazers (rotifers, ciliates, mixotrophic dinoflagellates) and colonial cyanobacteria. This reduces trophic connections, making foodwebs less stable and more sensitive to changes in phosphorus concentrations.

"Climate change and nutrient fluctuations interact to affect ecological networks in lakes", E. Merz et al., Nature Portfolio, preprint 2022 DOI.

Lake Balaton algal bloom linked to climate change

The major algal bloom in 2019, despite low P inputs, was probably caused climate-induced lake stratification, leading to deep-water anoxia and so P sediment release (internal P loading). Nutrient inflows to Lake Balaton (Hungary, 590 km^2) have been successfully reduced by twenty-five years of eutrophication management actions, including sewage P-removal, agriculture negative P-balances and 70 km^2 of wetland reflooding. P-inflows (external P loading) prior to the 2019 algal bloom were generally below 2 mgP$_{\text{-total}}$/m^2 lake surface/day since 2000, compared to around three times higher in the 1980's. The late summer 2019 algal bloom exceeded 300 mg -chlorophyll/m^3 (50% higher than ever recorded in pre-management blooms) and was unusually dominated by *Ceratium furcoides* (dinflagellate) and *Aphanizomenon flos-aquae* (blue-green). The bloom was preceded by two anoxic P-release pulses. The authors conclude that the bloom was the consequence of climate change, with temperatures leading to reduced lake mixing (stratification) and thus an ecological regime change. New management actions will be necessary to prevent such blooms reoccurring, such as modifying lake water levels.

"Record-setting algal bloom in polymictic Lake Balaton (Hungary): A synergistic impact of climate change and (mis)management", V. Istvánovics et al., Freshwater Biology. 2022;00:1–16, DOI.

Extreme rainfall events and agricultural P losses

Data for the State of Wisconsin, for 15 years at the HUC8 level (medium size water basins = c. 50 in the State), comparing weather, livestock and crop data, show that river water total P and N increase after rainfall events. River water concentrations of both P$_{\text{-total}}$ and ammonia-N increase immediately after rainfall events: +130% for P$_{\text{-total}}$ and +75% for N$_{\text{-NH4}}$ after ≥ 2 inches of rainfall. For N$_{\text{-NH4}}$ the increase remains significant for only around three days, whereas P$_{\text{-total}}$ remains significantly increased for four or more days. Also, the increase shows for N$_{\text{-NH4}}$ only in Spring – Summer, whereas for P$_{\text{-total}}$ it shows all year round. The data suggests that nutrient runoff spikes are higher in areas with more cropland and smaller livestock units (rather than CAFOs = concentrated animal feed units). The authors conclude that climate change, which is expected to exacerbate high rainfall events, will significantly increase agricultural nutrient losses to rivers.

"Climate change and water pollution: the impact of extreme rain on nutrient runoff in Wisconsin", M. Skidmore, T. Andarge & J. Folz, University of Illinois, conference paper 8/2022 LINK.

Research

Microplastics are taken up by and can be toxic to crop plants

Review of over 100 studies shows micro/nano plastics can be phytotoxic, impact plant growth and inhibit nutrient uptake, and can be found in crops, but impacts vary widely between different polymers and particle characteristics. Summarised studies cover a wide range of different plants, polymers, particle sizes, culture substrates and effects on plants. Tests often used high concentrations of microplastics (e.g. 2% w/w in culture substrate). Some studies show no effect, or even positive impacts (improved soil water retention due to microfibres), but most studies find phytotoxic effects, including reduced shoot or root growth, reduced biomass production, reduced photosynthesis. Microplastics can reduce plant nutrient uptake by adhering to the root surface or by oxidative stress to roots, but also by adsorbing nutrients and so reducing their availability in soils. Microplastics can modify essential mineral levels in plants (e.g. Ca, Cu, Fe, Mg, Mn, Zn), which may inhibit chlorophyll synthesis. They can inhibit seed germination by adhering to the seed. Studies confirm that microplastics can be taken up by plant roots and transported to above-ground plant tissue, so potentially entering the human food chain in crops.

"Micro(nano)plastics and terrestrial plants: Up-to-date knowledge on uptake, translocation, and phytotoxicity", F. Wang et al., Resources, Conservation & Recycling 185 (2022) 106503 DOI.

Excessive sewage sludge land application linked to nutrient losses

Increasing sewage biosolids use to 130 kgP/ha/y – 320 kgN/ha/y correlated to increased river P and N concentrations. In 2013, new State regulations ended Class B biosolids (sewage sludge) application in most of South Florida, resulting in a significant increase in application in the Upper Saint John's River Basin (USJRB, 4 600 km^2). Both total P and N application in biosolids, and area of fields receiving biosolids were already increasing in USJRB 1998-2013, but from 2013 both increased considerably further, with total nutrient application increasing around 4x and receiving area increasing around 2x. Application rates thus rose from c. 80 to c. 130 kgP/ha/y after 2013 and nitrogen from c. 170 to c. 320 kgN/ha/y. River total nutrient loads after 2013 increased by +40 to +200% for P and +5 to +20% for N. The authors estimate that this corresponds to 0.5 – 2 % of increased biosolids P applied, 0.2 – 1% for N. ESPP suggests that the higher biosolids application rates, after 2013, are excessive, because they are much higher than agronomic P requirements (see e.g. here), and that this shows that sewage sludge land application should be strictly limited to not exceed crop nutrient needs (balanced fertilisation), in particular for phosphorus which is usually "limiting" for this.

"Trends in phosphorus fluxes are driven by intensification of biosolids applications in the Upper St. Johns River Basin (Florida, United States)", A. Canion et al., Lake and Reservoir Management, 2022 DOI.

Optimising economic incentives for P-recovery in livestock units

Modelling of credits for P-recovery from manure in the Great Lakes area shows net economic benefit compared to eutrophication costs, but risk of favouring large livestock units. The study covers six US states in the Great Lakes basin, with a total of over 2 200 regulated CAFOs (Concentrated Animal Feeding Operations of > 300 animal units (one animal unit is defined as 1000 lbs of live weight). In two papers, firstly a fixed subsidy for P-recovery (22 US$/kgP, corresponding to estimated costs of eutrophication) and an obligation to implement in all regulated CAFOs is modelled, and secondly a system of P-credits tradeable between CAFOs with various P-credit prices. Combination with biogas production was also considered with prices of 30 to 120 US$/MWh. Biogas production impacts the choice of which P-recovery technology which is appropriate, and so its costs. With a fixed P-recovery incentive of 22 US$/kgP, capital costs (CAPEX) for P-recovery total 2.5 billion US$, or 5.2 billion if combined with biogas. Considering CAPEX, operating costs, value of recovered phosphates and the P-recovery subsidy, total net income for CAFOs is 230 million US$/year. However, the subsidy tends to favour larger CAFOs where economy of scale makes P-recovery and biogas production more cost-effective. Although this may be environmentally effective in reducing phosphorus losses and eutrophication, appropriate adjustment of the scheme to ensure fair incentives is necessary. At 22 US$/kgP incentive, P-recovery is net profitable for around 80% of CAFOs, representing around 2.3 million animal units (it is smaller CAFOs for which it is not profitable). The study concludes that total phosphorus recovery costs are lower than the economic impact of phosphorus releases to the environment, so that phosphorus recovery is not only environmentally but also economically beneficial.

"Analysis of incentive policies for phosphorus recovery at livestock facilities in the Great Lakes area", E. Martín-Hernández et al., Resources, Conservation & Recycling 177 (2022) 105973, DOI.
"A geospatial environmental and techno-economic framework for sustainable phosphorus management at livestock facilities", E. Martín-Hernández et al., Resources, Conservation & Recycling 175 (2021) 105843, DOI.

Long-term field trials suggest manure application can increase labile soil P

29 year maize field trial in China suggests that manure P fertilisation results in higher labile soil P than mineral P only. The trial was in "black soil" (loamy clay), pH 7.5, at Gongzhuling, Jilin Province, China, with a temperate continental monsoon climate. Fertilisers were applied as control (none), NK, NPK and NPK+manure. N, P and K were respectively applied at 165, 36 and 68 kg/ha/year, except in the NPK+manure treatment where total N was maintained at 165 kgN/ha/y, resulting in total P doubled to 75 kgP/ha/y and K to 145 kgK/ha/y. The P application rate in the NPK+manure treatment is thus very considerably higher than agronomic recommendations. Crop yield was significantly higher in the fertilised plots (compared to control) within ten years, and was significantly higher with P fertiliser (NPK, NPK+manure treatments, compared to NK only) in the second and third decades. Calculated soil P balance was negative and soil Olsen-P remained below the China environmental threshold level (50.6 $mgP_{\text{-Olsen}}$/kg) in all treatments except for NPK+manure, whereas soil P balance was positive and Olsen-P rose above the threshold in the third decade in the NPK+manure treatment. The proportion of labile soil P was also higher with additional manure application, suggesting that the application of organic carbon can increase soil P availability for crops.

"Effect of long-term fertilization on phosphorus fractions in different soil layers and their quantitative relationships with soil properties", Q. Wang et al., J. Integrative Agriculture 2022 DOI.

Analysis of sewage sludge options and costs in Austria

Data from the 635 municipal wastewater treatment works (wwtps) > 20 000 p.e. in Austria (treating 98% of the country's sewage) show LCA, costs and nutrient implications. Over 70% response rate for most parameters enables detailed analysis; Around 90% P-removal is achieved, mainly by chemical P-removal. Taking into account the fertilising efficiency in sewage sludge, only around 12% of P and 2% of N are currently usefully recycled. This is because 44% of P is currently landfilled in sewage sludge incineration ash (SSIA) or in sewage sludge used in "landscaping" (22%). Most N is lost in sewage works in denitrification (71%). Wastewater treatment contributes c. 0.3% of Austria's total energy demand, with N_2O losses from sludge incineration being a potentially significant greenhouse emission if incineration increases (whereas these could be stripped from incinerator offgases). Greenhouse emissions from sludge treatment are highly variable, depending on site specific factors such as incineration efficiency, use of composted sludge in agriculture (fertiliser replacement value) or in landfill (no replacement value). Sewage sludge management and disposal make up 0.3 – 20 % of total wwtp costs. The analysis does not show clear differences between different sludge management routes, with variations depending rather on wwtp size, technology and local factors, but does provide a basis for future analysis and scenario development for phosphorus recovery options.

"Systematic data-driven exploration of Austrian wastewater and sludge treatment - implications for phosphorus governance, costs and environment", A. Amann et al., Science of the Total Environment 846 (2022) 157401 DOI.

Algae recycling of fire extinguisher waste

Recycling of end-of-life mono ammonium phosphate (MAP) from fire extinguishers was tested by solvent treatment then use as fertiliser for microalgae growth. MAP is the main component of ABC fire extinguishers (see SCOPE Newsletter 127) and 100 000 t/y are generated as waste annually as fire extinguishers are serviced. The waste cannot be directly used as fertiliser because it is very fine powder and silicone-treated to ensure flow when used, rendering it problematic to handle and hydrophobic. In this study, eight different solvents were tested to render the waste power water-compatible, then it was tested for growth of several different freshwater and saltwater microalgae in 100 ml culture flasks. Several of these solvents showed to hydrophilise the extinguisher powder waste, rendering nutrients available for algal growth. Propan-2-ol = $(CH_3)2CHO$ (isopropyl alcohol) was selected for further assessment. The extinguisher waste treated with this solvent showed not toxicity to algae, and with Chlorella MUR269 showed good growth, nitrogen and phosphorus removal, even up to 2 gP-PO_4/l. This solvent is readily biodegradable, but the fate of the silicone from the waste extinguisher powder is not indicated.

"Microalgae-based circular economy approach to upcycle fire extinguisher powder waste", E. Nwoba, N. Moheimani, Resources, Conservation & Recycling 180 (2022) 106210, DOI.

Vivianite an effective catalyst for UV oxidation of pharmaceuticals

Synthetic vivianite was tested to catalyse degradation of tetracycline antibiotics by ultraviolet light and in synergy with peroxodisulfphate. Commercially purchased vivianite (= iron (II) phosphate [that is Fe^{2+}] = $Fe_3(PO_4)_2$. $8H_2O$ – see SCOPE Newsletter n°138) was tested at 0.4g/l with LED UV light (c. 300 mW) and 10 mg/l of antibiotics, in otherwise clear water, pH 4.5, stirred. Three different antibiotics were tested: tetracycline, oxytetracycline, chlortetracycline. *E. coli* tests, the degradation products showed lower toxicity than the antibiotics. With ten minutes of UV, only 4 – 10% of the antibiotics were photolyzed. With addition of vivianite (no UV), 20 – 25% of antibiotics were removed, probably by adsorption, whereas with UV and vivianite this increased to 28 – 47%. PDS (peroxodisulphate, 1 mM) with UV (ten minutes) achieved removal of 47 – 55%. 95% - 100% elimination of the antibiotics was achieved by vivianite + PDS + UV. Addition of inorganic ions (chlorine, nitrate, sulphate, carbonate) showed to not significantly deteriorate the antibiotic removal rate. Because the optical absorption edge of vivianite is c. 442 nm, sunlight was also tested, and also showed near 100% antibiotic photolysis with vivianite + PDS + sunlight. In *E. coli* tests, the degradation products showed lower toxicity than the antibiotics. Tests showed that elimination remained at around 100% after five reuse cycles (reuse of vivianite and PDS) showing that these are acting as reusable catalysts. Iron leaching showed concentrations of iron of 0.2 – 1.4 mgFe/l (presumably showing some vivianite loss). The authors suggest that this could be an application for vivianite recovered from wastewater treatment. ESPP notes that further research would be necessary to test whether recovered vivianite shows the same photocatalytic behaviour and that the photolysis of antibiotics is likely to only be effective in "clear" water (allowing light penetration) relatively free of other organics.

"Effective elimination of tetracycline antibiotics via photoactivated SR-AOP over vivianite: A new application approach of phosphorus recovery product from WWTP", X-H. Yi et al., Chemical Engineering Journal 449 (2022) 137784, DOI.

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