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ESPP – IFOAM Organics Europe webinar: Which recycled nutrients for Organic Farming ? and why ?

This webinar, co-organised by ESPP and IFOAM Organics Europe (the European umbrella organisation for organic food and farming), 18th September 2023, brought together nearly 200 participants online to discuss which types of recycled nutrient product could be desirable and admissible for use in Organic Farming, and under what conditions.

Slides from the webinar, list of registrants with emails (where authorised) and transcript of Chat have been circulated to all registrants.

EGTOP Reports: https://agriculture.ec.europa.eu/farming/organic-farming/co-operation-and-expert-advice/egtop-reports_en

The EU Organic Farming Regulation 2018/848 art.5(c) specifies as a "general principle" of Organic Farming "the recycling of wastes and by-products of plant and animal origin as input in plant and livestock production".

Eric Gall, Deputy Director IFOAM Europe, opened the meeting, referring to the European Commission Green Deal target to reach 25% Organic Farming by 2030. This recognises the benefits of Organic Farming for the environment, water and soil. By recycling nutrients, Organic Farming can improve these benefits. Phosphorus is a limited, non-renewable resource and the EU's conventional farms are largely dependent on imported inputs (phosphates, natural gas for nitrogen fertilisers), so nutrient recycling is also important for food security.

Organic farmers are therefore motivated to consider new recycled nutrient inputs, subject to these being cost effective and ensuring confidence in contaminant safety.

Recycled nutrients for Organic Farming: recognised need but with questions

Else Bünemann-König, FiBL, explained that Organic Farming is based on system thinking, with nutrient supply to plants through soil life. Carbon-containing organic fertilisers play an important role, as do other aspects of soil and crop management (such as including leys, or minimising soil compacting by tractor traffic). Circularity within the farm is a key aim for Organic Farming, but Organic farms do need to replace nutrients which are exported in crops and/or animal products in order to avoid long-term soil nutrient depletion.

The RELACS project (EU Horizon 2020) studied farmgate nutrient balances of 71 Organic farms in 7 countries, all of which had been operating organically for some time (averages per country: 9 – 24 years). Negative farmgate budgets indicated **nitrogen deficiency in 24% of Organic farms, potassium deficiency in 56% and phosphorus deficiency in 66% of Organic farms**. This is published in Reimer et al. 2023, summarised below. These results confirmed results from previous studies (see Reimer et al. 2020 in ESPP eNews n°49). This RELACS survey of Organic Farmers and interviews with Organic farmers also showed recognition of benefits (organic carbon, nutrient recycling) but strong concerns about contaminants in secondary nutrient materials, in particular for sewage sludge.

RELACS concluded that a focus is needed on ensuring long-term supply of all nutrients for Organic Farming. Phosphorus and potassium are today needed to avoid soil nutrient mining, and external nitrogen input is also needed to enable high productivity in Organic Farms, especially in those without livestock (biological nitrogen fixation is not sufficient). Despite that heavy metal contaminants in waste streams are today low, and that organic contaminants tend to bind to soil and not be taken up by plants, there are concerns about contaminants, in particular copper, zinc and plastics.

Following the RELACS project, but independently, **FiBL published a Reflections Paper 29/9/2021 on the acceptability of recycled phosphorus in Organic Farming**. This paper does not address other recycled nutrients. It aims to guide industry to focus on recycling processes likely to receive approval for Organic farming. The paper suggested that recycled phosphorus can be considered under the following conditions

- **from the following materials**: manure (factory farming excluded), food industry wastes, source separated household wastes, bones, sewage sludge/municipal wastewater;
- with **maximum 25% of P water-soluble**;
- **minimum use of synthetic chemicals** in the recycling process (and exclusion of synthetic N chemicals);
- **EU Fertilising Products Regulation contaminant limits**.

The RELACS project concluded that a multi-criteria decision tree could be developed to identify whether or not a recycled nutrient product is desirable for Organic Farming, taking into account whether EU Organic Farming has adequate supply of the nutrient without external sources, and considering all aspects of product origin, processing, and use, including secondary impacts such as use of non-renewable resources and GHG emissions.

ESPP notes that the US NOP (National Organics Program) Handbook includes Decision Trees to provide guidance as to which products can be eligible for use in Organic Farming in the US, for example "Guidance Decision Tree for Classification of Materials as Synthetic or Nonsynthetic".

EGTOP Opinions

Frank Willem Oudshoorn, Aarhus Innovationscentre for Okologisk Landbrug and **EGTOP** (the EU scientific committee for Organic Farming), noted that soils in Denmark often have high phosphorus because of historical P accumulation under conventional farming with intensive livestock production. Organic farmers in Denmark are subsidised to apply low N. The knowledge synthesis report (Vidensyntese 2023) looked at how to double Denmark's Organic production without increasing livestock numbers. This concluded that recycled nutrient inputs from wastes would be needed, including food waste, human sewage, meat and bone meal and digestate from conventional manure.

The EU Organics-PLUS project (https://organic-plus.net/about/) surveyed consumer knowledge and concerns about contentious inputs for Organic Farming, concluding that consumers were generally not very worried about use of nutrients from outside the organic chain. Processing can improve consumer confidence, for example struvite from sewage or digestates.

On the other hand, **the market for Organic products depends on consumer confidence, so strict rules on contaminants are necessary**. Long-term build-up of contaminants must be prevented. EGTOP generally aligns with EU Fertilising Product Regulation contaminant limits, but tighter limits can be defined either at the EU or national level for Organic Farming, and can concern e.g. microplastics, antibiotics, hormones, antimicrobial resistant genes.

Recent EGTOP Opinions on recycled nutrients include:

- **Recovered struvite and precipitated phosphates**. **Positive** Opinion, aligned with the EU Fertilising Products Regulation definitions and criteria. Authorised for use in Organic Farming by EU Regulation 2023/121
- **Animal Bone Biochar**. **Negative** Opinion because processing adds risks of additional combustion pollutants and loses nitrogen, with no clear benefits.
- **Biowaste from food processing industries. Positive** Opinion because well-defined stream with recycling value and composted/digested separately collected household biowaste is already accepted.
- **Nitrogen salt solution from ammonia stripping. Negative** Opinion (6-8 June 2018 concerning a dossier for use in feeding algae). New applications could be reconsidered.

Discussion in the meeting Chat and with speakers

It was noted that **Organic Farms are already today widely using external nutrient sources** (e.g. digestates, food waste) but that the **current sources of nutrients are inadequate to ensure nutrient balances** for Organic Farming. The nutrient deficit of Organic Farming certainly concerns phosphorus, but also nitrogen (more complex because it can be supplied by Biological Nitrogen Fixation) but also potassium (important for crops and often not considered).

It was noted that **certain inorganic fertilisers are today allowed under the EU Organic Farming Regulation** (see box below), including rock phosphate. However, phosphate rock has very low plant availability and is used very little.

Concerning the question of **nutrient solubility**, the EU Organic Farming Regulation 2018/848 specifies art. 5(g)(iii) that "*external inputs shall be limited to … low solubility mineral fertilisers*". One participant noted that Organic livestock urinating in a field are in any case spreading soluble nutrients. Participants suggested that soluble fertilisers tend to deplete soil biology, whereas Organic Farming aims to build soil life complexity. Other participants expressed concerns that water soluble nutrients in fertilising materials could lead to nitrogen gas emissions to air or to nutrient losses to water (eutrophication risk). Others however noted that some crops at times do need soluble nutrients, for example in early spring when the soil is too cold for biological mineralisation. A question was raised about use of nitrogen solubilising organisms, and it was answered that the aim of Organic Farming is to ensure that the soil ecosystem ensures such functions without adding external organisms.

Discussion also addressed the **exclusion of manure from "Factory Farming"** in the EU Organic Farming Regulation.

This is currently interpreted differently in different Member States. **Manure from conventional (non-Organic) farms is today authorised in Organic Farming, but with varying restrictions and conditions in each Member States.** Private Organic labels sometimes totally forbid its use. EGTOP is discussing this with the aim of harmonising across Europe, but this is expected to take some time. **The question is how to balance the need for nutrient inputs of Organic Farming and the benefits of recycling, with not supporting intensive livestock production**.

The question was raised of how to ensure that **GM (genetically modified) material** is not entering the Organic Farming supply chain from GM soya used in animal feed in conventional livestock production in Europe. It is also noted that manure can contain pharmaceuticals and hormones, often with levels of these contaminants higher than in municipal sewage.

It is recognised that intake of (conventional) manure is important in digesters for methane production, to optimise the digestion process and economics. Ammonia stripping could be implemented to avoid losses. It is proposed to discuss a possible compromise of accepting **digestate and nutrients recovered from digestate** where the digester is taking some conventional manure. In the Chat, the specific question of ammonia salts recovered from digestates was raised.

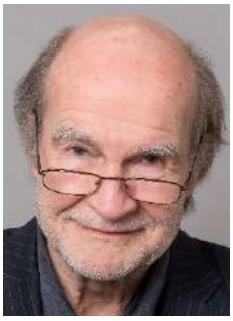
Acceptance of recycled nutrients in Organic Farming from conventional manure should **not facilitate intense livestock production** (factory farming) by providing a solution to this system's problem of local excess nutrient management.

Several comments in Chat considered that the origin (starting material) for recycled nutrients should not be a criterion, what is important is closing the cycle for nutrient and ensuring a product with appropriate nutrient qualities, minimal contaminants and low environmental impact in processing.

Discussion in the Chat also showed **questions about nutrients recovered from sewage treatment**. Recovery processes must ensure low levels of contaminants such as pharmaceuticals or microplastics. Incineration is seen by some as a solution to eliminate these contaminants and allow phosphorus recovery from ash, but others note that it loses organic carbon and nitrogen. Concerns were expressed about possible levels of **iron and aluminium**, resulting mainly from their use in chemical phosphorus removal in sewage works. The question of **sewage sludge incineration** was also discussed, and whether or not the Organic movement wishes to use ash-derived recycled phosphorus (or potassium) recycled fertilisers. On the one hand, combustion means loss of nitrogen and organic carbon, on the other hand incineration will eliminate organic contaminants and microplastics.

Discussion of recycled nutrient products

Calcined phosphates



Calcined phosphates were presented by **Julian Künstler, Metso Outotec** & **Ludwig Hermann, Proman.** These products are produced by thermos-chemical processing of ashes to reduce contaminants (heavy metals) and render phosphorus plant available (but not water soluble). EGTOP gave a **positive Opinion** in in 2016 (subject to authorisation under EU fertilisers regulations), but this covered only calcined phosphates from municipal sewage sludge incineration ash (because only this specific product was included in the dossier submitted). Calcined phosphates are today authorised under the EU Fertilising Products Regulation CMC13.

Inorganic phosphate fertilisers derived from ashes

Inorganic phosphate fertilisers derived from ashes were presented by **Lucas van der Saag, ICL Growing Solutions**. ICL Amsterdam has today an operational process producing mineral fertilisers from sewage sludge incineration ash. The product is certified under the EU Fertilising Products Regulation (CMC13, Module D1) and is REACH registered. The process takes the ash as such: it is upgraded using sulphuric acid (an industrial by-product) and granulated, with no generation of processing waste. The product is stable, odour free, easy to handle, effectively free of cadmium and fluorine (which are found in most commercial mineral fertilisers) and has phosphorus around 20 – 25% water soluble but > 90% NAC-soluble. ICL are developing LCA data which will be shared. Finally, the product has undergone agronomical field trials and small differences in effectivity can been seen compared to standard mineral fertilizers.

Recovered nitrogen from ammonia stripping

Recovery of ammonium sulphate (aqueous solution or dried salt) was presented by **Denis De Wilde, Detricon, Alexandre Bagnoud, Membratec** (left) and **Gunnar Thelin, Ekobalans** (right). Nitrogen recovery from ammonia stripping is today a mature technology. Examples of operational installations were presented including from municipal bio-waste processing and municipal sewage works. Ammonia stripping from digestate can be achieved without chemical dosing (by temperature, pressure and driving off CO_2), avoids ammonia losses to air, enables increased biogas production (ammonia interferes with methanisation) and can reduce energy use and N_2O losses in sewage works (by improving biological oxidation). Use of sulphuric acid (an industrial by-product) enables recovery of the nitrogen as ammonia sulphate solution, which can be concentrated up to c. 8% N/ww or as ammonium sulphate crystals (c. 20% N). Very low levels of contaminants are achieved by the gas stripping and/or by membrane processes. Ammonium sulphate is an effective nitrogen fertiliser, supplying also sulphur.

Risks of ammonia emissions in field application can be mitigated by soil injection of solution, or can be combined with organic by-products for an organo-mineral fertiliser.

Discussion questioned whether Organic Farming wanted such a soluble N fertiliser. Comments noted that the product is similar to natural N compounds in manure enabling supply of a fertiliser N source for Organic Farming, or that a low-solubility product could be produced by reacting stripped ammonia with CO_2 to generate ammonium carbonate. Ammonium carbonate as such is however not stable, risking ammonia losses, so that this would need to be addressed.

Biochars

Biochars from food waste, food industry wastes were presented by **Marcel Rensmann, Pyreg** and **Donata Chiari, European Biochar Industry Consortium.** The Organic Farming Regulation Annex II currently allows biochars from plant materials (only) for use as soil amendments in Organic Farming. Biochars have been shown to provide agronomic benefits by beneficial soil organic carbon which stimulates root biomass and water use efficiency (Schmidt et al. 2021, review of 26 global meta-analyses). Biochars from food waste processing and similar can also provide nutrients (phosphorus, potassium, micronutrients). Biochars are now authorised under the EU Fertilising Products Regulation (CMC14), subject to quality criteria including limits on pyrolysis contaminants such as PAH (but sewage sludge biochars are not today authorised under this Regulation). Compared to composts or digestates, pyrolysis to produce biochars offers the advantage of eliminating contaminants (pesticide residues, PFAS, microplastics …).

Discussion questions noted that nitrogen is "lost" in pyrolysis, although in theory it could be partly recovered, and biochars can also be used for capture of nitrogen losses from e.g. composting, resulting in N-enriched biochar.

Andrea Beste, Gesunde-Erde (Healthy Earth) and EGTOP, questioned the environmental benefits of biochars, taking into account that some CO_2 is produced and much of the nitrogen is lost during pyrolysis and that some contaminants may not be eliminated. ESPP notes that plant-derived biochars are already today authorised under the EU Organic Farming Regulation (but have low nutrient content) and suggests that the question of biochars be considered differently for specific inputs, depending on the nutrient value and the effectiveness of the pyrolysis process for eliminating relevant contaminants.

Comments in the Chat discussed the trade-off between higher temperature pyrolysis, which can reduce plant availability of phosphorus, and lower temperatures which will not eliminate some contaminants. In particular, studies suggest that pyrolysis at around 650°C or higher can eliminate PFAS and that appropriate operating conditions can ensure that PAH are not generated. These trade-offs will again depend on the input materials.

Recycled fertilisers from aquaculture and marine wastes

Krister Hagström, EasyMining RagnSells, presented recovery of secondary nutrients from aquaculture (fish farm sludge). **Aquaculture** in Scandinavia is moving towards collection of fish wastes, to reduce nutrient emissions, organic pollution and fish parasite dissemination risk in coastal waters. Around 70% of wastes can be collected in open cage aquaculture systems. Norwegian aquaculture sludge could provide energy for 600 000 households (biomethane from sludge digestion or combustion) with potential for 33 000 tP/y phosphorus recycling. RagnSells is developing integrated processes for recovery of energy, nitrogen and phosphorus, as well as return of organic materials to soil after hygienisation and removal of salinity.

Anne-Kristin Loes, Norsok, presented recycled fertilisers from seafood processing and seaweed. **Seafood processing** generates significant volumes of residues including bones, heads and other non-consumable fish parts, rich in nitrogen, phosphorus and calcium. Some residues are recycled to aquaculture or animal feed, but around 4 000 tP/y in Norway are currently not valorised. Nitrogen, potassium and magnesium can be extracted from brown seaweed (harvested or cultivated), and combined with processed seafood by-products to produce a nutrient-balanced recycled fertiliser, which has shown positive results in agronomic trials.

These marine sources represent significant potential for nutrient recycling in coastal countries. Certain seafood processing byproducts are specifically authorised for use as fertilisers in the EU Organic Farming Regulations: fish meal – without limitations, mollusc waste and shellfish chitin from organic aquaculture or sustainable fisheries only, seaweed and seaweed processing by-products (see below).

However, questions remain to be clarified, see box below.

General comments and questions in the Chat:

- Lake sediments are rich in nutrients. Can these be used as a fertiliser in Organic Farming ?
- Should recycled nutrients from separately collected human faeces and urine be accepted in Organic Farming ?
- Concerns about pesticide/herbicide residues in plant-derived secondary materials.
- What is important to decide whether or not a secondary fertiliser is appropriate for use in Organic Farming: The input material ? Quality and contaminant safety of the final product ? Chemicals and energy used in the recovery and recycling process ?
- How to measure soil phosphorus and how to take into account long-term soil phosphorus status ?
- How to analyse plant availability of phosphorus in fertilising products ? (beyond the 80% NAC solubility defined by the EU Fertilising Products Regulation).
- How to measure farm gate nutrient balances or deficits .

Conclusions

Eric Gall, IFOAM Organics Europe, concluded that **nutrient recycling is very important for the development of Organic Farming in Europe**, both for environmental objectives and to support productivity for food production. The webinar showed that there is important potential to develop nutrient recycling routes to supply Organic Farming nutrient needs, with agronomically effective products.

However, **there are significant questions and trade-offs** concerning acceptability of non-Organic ("conventional") inputs to Organic Farming, compatibility with Organic Farming principles (feeding the soil not the plant, avoiding non-biological nitrogen inputs), contaminants, Life Cycle Assessment of recycling processes and consumer perception, as well as regulatory questions (EU Fertilising Products Regulation, EU Organic Farming Regulation, national Organic Farming criteria).

The Organic movement should prepare to take up these challenges and there is now a need to define an effective decision-making process within the movement, across the EU, to define guiding principles of which recycled nutrient products are desirable for Organic Farming, under what conditions. This should provide guidance for industry and research in developing and proposing recycling nutrient products to EGTOP for inclusion into the EU Organic Farming Regulation annexes.

Proposed follow-up actions

The following actions are proposed as outcomes of the webinar:

- Producers to write to EGTOP requesting an update of the 2016 Opinion on **calcined phosphates** from sewage sludge incineration ash only, submitting information on chemicals and energy used in the process, on possibilities for limiting aluminium content, and on potential for nitrogen recovery.
- Producers to prepare and submit to national authorities, for transmission to EGTOP, dossiers on **biochars**, **inorganic phosphates derived from ashes,** recycled nutrient products from **aquaculture sludge,** and recycled nutrient products from **seafood processing.** Dossiers should be based on products for which industrial-scale production is either operational or at least permitted / under construction after pilot-scale demonstration.
- Propose to the IFOAM Organics Europe Board to consider adopting a decision to **confirm the objective to develop the use of recycled nutrients in Organic Farming** and to engage actions to facilitate this by clarifying principles of acceptability.
- Develop a "**Reflections paper" on recycled nitrogen products in Organic Farming** (similar to the FiBL Reflections Paper on recycled phosphorus), proposing criteria for acceptability of recycled nitrogen and/or clarifying questions to be answered.
- Develop proposals on **use of conventional manures in recycled nutrient products for Organic Farming** (including aquaculture sludge, insect frass), addressing the conditions for exclusion of "factory farming", and how to consider sources containing a mixture of conventional manures with other à priori acceptable sources (e.g. digestate from digesters intaking manure, food waste, agricultural by-products …).

Studies say Organic Farming needs recycled nutrients

Study of 71 Organic farms across Europe concludes that more than half have negative phosphorus balance, 2/3 negative potassium balance and ¼ negative nitrogen balance. This survey was part of the RELACS EU Horizon 2020 project. The surveyed farms covered seven countries, had generally been under Organic production for a decade or more, and were arable farms of which many also had livestock (overall average 36% of farm land under grassland or fodder crops). Because some farms had positive nutrient balances, average farmgate balances (using NutriGadget) were -1 kgP/ha, -2 kgK/ha and +28 kgN/ha. However, these balances, based on inputs minus outputs in crops / byproducts do not account for losses of nutrients to air or water. The identified phosphorus deficits confirm conclusions of previous studies (Watson et al. 2002, Gosling and Shepherd 2005, Nowak et al. 2013, Cooper et al. 2018, Möller 2018). This new study shows that Organic farms without P deficits are often achieving this by external P inputs, including from "conventional" (non-Organic) manure. Overall, the studied farms relay for 18% of P, 23% of K and 16% of N on external "conventional" nutrient inputs, but with high variations. The authors note that "can be considered moderate, the proportion is important considering the nutrient deficits observed". The external non-Organic nutrient sources used were composted municipal solid waste, municipal biogas digestate, commercial fertilisers derived from organic wastes and in some cases also non-Organic livestock manures. The study suggests that although biological nitrogen fixation (BNF) can supply adequate N for Organic farming, reliance on this results in reduced productivity per ha with farms relying more on BNF and less on external nutrient inputs showing generally lower productivity. The authors conclude that "access to nutrients outside of the organic farming system, preferably from recycled sources, are needed to ensure the sustainability of nutrient management in organic farming". The study also assessed Organic farmers attitudes to external recycled nutrient inputs. 80% were willing to use recycled fertilisers, with >50% acceptance for animal by-products, digestates and household compost, but a much lower acceptance for products from sewage sludge (<5%). Organic farmers considered recycled fertilisers as positive in closing nutrient cycles and providing organic carbon to soil, but expressed concern about possible contaminants and in some cases also about societal acceptance of use of sewage sludge in Organic Farming.

A previous study concluded that if global agriculture were to become 100% Organic (compared to < 2% today), nitrogen limitation would mean food production more than 1/3 lower than from conventional agriculture. Barbieri et al. 2021 used the Global Organic Agriculture Nutrient Model (GOANM) to estimate production locally across a global grid, modelling over 200 production – demand combinations. This concludes that without external nitrogen inputs, the 100% Organic scenario would decrease global food production by -36% (calories). Despite crop diversification resulting in healthier diets, it would be impossible to meet today's food needs. The authors conclude however, that if there was a reduction in human diet calorie intake and significant changes in livestock production, then around 50% Organic Farming worldwide could feed today's population. The shift in livestock would mean 20% less livestock, more ruminants, geographical redistribution, more dairy but less meat, increased grazing of existing grasslands.

ESPP notes that such conclusions depend strongly on the hypotheses concerning human dietary choice.

"Sustainable growth of organic farming in the EU requires a rethink of nutrient supply", M. Reimer et al., Nutr Cycl Agroecosyst (2023). https://doi.org/10.1007/s10705-023-10297-7

"Global option space for organic agriculture is delimited by nitrogen availability", P. Barbieri et al., Nature Food vol. 2 May 2021 https://doi.org/10.1038/s43016-021-00276-y

Questions about fish and seafood materials

The following questions need clarification concerning the use of waste or residues from fish, seafood and marine products in fertilisers for Organic Farming

- Status under the **EU Fertilising Products Regulation (FPR) :**
  - "*fish meal*" is authorised for use as a fertiliser under the Organic Farming Regulations (2021/1165, Annex II) but is NOT included in the DG SANTE Delegated Act 2023/1065 defining materials to be possibly added to CMC10. Is it covered in this Act under "meat and bone meal" ?
  - fish excrement (so effectively, slurry from fish production aquaculture) is excluded from the definition of "*manure*" in the EU Animal By-Products Regulation 1069/2009, but is not excluded from the definition of manure in Regulation 1774/2002 (health rules defining ABPs not intended for human consumption). It is therefore unclear whether or not fish aquaculture slurries can be authorised as an input to EU FPR composts and digestates (CMCs 3 and 5) or to ABP "Processed Manure" (in the future, when "Processed Manures" is added to the EU FPR CMC10).
- The **Organic Farming Regulations** (2021/1165, Annex II) appears to:
  - NOT allow fish excrements as such (only "*farmyard manure*" and "*liquid animal excrements*" are listed)
  - ALLOW fish excrements as inputs to composts ("*animal excrements*")
  - EXCLUDE fish manure input to biogas digestates ("*animal by-products … material of plant or animal origin as listed*")
  In all cases for Organic Farming "*factory farming origin forbidden*" … but is aquaculture considered "*factory farming*" ?
- In that **seaweed** is an "*algae*", the Organic Farming Regulations (2021/1165, Annex II) authorise its use as fertiliser on condition that it is from Organic cultivation or from sustainable collection, and if processed only by drying or other physical processes, fermentation, or extraction with water, acid or alkali.

Which recycled nutrients & inorganic fertilisers are authorised today in Organic Farming

The following are today authorised for use as fertilisers under the EU Organic Farming Regulations. This is a simplification/summary, for precise information see Annex II of EU Regulation 2021/1165 as updated by 2023/121.

Secondary nutrient materials

Recovered precipitated phosphates (e.g. struvite, calcium phosphates)	Must meet EU FPR requirements* Factory farming origin forbidden
Farmyard manure - inc mixed with bedding and feed - inc dried - inc composted Liquid animal excrements	Factory farming origin forbidden
Composted or fermented (digestate) household waste	
Composted or fermented (digestate) vegetable matter	
Biogas digestate of materials in this list and of Cat.3 animal by-products.	Factory farming origin forbidden
Guano	
Dejecta of worms and insect frass	
Mushroom culture wastes	Initial composition limited to materials in this list
Certain Animal By-Products (bone meal, blood meal, fish meal, feathers, wool, dairy products, hydrolysed proteins …)	
Products of plant origin and plant material processing byproducts	
Algae and algae products	Specified processing only Organically produced or sustainably collected.
Mollusc wastes, shellfish chitin	Organic or sustainable fisheries only
Wood ash, wood chips/sawdust, composted bark	
Biochar of plant origin	
Thomas phosphate slag	From iron smelting, main component = calcium silicophosphate

Mineral fertilisers

Soft ground rock phosphate	Formic acid P solubility requirement
Aluminium calcium phosphate	Specified production process and P-content
Crude potassium salt	
Potassium sulphate	Extracted from crude potassium salt
Potassium chloride	Natural origin
Elemental sulphur	
Calcium sulphate (gypsum)	Natural origin
Magnesium sulphate	Natural origin
Inorganic micronutrient fertilisers	

** For **recovered precipitated phosphates (inc. struvite),** Regulation 2023/121 states that (to be used in Organic Farming) these "must meet the requirements laid down in" the EU Fertilising Products Regulation (FPR). The European Commission has indicated that they consider this to mean meeting ALL of the FPR requirements, so including Annex IV Conformity Assessment. In effect, the recovered phosphate must therefore not only meet the criteria of the FPR (CMC12, PFC) but also be validated as a CE-mark fertiliser (in discussion of the FPR FAQ at the Fertilisers Expert Group 28-29 November 2023).*

RAMIRAN 2023 - Europe's leading manure conference

RAMIRAN, Europe's leading, biggest and most dynamic manure and organics management meeting, with 250 participants, 100 presentations, 180 posters, presented worldwide innovation in manure management, covering organic nutrient utilisation, air and water emissions, manure processing technologies, policy & regulation, with particular focus on nutrient use efficiency, nutrient recycling and manure climate emissions.

RAMIRAN is the Recycling of Agricultural, Municipal and Industrial Residues in Agriculture research and expertise Network, which evolved from a UN FAO initiative of 1978. The 25th anniversary RAMIRAN, at Cambridge University UK, 12-14 September 2023, was organised by ADAS, Bangor University and Rothamsted Research.

RAMIRAN2023 conference, sides of keynotes, book of abstracts: https://ramiran2023.org/ RAMIRAN network: http://ramiran.uvlf.sk/

ESPP presentation slides: Regulatory update on organics recycling to fertilisers in Europe: Slideshare.

ESPP's takeaways

Dynamic research …

*The conference showed the **wide, active and ambitious research addressing manure management** in Europe and worldwide, and the efforts made by researchers to disseminate to farmers. Many researchers presented work underway to improve nutrient use and reduce emissions to air and to water from current manure valorisation routes (slurry application to fields, anaerobic digestion and digestate valorisation, composting), including a range of studies to analyse and better understand ammonia and N_2O (greenhouse) emissions from composting and from land application of manure/slurry, as well as looking at improving soil health. Manure nutrient recovery technologies presented included ammonia stripping to aqueous solutions, electrocoagulation (iron phosphate), pyrolysis, biological P-solubilisation. A number of studies looked at processing manures and other organic materials to organic or organo-mineral fertilisers and at agronomic testing of these.*

The wide range of research underway to improve manure nutrient management, reduce nutrient losses and address atmospheric emissions, shows the engagement of the research community worldwide, but also of government R&D funding and of farmers participating in projects and innovation.

… but little application in practice

*However, ESPP's takeaway is the frustration, repeatedly expressed, that **uptake into mainstream agriculture is slow or inexistent.***

*Policy objectives are not translated into regulation and funding conditions. For example, a year and half after **the EU Farm-to-Fork Strategy fixed -50% nutrient loss reduction targets** (June 2020), the revision of the Common Agricultural Policy (CAP, December 2021) included farm nutrient balance monitoring only as "advisory" and not as obligatory, not as a condition for EU farm subsidies.*

Techniques which have been recognised as good practice for many years, and are included in EU BAT documents, are still widely not applied, or only in some countries: e.g. manure acidification, injection not surface application of digestate …

*Often, nutrient recovery for recycling, or techniques to reduce nutrient losses, are **not implemented by farmers because of costs, and because farmers cannot pass costs on in higher prices** to supermarkets and to consumers.*

*This is challenging in the current context of inflation and political sensitivity of food prices. On one hand, food and drink being <15% of household spending in Europe, on the other hand **"food poverty" is a real problem for part of the population** (Eurostat indicate that nearly 10% of Europe's population cannot afford a meal with protein every two days and nearly 20% are at risk of poverty). To address this, action is needed to help poorer families, for example by targeted food vouchers and with education (home cooking rather than prepared food products).*

Need to change diets …

*A critical question, underlined by speakers and participants, is that of diet. Ben Van Salm, Wageningen UR, underlined that re-coupling livestock to land is only possible with reductions in livestock numbers, and that this is **driven by dietary choices**.*

… and to change the CAP

*ESPP notes that one third on average of farmers' income in the EU comes from **public subsidies via the CAP**, so that this would seem to be an important route to ensure mainstream implementation of nutrient recycling and nutrient management, through conditioning of CAP subsidies, whilst ensuring not to deteriorate farmers' incomes.*

*ESPP suggests that maybe now is the time to turn some of the energy, enthusiasm and expertise seen at RAMIRAN towards **defining actionable proposals to change EU farm subsidy conditions for manure nutrient management in the next CAP revision** several years from now, and towards **addressing food poverty and farmers' capacity to pass on environmental costs.***

Presentations and posters

UK and EU policies

A video message from **Secretary of State in England's Department of Environment Food and Rural Affairs Trudy Harrison**, stated the government's commitment to Circular Economy and a Green Clean Future, indicating that better reuse of organic nutrients is key to these objectives. The government has committed to 200 million UK£ to further investments in slurry storage and 25 million UKUK£ to R&D into manure management and recycling.

Claire Northbridge, UK Department for Environment, Farming and Rural Affairs (DEFRA), opened the conference with a vision of context and challenges in England. Farmers understand the economic value of nutrients lost and the pollution impacts of inappropriate manure management. But only 14% of UK water bodies currently meet good ecological status. DEFRA has funded investments in slurry storage, yet **levels of farmer non-compliance to slurry regulations remains high** (<25% compliance for 6 months slurry storage, for example). DEFRA has announced 25 million UK£ funding for R&D into manure management, covering e.g. processing, spreading, nutrient separation, contaminant removal, biostimulants, innovative organic fertilisers with reduced nutrient losses. An outstanding problem remains that of nutrient disbalances: in livestock intensive regions, slurry is stored but then finds to use.

Participant comments emphasised that currently nearly all UK water bodies fail Water Framework Directive Good Quality Status chemical parameters, and that **more than 50% of nutrient inputs to surface waters are from agriculture**. The UK has binding legal targets (Environment Targets Water Act 2023) to reduce agricultural P, N and sediment losses to surface waters by -40% by 2038 and to reduce wastewater losses of phosphorus by 80%.

But there is no indication that post-Brexit UK farm subsidy policies will ensure achievement of these objectives.

Chris Thornton, ESPP (European Sustainable Phosphorus Platform), updated on policy and regulatory developments for nutrient recycling in Europe (slides here). EU nutrient recycling policies are in the context of the Green Deal target to reduce nutrient losses by at least -50% while ensuring no deterioration on soil fertility and Circular Economy and Critical Raw Materials policies. Currently in discussion in European Parliament and Council are **the revision of the Urban Waste Water Treatment Directive, with a proposal to introduce EU-wide P and N reuse and recycling requirements for sewage treatment**, and the Critical Raw Materials Act, which proposes to maintain Phosphate Rock and Phosphorus (P_4) on the EU Critical Raw Materials List. P-recovery from municipal wastewater is now included in the EU "Taxonomy" (green investment criteria)

Melissa Wilson, University of Minnesota, showed successful outreach and information programmes for farmers promoting better manure management practices. Research aimed at testing real farmers questions on how to improve manure use. **Sidedressing of manure into standing maize** (see photo) reduces losses, because the plants can uptake nutrients more rapidly than on bare soil, and reduces need for manure storage capacity. Tests showed that the maize plants were not damaged by a standard drag hose application and that the manure was effective for crop growth. Online videos (here) of virtual field tours are effective in reaching thousands of farmers.

Nicholas Hutchings, Aarhus University Denmark, discussed pathways to net zero agriculture 2050. Measures to reduce impacts of current production systems are necessary but unlikely to be sufficient (e.g. increased used of crop residues and manures for renewable energy). Restructuring of production – and so land use - from livestock (and reduced diet consumption of animal products) to biomass production, and conversion of cereal to perennial cropping will be needed, enabling carbon capture, reduced nutrient loss and improved soil quality. Implementation poses challenges of farmer support to adaptation and of equity, as well as ensuring that imported food does not export environmental impacts and unfairly compete with EU production.

Ammonia losses and leaching from manure

Xuan Wang, China Academy of Science, indicated that **livestock represent one third of global reactive nitrogen emissions**. China animal protein production in China has increased 6x over the last thirty years with spatial decoupling of livestock. Over half of livestock in China are today in landless farms and nearly ¾ of manure nitrogen is lost in manure management. **Greenhouse emissions per g protein production have been more than halved since 1980, as have feed requirements** (Bai et al. 2018).

Nonetheless, **livestock ammonia emissions cause 60% of air particle related deaths in livestock intensive regions of China**. Under a Business As Usual scenario, 60% of China's population will be exposed to high air ammonia by 2050. Geographical redistribution of more than half of all China's livestock would be necessary to reduce this to 10% of China's population.

A critical problem is the regional concentration of livestock, secondary N and P exceeds crop needs in 30% and 50% of counties in China (Jin et al. 2020 DOI)

Prof. Wang emphasised the important nitrogen losses in composting of manure (ammonia, N_2O) and in manure application. Ammonia losses can be reduced by half by injection rather than surface spreading and by manure acidification in stable / storage / spreading (Zhang et al. 2021 DOI). Optimising protein in diet can reduce N and P in manure without impacting yield (Guo et al., 2019). Actions are also needed to reduce N emissions from composting processes.

China is leading the way in new routes to food / animal feed protein from secondary organics, with 13 000 earthworm or mealworm production units, 800 black soldier / fly units, 120 insect units (Bai et al. 2023 DOI).

Photo 40 m^3 manure treatment reactor, pig farm, Jinzhou Shijiazhuang.

Karl Richards, Teagasc, noted that **farming in Ireland accounts for over 90% of ammonia emissions and one third of greenhouse emissions**. The Government has set legally binding targets of -25% agriculture greenhouse emissions reduction by 2030 and -1%/year ammonia emissions reduction to 2030, -5% after that. This will be challenging as dairy production is expanding to meet global food demand. Ammonia, methane and N_2O emissions from manure management can be reduced by appropriate storage, aeration, acidification and other additives, spreading techniques (e.g. trailing shoe). It is important to ensure that techniques to decrease emissions of one gas do not increase other emissions.

Alison Rollett, ADAS indicated that nearly 90% of ammonia emissions in the UK are from agriculture and nearly one third are from spreading of digestate and manure. These emissions cause some 25 000 premature deaths annually be generating airborne particulates. The UK has committed to reduce ammonia emissions by -16% (National Emissions Ceilings).

Manure acidification and injection (rather than surface spreading) are techniques known to reduce ammonia emissions, included in EU BAT (Best Available Technology) for pig and poultry farms ("Intensive Rearing of Poultry or Pigs").

ADAS has tested the N2 Applied plasma manure upgrading process (see ESPP eNews n°58). This increases nitrogen in slurry or digestate by x1.5 to x2 (so increasing fertiliser value for farmers), whilst lowering pH and reacting ammonium to stable nitrogen forms. The ADAS tests have shown **reductions in -60% to -90% in ammonia losses, doubling of nitrogen use efficiency by crops, increases of around 150% in crop yield**.

Hanna Frick, FiBL, compared ammonia emissions and nitrate leaching with application of 15N-labelled manure (cattle slurry) to mineral fertiliser (ammonium nitrate, same N application rate), looking at behaviour of N in soil, in field and pot tests. In the field, **ammonia losses were around three times higher from manure (surface application) than from mineral N fertiliser** (10% vs 3%). Around 50% of the mineral fertiliser N was recovered in crops in rotation (grass-clover, maize, wheat), compared to around 20% from manure, whereas 60% of manure N was held in soil after 2 ½ years compared to 30% from mineral fertiliser. **Cumulative nitrate leaching was twice as high from manure as from mineral fertiliser**, but with >95% of leached N in both cases coming from mineralisation of soil N not from the fertilisation. Pot trials suggest that neither nitrification inhibitor (DMPP) nor biochar were effective in improving N recovery to biomass or soil, whereas anaerobic digestion of manure did improve crop N uptake.

Stephen Nolan, GlasPort Bio, presented results of lab scale (20l) tests of additives to reduce greenhouse and ammonia gas emissions from stored manure (Horizon 2020 SME GasAbate N+ project, see ESPP eNews n°70). Over 50 days storage, **greenhouse gas emission** was reduced significantly **by >80% for CH_4 and >50% for CO_2,** while N_2O, H_2S and ammonia emissions were also considerably reduced. After storage, the biogas production potential was nearly 20% higher with the additive.

Recycled nutrients in the field

Anne Bhogal, ADAS, indicated that application to NVZ limits (Nitrate Vulnerable Zone nitrogen application rates) mean input to soil of approximately 2 tC_{-org}/year for biosolids and 3 tC_{-org}/year for manure. This application has been **shown to increase soil organic matter (SOM) over time**, e.g. around +2.5% increase in SOM with 90 tOM/ha manure over 20 years or 50 tOM/ha green compost over 9 years (Bhogal et al. 2018). Organic material in soil can improve water holding (drought resilience), biological nutrient cycling, root development, soil structure and workability and can reduce nutrient losses to air and to water. However, reviews by Hijbeek et al. (2016, 2018) concluded that most studies do not show a crop yield benefit from increases in soil organic carbon associated with organic inputs. Benefits are found in tropical soils, and only tend to be seen in Europe when water is constrained, in particular for light soils, for root crops, maize and spring crops, and occur following repeated applications of manure, but not of slurry. Increases in soil carbon following manure additions have also been proposed as a climate change mitigation strategy, but there is much debate about whether this is genuine carbon sequestration (See British Society for Soil Science 2022 for further discussion of this topic).

Ruben Sakrabani, Cranfield University, made an overview on organo-mineral fertilisers. He reminded of the EU Fertilising Products Regulation definition: a co-formulation of inorganic fertilisers and materials containing organic carbon and nutrients of solely biological origin. **Field trials show yield results comparable to mineral fertilisers** (e.g. Deeks et al., End-o-Sludge project, 2013, see SCOPE Newsletter n°96; Burak & Sakrabani 2023). Benefits include organic matter input to soil, recycling, carbon capture. Challenges to development and uptake include traceability, contaminants, drying cost, spreading machinery and regulatory complexity (end-of-wase, certification).

Ana Robles, UVIC Beta Technology Centre, summarised results from the **Fertimanure Horizon2020 R&D project**, producing and testing 18 recycled fertilising materials from different types of animal manure. All of these showed crop yield and nutrient leaching comparable to mineral fertilisers and in some cases lower N_2O emissions from use (14 field trials with 10 different crops: potatoes, ryegrass, winter wheat, tomato, spinach, cabbage, maize, sugar beet, grass, lettuce).

Elizabeth O'Carroll, TEAGASC, presented three year field results from Ireland testing seven secondary nutrient materials on grass (13 harvests), compared to triple superphosphate (TSP and control. **Two recovered struvites showed higher cumulative grass harvest than with TSP from the first harvest to the end of year three**, reaching +50% higher after three years. Dairy sludge after aluminium P-removal and cattle slurry achieved similar high yields, but only after two years. Poultry litter ash and calcium dairy sludge gave considerably lower yields than TSP after 1-2 years but close to TSP by end of year 3. **Sewage sludge incineration ash gave low yields throughout, even after three years**.

Eva Mitchell, University of Bangor, presented soil analysis of fields having received long-term application of sewage biosolids in Wales, and initial results of field trials of a range of recycled fertilising materials (cattle manure slurry, food digestate, green waste compost, sewage biosolids, with or without gypsum). Fields have received biosolids showed in some cases higher available phosphorus than fields which had not (mineral fertilisation), but on average the difference was not significant. Biosolids receiving fields showed slightly higher soil copper, zinc and lead but lower nickel. **Analysis of biosolids from four sewage works in Wales showed wide variation of available phosphorus**. Initial results show varying soil P availability a few weeks after application of the different materials.

Wim Van Dijk, Wageningen University & Research, looked at uptake and fate in soil of manure nitrogen after three years in field trials, cut grassland, using cattle and pig slurry, digestate and two mineral fertilisers (calcareous ammonium nitrate; urea with inhibitor). In the first year, apparent N recovery (uptake in crop comparted to no fertiliser control) was around 80% with both mineral fertilisers, not increasing with years 2 and 3. With manure materials, ANR generally increased over the three years, from around 40-60% ANR in the first year to 50-70% two years later. **In 2 out of 3 years, autumn soil mineral N was significantly higher in the plots receiving manure products**, compared to mineral fertiliser and control plots, but nitrate levels in the ground water were not significantly increased.

Andrea Bauerle, University of Hohenheim, presented the results of field trials of two recycled fertilisers on spring barley in Germany (**Lex4Bio Horizon2020 project**). The materials trialled were a solid organo-mineral fertiliser (produced from meat and bone meal, phosphate rock, vinasse and chicken manure) and a solid organic fertiliser (keratin-based, produced from hornmeal / hydrolysed pig bristles) all tested at 107 kgN/ha, compared to a mineral fertiliser and unfertilised control. **The two recycled fertilisers gave 15 – 25% lower grain yields than the mineral fertiliser** (organo-mineral higher than organic), but significantly higher than the control. The N content of the grain was also slightly lower with the recycled compared to mineral fertiliser. Soil tillage with plough resulted in higher yields than with cultivator. Two further years of field trials are underway. Two previous years of field trials with 18 recycled fertilisers across European sites are available here DOI.

Manish Sharma, University of Western Australia, presented 60-day pot trials of wastewater recovered struvite on chickpea and on wheat (soil pH 5.1). The struvite showed to be a somewhat more effective phosphorus fertiliser than MAP (monoammonium phosphate) with chickpea, but less effective with wheat (granule size of both fertilisers was 2-3 mm). Phosphorus leaching losses to water (from pot base) were lower with struvite than with MAP. The authors suggest that differing results may be due to release of carboxylates from chick pea roots and that further research is needed into which plant species are effective in accessing non water-soluble phosphorus in recycled fertilisers and in soil, and by what mechanisms.

Bert Everaert, Inagro, presented field trials on maize, potato and winter wheat of aqueous ammonium nitrate solution, recovered from ammonia stripping of manure (Operational Group Renure). The recovered solution had a nitrogen content of 10 – 15% N (wet weight, of which around half recovered nitrogen, half from nitric acid use for stripping), with considerable variability, compared to 27 – 40% N in commercial nitrogen fertilisers. **The recovered ammonium nitrate solution showed performance comparable to commercial nitrogen fertiliser** (crop yield, N-uptake). However, the relatively low N content (per weight) of the recovered aqueous solution poses challenges of transport costs (unless used locally) and of increased tractor traffic on fields for application (soil compacting). Other challenges are the stability of the ammonium nitrate solution and its status under the Nitrates Directive.

Lelenda Kebalo Florent, INRAE France, presented 3 ½ month greenhouse pot trials with tomatoes using secondary organic nutrient materials / mineral nitrogen fertiliser in combination or alone/ guano/ control (no fertiliser). The study tested combinations of green waste compost, food waste compost, cow manure with either human urine, food waste digestate or mineral nitrogen fertiliser. Mineral fertiliser, guano and the combinations of secondary organic materials, all gave similar fruit yields (fruit weight and number), all around twice as high as control. Nitrogen use efficiency (based on the total N applied) was considerably higher with the mineral fertiliser and with guano. Soluble sugar in the tomatoes was significantly higher with most of the organic materials (including guano) compared to control and mineral fertiliser. No risk of heavy metal presence in tomato fruits was observed.

Theodore Welby, Cranfield University, presented field trials (one year) with spring barley and oilseed rape, comparing a mineral nitrogen fertiliser and control (no fertiliser) to three variations of the CCm organo-mineral fertiliser (see SCOPE Newsletter n°145). This combines ammonia carbonate (from recovered CO_2 and ammonia stripping) with fibrous organics. The three variations had differing nutrient / organic material ratios. Most of the results were not statistically significant, including no statistically significant difference between yields with chemical fertiliser compared to control, at 50 – 200 % recommended fertiliser dose.

Jochen Mayer, Agrsocope, Switzerland, presented a field trial comparing solid mineral nitrogen fertiliser (ammonium sulphate) to four organic materials: cattle slurry, cattle slurry digestate, this digestate plus biochar, household waste digestate liquid fraction. The 15N-labelled materials were surface applied to maize, winter wheat and winter barley. **Apparent N use efficiency and ammonia N use efficiency were both around twice as high with the mineral fertiliser**. Nitrate leaching downwards in soil was overall low (c. 25 kgN/year) including in the control (no fertiliser). N_2O emission were low (1-2 kg N/ha/year). Ammonia air emissions were very high for all fertiliser applications (42 – 58% of applied ammonia-N).

Soil phosphorus and eutrophication

Mario Álvarez Salas, ETH Zurich, showed data on P-fractions in secondary nutrient materials and in soil, with 20-year application of high loadings in the **CRUCIAL long term field experiment, Denmark** (250 - 500 kgP/ha/year). Materials applied were household waste compost, sewage sludge (sewage works using iron salts for P-removal), three manures/slurries, human urine and mineral fertiliser. With these high P loadings, results showed P accumulation in topsoil, but only for around one quarter to one half of applied P, with the remaining P being lost or moving to deeper soil. **P_{total} losses were lower with sewage sludge than with compost or cattle manure**. The ratio of soil P accumulation versus loss did not correspond to P-fractions in the applied materials.

Majken Meldorf Deichmann, SEGES Innovation, presented trials of phosphorus traps to treat drainage water from peatlands. In order to achieve greenhouse gas reduction objectives, Denmark aims to rewet over 50 000 ha of drained peatlands, because **CO_2 loss from drained – cultivated peatlands is estimated to contribute nearly one third of Danish agriculture climate emissions** (more than livestock = c. 22%). Risk of increased phosphorus losses is currently blocking a third of rewetting projects. At three study sites, different P-trap systems were tested, including electro-flocculation (iron, plus chitin coagulant), sedimentation, biochar and sorbent filters. These systems achieved up to around 2/3 removal of total P. Challenges are cost for small scale systems and impacts on effectiveness of dissolved organics in water, which can be important for peatlands.

Penny Johnes, University of Bristol, explained the importance of nutrients linked to dissolved organic matter (DOM) for eutrophication. In several studies, radiolabelling, laboratory bioassays and field mesocosms show that uptake of DOM phosphorus and nitrogen, chlorophyll response and protein synthesis vary between algae species, seasons, different sites/environments and different dissolved compounds (amino acids, glucose-phosphate, orthophosphate). Overall, both dissolved organic nitrogen and dissolved organic phosphorus are available to algae and other plants, with uptake rates equal or even higher than for inorganic nutrients. Uptake is fastest in low-nutrient waters, but the **dissolved organic nutrients also drive eutrophication in nutrient-enriched waters**.

Nutrient recycling processes

Oscar Schoumans, Wageningen University & Research, summarised pilot-scale testing of a range of manure processing technologies in EU Horizon funded research projects **SYSTEMIC** and **FERTIMANURE**. These trials show the importance of solid/liquid separation technologies, as this is key to partitioning nutrients and organics, reducing water content of solid products and particulates in liquid fractions intended for nutrient recovery (e.g. interference with membranes).Separation efficiency can vary by factors of 2-3 between centrifuge, screw press and filter press. Similarly, quality of "mineral concentrates" varies widely between membrane trials, with variability of factor 10+ in e.g. organic carbon content or nitrogen species. Recovered ammonia solution "concentrates" contain 7-8% recovered N / wet weight. These large research projects have shown that valorisation of manure is technically possible, that the recovered fertilisers can provide good agronomic properties, especially if adapted to crop needs by blending with other nutrients. However, careful attention to application conditions is essential and processing costs are high compared to bulk mineral fertilisers.

Matias Vanotti, US Department of Agriculture, presented tests of fermentation of pig manure solid fraction to solubilise phosphorus, enabling recovery by precipitation. See similar work by Daumer, INRAE, in ESPP SCOPE Newsletter n°138 Addition of peach waste (non-saleable fruit) to the manure provided both sugar and acidity, with 'lactic acid' fermentation (acidophilus bacteria) leading to pH<5 and **solubilisation of >80% of phosphorus**. After removal to recovery of the solubilised phosphorus, >80% of protein was recovered by alkali extraction.

Ari-Matti Seppänen, LUKE Finland, showed trials processing composted to pelletised fertilisers (thermophilic compost of slaughterhouse wastes and other organic materials). The compost was blended with ammonium sulphate and urea. **Over fifty pelletising tests were carried out with compression ratios 4:1 to 8:1**. Pellets with <10% moisture content were produced. Initial conclusions are that pellets with high nutrient content could be produced, compatible with farmers spreading equipment. Crop trials are now planned.


Marie Kirby, Harper Adams University UK, presented iron electro-coagulation (Elentec) to precipitate phosphorus from the liquid fraction of cattle manure (after micro-filtration). The Elentec containerised installation was tested on-farm over an 8-month period, treating multiple 1,000 l in batch/cycles 3-9 hours. Further work will scaleup to continuous operation at 2 m^3/h.. Around 98% P-removal from the liquid was achieved. The recovered material was an iron phosphate slurry, containing approx. 1gP/l., 4 gN/l and 2 gK/l.. **This iron phosphate slurry showed to be an effective phosphorus fertiliser** for rye grass duration pot trials, showing growth around double over after 4 sequential cuts (115 days) compared to commercial P fertiliser.

Matt Taylor, Assured Biosolids Ltd, presented developments in the UK's BAS (Biosolids Assurance Scheme) to minimise impacts of agricultural use of treated sewage sludge. The UK BAS scheme, developed by the UK water companies with farmers and food chain stakeholders, ensures **audit of all UK sewage sludge to land, enabling use of approximately 850 000 t/y (dry matter) sewage in agriculture, worth UK£ 60 million to farmers** (considering the value of P and N only). 20 measures have been introduced to minimise nutrient losses to water, including limits to application on certain soils or near watercourses, tighter P application restrictions, training and information of farmers, including nutrient management plans. The BAS Quality Assurance schemes can complement regulation, and accelerate and improve regulatory implementation.

Ammonia recovery


Giorgio Provolo, Università degli Studi di Milano, presented on-farm pilot scale testing of ammonia stripping/recovery from pig manure digestate, after screw press filtration (30 m^3 15-30 day batch process = 1 – 2 m^3/day, operated for a total of 8 runs). After 15 days, 40 – 70 % of ammonia nitrogen was removed from the digestate by maintaining at 30 – 45°C. The resulting ammonium sulphate solution was diluted by water carry-over from the stripper (with evaporation, ammonia comes off not as gas but dissolved in water droplets), generating **aqueous ammonium sulphate solution with up to 5% N wet weight.**

Mercedes García-González, University of Valladolid, presented pot trials of recovered ammonium sulphate solution. Ammonia was recovered from manure treatment by gas permeable membrane technology, resulting in a dilute solution (2.8% N/ww) containing also other elements including (in mg/l): molybdenum = 114, potassium = 9, iron = 6, boron = 3.5, zinc = 3, cobalt = 2.6, copper = 1.5, phosphorus = 0.1. This solution was compared to synthetic ammonium sulphate for germination and then for growth of barley (13 weeks) and spinach (5 weeks) in three different soils Germination, barly flag leaf length and number of leaves on spinach are reporter. **The commercial fertiliser showed lower germination and growth than the control in all trials** (no fertiliser) and the recovered ammonium sulphate showed lower in some cases, higher in others. Overall results were better with the recovered ammonium sulphate than with the synthetic ammonium sulphate.


Elio Dinuccio, Università di Torino, presented tests of a 3-stage multi-membrane process to produce "mineral concentrate" from liquid fraction of cattle manure (LIFE-OPTIMAL project). A centralised biogas plant treats over 63 000 t wet weight of dairy manure per year. Digestate as solid-liquid separated using a screw press, followed by a vibrating sieve (to reduce downstream membrane fouling). The liquid fraction was then treated in a pilot 3-stage reverse osmosis membrane unit (60-120 m^3/day continuous operation), which was operated for six months and monitored over two sampling campaigns. **The final "concentrate" from the membrane system was an aqueous liquid with 0.6% N, 1% P wet weight.** The solid fraction was dried (using energy from biogas combustion for electricity) and pelletised. Around 50% of the manure N was transferred to the "concentrate" and nearly 100% of this to the pellets.

Wen Zhang, New Jersey Institute of Technology, presented lab scale (c. 1 litre) tests of an **electrochemical flow cell to convert nitrate to ammonia,** recovered by membrane stripping to ammonium sulphate. The cell used a PTFE (PFAS) membrane coated with copper catalyst for electrochemical nitrate reduction. Paired electrolysis enabled proton and hydrogen transfer between cathode and anode chambers to minimise acid/base use for NH_3 capture. Lab testing generated **aqueous ammonium sulphate solution with 0.035 %N/wet weight**. See publications DOI, and DOI.

Laboratory and research

Lotte Veenemans, Wageningen University & Research, showed laboratory tests comparing analysed carbon and nitrogen characteristics to CO_2 emissions over four months in two soils for 16 recycled fertilising materials (composts, digestate, manure, straw, struvite, grass, …). The RothC model was used to estimate decomposable fractions. **The behaviour of carbon from organic fertilising products could be well explained by the model based on simple laboratory analyses.** Results show furthermore that using C/N ratios per pool is too simplistic to explain nitrogen turnover.

Sylwia Siebielec, Poland Institute of Soil Science and Plant Cultivation, presented work underway to integrate selected biostimulant bacteria into organic recycled materials (e.g. digestate, compost, biochar) to improve fertiliser effectiveness and drought resistance (Poland national NCBR project INNO-MIK). Bacteria were selected to be able fix atmospheric nitrogen, solubilise phosphorus, produce siderophores (iron chelaters) or phytohormones. To date strains of Streptomyces, Azotobacter, Bacillus and Pseudomonas bacteria have been selected and injected into the organic materials. Greenhouse pot trials will now be carried out.

Maja Rydgård, Copenhagen University, presented an inventory model for regional LCA modelling of the impact of recycled phosphorus applied to fields for regions in Denmark and in Italy, considering struvite, sewage biosolids (from chemical, and from biological P removal sewage works) and sewage sludge incineration ash. The model took into account labile and stabile P in the recycled materials and in soil. The model estimates higher P-losses from ash and iron-rich biosolids, because P is less plant available, so tends to remain longer in soil with risk of loss with soil erosion, especially in the hillier Italy Piemont region. **Struvite shows lower modelled P losses and higher mineral fertiliser replacement.**

Veronika Hansen, University of Copenhagen, presented soil incubation tests (330 days) with eight different recycled fertilising materials: cattle manure digestates, household biowaste digestate, two composts, meat and bone meal (MBM), Fertigro, insect frass. Fertigro is a residue from production of medical heparin, containing c. 12% N/ww and c. 5% sulphur (see Gomez Munos et al. 2023). Fertigro and MBM showed the highest N release, with digestate and insect frass also significantly releasing N, but very little N release from composts. On the other hand, MBM and Fertigro showed reduced soil fertility (microbial biomass carbon) compared to the untreated control, whereas **composts and digestates showed slightly increased soil fertility, and insect frass a significant increase**.

Fien Amery, Institute for Agricultural and Fisheries Research Belgium (ILVO), showed data on compost quality from 119 different composts from five European countries, with manure, green and or fruit & vegetable wastes as inputs. Conclusions are that **compost characteristics vary widely, as a function of composting process and input materials**. Organic matter considerably impacts other properties. Microbial biomass can serve as a compost quality indicator.

Egor Moshkin, United Experts, presented results of a survey on attitudes to five different recycled fertiliser materials: struvite, biochar, ash, ammonia sulphate and ammonia nitrate. (**Ferticycle Horizon 2020 project**) The survey was open online January – June 2022 and received around 350 responses, of three quarters were farmers. **Around half of the respondents would be willing to purchase the recycled fertiliser materials with price equivalent to mineral fertiliser**, and around three quarters of respondents if they were 30 – 45% cheaper than mineral fertiliser. Psychological aspects have more impact on declared willingness to purchase than on the price farmers would be ready to pay.

Vishal Zende, University of Limerick (REFLOW EU Horizon 2020) presented analysis of Cat. 1 meat and bone meal ash (MBM from a commercial rendering plant in Ireland) and dairy food industry wastewater treatment sludge ash (commercial industry sludge burnt in a laboratory fluidised bed). Both ashes show phosphorus contents (13 – 17%), higher than low-grade phosphorus rock from Egypt. With MBM ash, the P/Ca ratio is compatible for industrial phosphoric acid production, whereas dairy ash would need to be upgraded (for example using the Prayon GetMoreP process). Heavy metal levels were below EU Fertilising Product Regulation limits and below levels in the analysed phosphate rock (except for zinc which was higher). **The Cat1 MBM ash would be good input material for phosphate fertiliser production,** but that the EU currently excludes Cat1 ash from use in fertiliser production. The dairy waste showed high aluminium content (from use of aluminium salts in dairy wastewater treatment) which could pose problems or require additional processing.

European Waste Water Management Conference

The AquaEnviro EWWMC Conference 2023 brought together nearly 300 participants in Manchester, UK, plus 40 online, covering nutrient removal and recovery, N_2O emissions and net-zero energy, micropollutants, process optimisation. The conference ran three parallel sessions for two days, with 75 presentations, and some 30 posters and company stands.

ESPP opened the nutrient sessions with a summary of **current developments in EU water policy**: Green Deal and nutrient loss reduction targets, Urban Waste Water Directive ongoing recast, Sewage Sludge Directive and Water Framework Directive revision perspectives, sewage phosphorus recovery in the EU Taxonomy, sewage recovered nutrients in the EU Fertilising Products Regulation (End-of-Waste) and in Organic Farming.

Innovative nutrient removal:

Matthew Langdon, Brandy Nussbaum, Veolia: **NaturP** - an MBBR (moving bed biofilm reactor) with one unit installation for combined enhanced biological phosphorus removal (EBPR) and nitrification-denitrification (ammonia and total nitrogen removal). The system is compact (total cycle time 6 – 10 hours), robust (no mechanical mixing, bubble aeration) and flexible (installation with or without primary treatment) and so is adapted for small-medium sewage works. Final solids removal can be by flotation (DAF) without chemical dosing or microfiltration (Veolia Hydrotech). Pilot installations have been tested in France and discharge < 1 mgP_{total}/l , < 10 $mgN_{soluble}/l$ are achieved. Veolia are now looking for a greenfield site, around 10 000 p.e. for a first full scale installation.

Paul Wisdom, Power&Water – **Soneco® -** phosphorus precipitation by electro-generation of metal ions from sacrificial anodes (see SCOPE Newsletter n° 125). Ultrasound prevents passivation (formation of a passive layer on electrodes). The system avoids the use of liquid iron or aluminium chemicals, and so avoids the need for tanker deliveries, ferric storage tanks, water supply for safety showers, etc. which can be challenges for small sewage works. It can be easily turned on and off, and does not deteriorate when not in use. Alkali dosing for pH correction is not needed. Soneco installations are today in the UK, Norway and Singapore. A three month trial has been carried out with Scottish Water at Bo'ness, using iron plate anodes and **Mecana** filters to remove iron phosphate particles. Discharge below 0.2 mgP_{total} /l was achieved. A study conducted by MMB concluded that Soneco showed c. 80% lower embodied carbon and c. 50% lower operational carbon compared to liquid ferric dosing.

Simon Radford, EVOQUA, Xylem Group, Flemming Wessman, ENWA Norway: **CoMag** enhanced chemical P-removal (see SCOPE Newsletter n°141) project for Fredrikstad Norway, capacity 6600 m^3/hr. CoMag uses a natural mineral, magnetite (iron oxide), to ballast flocculation (plus polymer dosing prior to the clarifier) to improve removal of phosphates (usually after precipitation by iron or aluminium dosing) and BOD removal. The magnetite is recovered from the waste sludge by a magnetic drum and then reused. The system enables high levels of particulate removal in a compact system which in Norway is very important as all plants are located indoors. At Fredrikstad wwtp the CoMag system will be designed to deal with both stormwater or, when this is not required, will be used as a polishing tertiary treatment step downstream of the main wwtp (which operates chemical P-removal and DAF solids removal by flotation). Including storm events, the objective of the plant is to achieve P_{total} removal to > 95%, which is a new requirement for the Oslofjord to which the plant discharges. Commissioning is planned for 2026. Photo: Clarifier after CoMag at Finham wwtp (Severn Trent), clarifier, see SCOPE Newsletter n°141.

Jeremy Biddle, Bluewater Bio – **FilterClear**: this is a filter system with four layers of media (anthracite, silica, alumina and magnetite) used for final discharge polishing, to remove small particulates and precipitated phosphorus (downstream from iron or aluminium dosing). FilterClear can accept a high inlet solids concentration (up to around 100 mgSS/l) and data from Severn Trent demonstrate that the system can achieve 0.1 - 0.5 mgP_{total}/l (depending on dose rate) and iron < 2 mgFe/l, on a consistent basis. The system is modular, uses standard equipment (pumps, blowers, actuated valves) for ease of maintenance, skid installation for rapid delivery and installation, flexible inflow/outflow connection possibilities, low maintenance. Filter media attrition is around 2%/year, requiring top-up every five years. Around 80 full scale installations are operational worldwide (total installed capacity today over 300 000 m^3/day) including Barton and Codsall, both UK (photos) (see SCOPE Newsletter n°s 141, 133, 125). Two 70 000 m^3day installations (each using four horizontal filters) are now under construction at Newthorpe wwtp and Rushmoor wwtp, Severn Trent Water, UK.

Connor Sandalls, Shirly Liang, Adela Martin, Imran Baloch, Southern Water, Candice Cameron, University of Portsmouth, presented experience of introducing second-point ferric dosing at Petersfield wwtp, Hampshire, UK (24 000 p.e.). The site has hard water and uses settlement, trickling filters and humus tanks for treatment. Primary ferric dosing is before the primary settling tanks. The trial demonstrated that by introducing a **second ferric dosing point prior to the** humus tanks (without alkali dosing), the site can reliably achieve ≤0.6 mgP_{total}/l.

Mariana Pinheiro, Graham Lea, Southern Water, presented optimisation of **chemical P-removal using ferric** at a small sewage works (3 600 p.e.). Modification of the alkali dosing point (alkali is needed necessary because of soft water), optimisation of the ferric dosing and mixing with the wastewater flow (one dosing point into a mixing tank, after trickling filters and before humous tank), and use of Mecana filters for removal of fine particles from discharge, is now achieving 0.1 mgP_{total}/l.

Paul Lavender, Royal HaskoningDHV, summarised ongoing developments of the **Nereda®** process (see SCOPE Newsletter n° 133). This is a compact one-unit enhanced biological phosphorus removal (EBPR) reactor system using granulated sludge, adapted for small or medium size sewage works. Over one hundred units are today operating worldwide (photo: Dungannon, Northern Ireland). Work underway in the UK is optimising operation under high peak flows. Tests are also underway to reduce N_2O emissions, showing that modification of the biological P-removal cycles can reduce emissions by around 60% without significantly deteriorating phosphorus removal.

Ben Hazard, Te-Tech Process Solutions, Connor Sandalls, Southern Water, presented experience with the **te-cyc** sequencing batch reactor, a compact unit system for EPBR P-removal, at Hawkhurst South wastewater treatment works (**photo**), near Maidenhead (2300 p.e.). With some ferric dosing in the primary tanks in addition to the te-cyc bio-P removal, and with **Mecana filters** on the discharge to remove fines, < 0.3 mgP_{total}/l is achieved without dosing of alkali (despite soft water), as well as iron discharge consent of 4 mgFe/l and ammonia 3 mg/l (70% removal of total nitrogen).


Rosie Nelson, Thames Water, Jason Stopps, Atkins, summarised the Evenlode river (headwater of the Thames) **AMP6 catchment phosphorus reduction trial**, working with farmers and nature-based solutions to cost-effectively reduce catchment phosphorus loads. The catchment has nearly 180 km of rivers, 19 wwtps, 34 000 ha, with 260 farms with nearly 50% of land area covered by 32 landowners. A catchment fund provided grants for infrastructure (e.g. creation of wetlands) or annual payments for farm management measures from 2016 to 2020. Over UK£ 400 000 has been paid to farmers leading to an estimated 165 kgP/y loss reduction, and a cost effectiveness of UK£ 2 500 / kg P reduction. The trial demonstrated that taking a catchment management approach is cost effective at reducing phosphorous when compared to investment in traditional P-removal options for rural wwtps. The scheme also brings an estimated UK£ 70 to 140 000 per year in other benefits (biodiversity, flood risk mitigation, climate regulation). Collaboration with catchment partner organisations and governance are considered key to successful uptake.

On-farm P loss reduction in the Evenlode catchment: Farmyard treatment using created wetland to capture nutrient flow pathways.

Sewage works N_2O and air pollution emissions

The water industry in the UK contributes 2 – 5% of total greenhouse emissions, and nitrous oxide (N_2O) is the largest contribution.

Jeremy Black, Atkins (for UKWIR), summarised an assessment for UKWIR of wastewater treatment emissions of the five air pollutants targeted for possible health impacts under the UK Clean Air Strategy 2019: sulphur dioxide, non-methane VOCs, $PM_{2.5}$, NO_x, ammonia. Levels of uncertainty for wastewater treatment emissions are very high, but nonetheless it seems clear that the sector's emissions make up a very small part of total UK emissions (<1% for ammonia, <0.5% for NO_x). Most ammonia is from sewage sludge treatment and land application. Most wwtp NO_x is from combustion other than sewage sludge incineration (e.g. methane combustion for cogeneration). UKWIR has developed a Workbook tool for sewage works operators to estimate emissions. The full report and accompanying workbook are available from UKWIR (ref 23/CL/01/37).

Elisa Allegrini, Maxime Nibart, Craig Lewis, SUEZ, presented **AirAdvanced® Scan360**, a complete air quality GHG quantification service, including onsite Greenhouse gases (N2O, CH4 & CO2) measurement and quantification, as well as operational data analysis with a view to optimise and reduce site's attributing nature to process emissions (optimise effluent quality and limit its environmental impact). The service identifies the main emission sources in the WwTW and propose solutions to reduce or mitigate emissions. Process emissions can vary between sites, so that site specific data is essential for mitigating emissions.

Robert Kelly, Clément Romand, Craig Lewis, SUEZ, and **Ziye Dai, Peter Vale, Jess Alce, Severn Trent Water**, presented development of AirAdvanced® ActiLayer, a cover system including a UV activated catalyst filter which generates OH^+ and O^- radicals which convert N_2O to nitrogen gas, and also removes VOCs and sulphides. Pilots have been tested in Nantes, France, and at Spernal, Severn Trent UK. A full-scale test is now planned at Strongford, Severn Trent. Results suggest that the system is effective in mitigating N_2O process emissions. The system can be integrated into existing infrastructure, so providing a cost-effective route to reducing N_2O emissions, which will be important in moving towards wastewater treatment net zero objectives.

Photo: Air-Advanced®-ActiLayer's small-scale trial test, Spernall wwtp UK ©SUEZ.

Joshua Williams, Keeley-Ann Kerr, Dr Michael Gerardo, & Jose Porro, Welsh Water & Cobalt Water Global, presented their operational experience of measuring N_2O emissions from sewage works over the last two years, using the machine learning risk decision support system from Cobalt Water alongside physical monitoring. Emissions results varied depending on the dissolved oxygen risk level or with time of year. Various mitigation techniques have been tested, including the impact of increased dissolved oxygen levels. Next plans are to begin long-term monitoring campaigns

Stephen Palmer, MHV (Stantec group), presented the microbial pathways of ammonia to nitrate to nitrogen (nitrification – denitrification). N_2O emissions result from disbalances between the turnovers of these different microbial processes, in particular if nitrite accumulates. Control actions should aim to optimise dissolved oxygen in the aeration zone (nitrification), avoid oxygen or nitrite accumulation and ensure optimal carbon/nitrogen ratio in the anoxic zone.

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