

European Sustainable Phosphorus Platform

Public policy

Circular Economy EU Commission consultation open

Public consultation on 'Roadmap' for Circular Economy. Phosphorus management and recycled organic fertilisers are proposed key measures.

UK phosphorus flows Data to support P management decisions

Assessment of phosphorus stocks and flows in the UK, targeting agriculture, food and wastewater

BioRefine UK Nutrient Platform meeting

Stakeholders in the UK met in London to discuss objectives, organisation and possible funding of a UK Nutrient Platform.

Case study Phosphorus management in Denmark

Sustainable Coastal Management project Novia UAS summarises P sustainability in Denmark

Organic recycled nutrient products

Finland

P-availability in manures and sewage sludge

Study shows good plant availability of phosphorus in sewage sludge and manures.

Phosphorus availability Different phosphorus forms in biowastes

Forms of phosphorus in 15 biowastes were analysed. Aluminium, calcium and iron reduced plant availability.

Composts and digestates Nutrient and contaminants

Quality and safety of organic secondary fertiliser materials.

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Sewage sludge

Varying removal of pharmaceuticals

13 pharmaceuticals showed varying rates of reduction in different sewage sludge treatments

Sustainable aquaponics

Fish production, hydroponics, recycling

Nutrient recycling by combining aquaculture with hydroponic crop production

Soil phosphorus and P stocks

Wastewater treatment

Iron dosing and P-recovery perspectives

Iron P-removal is highly effective and compatible with sewage treatment technologies. But how to recover P?

Soil analysis

New techniques for assessing soil P

Review of innovative methods for measuring soil phosphorus and its metabolism

Uganda - food security Wastes to reduce soil nutrient deficits

Material flow analysis in Uganda shows potential of human exxcreta to reduce soil nutrient deficits in agricultural soils.

Anthropogenic P resources Evaluation of phosphorus stocks in Austria

Framework for evaluation of anthropogenic resources, applied to the case study of P stocks in Austria

3-4 Sept. 2016, Ghent, Belgium Workshop on nutrient data & monitoring to support decision making

Data on Nutrients to Support Stewardship project DONUTSS ESPP – BioRefine contact brusselsoffice@phosphorusplatform.eu



Circular Economy EU Commission consultation open

The European Commission has opened (deadline 20th August 2015) a public consultation on the Circular Economy

http://ec.europa.eu/environment/consultations/closing_the_loop_en.htm based on a proposed 'Roadmap' (April 2015, 9 pages) intended to make more ambitious the (now withdrawn) 2014 'Circular Economy Package'.

The document refers to the Commission's **Communication on Sustainable Use of Phosphorus** (2013, see SCOPE Newsletter 107). It is indicated that an Action Plan will identify key measures across the value chain, citing as possible specific areas of intervention waste management, **development of markets for secondary raw materials (e.g. organic fertilisers)** and **critical raw materials (including phosphorus).**

The Commission announces its aim to "create conditions for the development of a circular economy ... a clear and ambitious political vision combined with effective policy tools"

Markets for secondary raw materials

The Commission's Roadmap emphasises from the start the importance of exploring synergies, citing as clear examples product policies and "*the development of well-functioning markets for secondary raw materials*".

The Roadmap further identifies as objectives "decreasing residual waste while increasing the use of secondary raw materials in the EU economy".

Amongst possible specific areas of intervention in the Action Plan to identify key value-chain measures could include: "waste management, development of markets for secondary raw materials (e.g. organic fertilisers) ... critical raw materials (including phosphorus), ... sustainable chemical production, bio-economy, extraction of secondary raw materials, food, water use ..."

This will be supported by research and innovation, a **financing and support framework** for the circular economy, and a mixture of legislative, non-legislative and financial instruments. Addressing barriers arising from existing legislation will be a priority.



Documentation

The Roadmap includes detailed lists of relevant existing EU policy initiatives (20), including the Commission's Communication on Sustainable Use of Phosphorus (2013, see SCOPE Newsletter 107). the 2011 Roadmap to a Resource-efficient Europe, the 2011 Bioeconomy Strategy, the 2008-2011 Raw Materials Initiative and the EIPs on Raw Materials, Water and Agriculture.

The document also provides a detailed list of relevant studies and consultations concerning the circular economy, **job creation** in recycling and in the environment, jobs related to resource efficiency and raw materials policy.

European Commission (lead directorates Environment and Grow), Roadmap: Circular Economy Strategy, 04/2015 http://ec.europa.eu/smartregulation/impact/planned_ia/docs/2015_env_065_env+_032_circu lar_economy_en.pdf

UK phosphorus flows Data to support P management decisions

SFA (Substance Flow Analysis) of phosphorus in the UK food production and consumption system identifies key points for phosphorus management and proposes actions. Overall, the UK population consumed around 31 ktP in 2009, with net imports of 114 ktP, losses to water of 42 ktP and soil accumulation of 38 ktP. Key areas for action are identified as wastewater P-removal and Precovery, manure, food waste and sewage sludge management.

This P-SFA covers the UK (England, Scotland, Wales and Northern Ireland) and focuses principally on the agriculture, food and wastewater systems, using data from base year 2009. **One conclusion is that data needs to be updated** and also that **SFAs are needed at a more local scale** to define specific measures such as regional recycling policies.

STAN (Software for Substance Flow Analysis), developed by Vienna Technical University, was used *www.stant.web.net* with an approach similar to Senthilkumar (SCOPE Newsletters n°s 93 & 104).

Detailed tables are provided in the paper indicating for each phosphorus flow and stock the estimated amount of phosphorus per year (ktP/year) and also the level of accuracy / errors (confidence limits), summarising for each flow the data sources and calculation methods.





31 phosphorus flows and 13 stocks are assessed. The paper also provides a brief comparison to data available for other countries (Australia, Austria, China, Finland, France, Japan, Netherlands, Turkey, USA, EU15).

Net imports

The SFA shows that the UK is a major net phosphorus importer, with total imports of 138 ktP/y (of which 56% in fertilisers) and exports of only 24 ktP/year (crops and other products).

Of the net annual UK phosphorus import (118 ktP/y), 35% is lost to water bodies and 32%

accumulates in soils. The remainder is lost or accumulated to incineration / landfill / compost or other disposal or non-food uses. Over 2/3 of the soil P accumulation is occurring in grasslands, where manure is the main P input (79%).

SCOPE editor note: the figures for detergents (9% of P imports) have or will soon significantly decrease with the EU bans of phosphates in domestic laundry and dishwasher detergents (2013, 2017).

Agricultural P use

Total P input to UK agricultural land is estimated at 269 ktP/y, of which 62% manure, 27% fertilisers and 8% sewage sludge. However, only around 30 ktP/y is consumed in human foods.

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Comparing net inputs (114 ktP/y) to production of food and feed systems, the agri-food system shows an overall efficiency of around 46%

For livestock production, total P inputs (feeds, grass) are 200 ktP/y, with an output of 33 ktP/y in animal products, indicating an "efficiency" of 17%.

Wastewater phosphorus management

Total phosphorus entering UK sewage works is estimated at 55 ktP/y, of which c. 32 ktP/y is removed to sewage sludge and 23 ktP/y is then recycled to agriculture through spreading of treated sewage biosolids.

SCOPE editor note: The loss of phosphorus to surface waters in the UK is in part not a eutrophication issue, in that 43% of sewage goes to works discharging to coastal waters which are not eutrophication sensitive http://webarchive.nationalarchives.gov.uk/20130822084033/http://www.def

ra.gov.uk/corporate/consult/detergents-regs2005/clarification-for-IA.pdf)

The paper points to a number of tools to improve phosphorus management and efficiency: optimising phosphate fertiliser application rates in agriculture, improving distribution of animal manures, improving sewage treatment P-removal in eutrophication sensitive areas, optimising sewage biosolids recycling to farmland (BPEO Best Practicable Environmental



P-flows through UK waste water treatment works (Cooper & Carliell-Marquet 2013)

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Option), implementing P-recovery from sewage and manures where efficient agricultural application is not possible, EU Landfill Directive and UK Landfill Tax, Courtland Commitment to improving resource efficiency (UK Climate Change Act) and long-term vision through the UK Government Waste Policy Review.

"A substance flow analysis of phosphorus in the UK food production and consumption system", Resources, Conservation and Recycling 74 (2013) 82–100 http://www.sciencedirect.com/science/article/pii/S0921344913000 578

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BioRefine UK Nutrient Platform meeting

industry, 60 participants from research. consultancy, public agencies and farming organisations met at the Royal Society of Chemistry, London, to discuss objectives, organisation and possible funding of a UK Nutrient Platform. This meeting, organised by InterReg project), BioRefine (EU follows meetings in London (24/9/2013, see SCOPE Newsletter n°98) and Leeds (24/10/2014, see http://link2energy.co.uk/biorefine-nutrientplatform-event).

Erik Meers (BioRefine) and **Andrew Ross (Leeds University)**, explained the **BioRefine InterReg project** and the **European BioRefine Cluster** (see SCOPE Newsletter 103). Nutrient recovery and recycling is one of the objectives of biorefinery development.

The BioRefine Cluster brings together around 20 projects on biorefineries, so enabling **synergy**, **continuity and transfer of R&D to implementation** beyond the time-horizon of each project.

The facilitation of national nutrient platforms and exchanges with existing platforms, in the BioRefine InterReg project, also contributes to taking innovation to implementation.

CynthiaCarliell-Marquet(BirminghamUniversity),presented the phosphorus mass flowanalysis (MFA) carried out for the UK in 2013(Cooper et al., summarised in this Newsletter).Keyfigures for the UK derived from this analysis include:



- Agriculture is c. 80% efficient for P for crop production (output in crops and grass / farm input in fertilisers, manures, etc) but only 16.5% efficient at producing animal products
- Increasing rate of P-removal in sewage works, but a decreasing rate of sludge land spreading
- **Phosphorus accumulation in soils**, mainly due to manure application to grassland

Phosphorus management indicators

This MFA proposed a number of "simple" indicators which can be used to **compare phosphorus management performance**:

- Net P imports
- Agricultural efficiency (as above)
- Mineral fertiliser consumption
- Rate of P-recycling
- **Rate of P losses** (mainly to water bodies and to incineration ashes)

DrCarliell-marquet underlined that this MFA is not spatialized, so does not provide data useful for regional nutrient management. Also, the data used was from 2009 and should be updated.

Miller Alonso Camargo-Valero, University of Leeds, summarised issues around nitrogen management. The massive increase in anthropogenic nitrogen fixation over the last century, with corresponding losses to surface waters, leads to ocean dead zones and algal blooms, e.g. blooms of *Emiliana huxleyi* off Cornwall.

In the UK, total dissolved nitrogen flows have increased c. 0.6%/year over the last 20 years. **Sewage works operate nutrient removal, but not nutrient recovery and recycling**. Although 70% of sewage sludge is recycled to agricultural land, most of the nitrogen [see note below] originally in raw sewage is released to surface waters in the form of nitrate within the final effluent of sewage treatment works, whilst at the same time the UK imports nearly 60% of its nitrogen fertiliser consumption.

NOTE: SCOPE Newsletter Editor's comment: the above statement may not apply for all UK water companies. One water company estimates that around ^{1/2} of sewage works inflow nitrogen goes to receiving waters as nitrate, but that in their sewage works operating biological nutrient removal (EBPR) 30-40% only of influent leaves as nitrate in discharge, around 10% goes to sewage sludges and 50-60% is removed to atmospheric nitrogen

Simon Leaf (Environment Agency for England) explained that phosphorus losses causing freshwater eutrophication are a major concern for ecology, water body uses, drinking water and irrigation water supply, e.g. through toxic blue-green algae blooms.

There has been **considerable progress since the 1990's** (reductions in P in detergents, P fertilisers, livestock numbers) with a large programme of increasing P-removal in sewage works targeted at waters affected by eutrophication. For example, average river concentrations in East Anglia have been reduced from 1 mgP/l to < 0.2mgP/l.

However, phosphorus remains a major challenge. P is the **cause of failure to achieve Water Framework Directive good status objectives** for 58% of assessed river water bodies and 74% of assessed lakes, and also causes below favourable conditions in biodiversity areas (Sites of Special Scientific Interest, Habitat Directive areas).

The causes of these issues are 60 - 80% municipal sewage works, 20 - 30% agriculture in terms of national apportionment.

Further eutrophication control measures

Perspectives regarding potential further control measures, identified by the Environment Agency include:

- Water Framework Directive river basin management plans are to be updated by December 2015 and measures to further reduce point and diffuse sources of nutrient pollution will be an important feature
- To inform future measures, a national programme of trials is agreed, aimed at **improving phosphorus removal in sewage works**, down to 0.1 mgP/l discharge – this is a possible opportunity to consider P recycling and recovery implications and potential
- Optimising biosolids reuse in agricultural application (currently 70% of biosolids)
- Considering **possible incentives to develop biological phosphorus removal** (BPR). At present, the regulation of UK water industry funding mechanisms strongly pushes water companies to prefer chemical P-removal (because this is perceived as more reliable for meeting tight river P standards and because costs for chemical purchase and sludge management can be passed on to household water bills, whereas investment and personnel expertise needed for bio-P cannot)



- Trials of **flexible catchment permitting**, could help to accommodate BPR and reduce the water industry's preference for chemical P-removal because of 'discharge consent reliability'
- **Catchment schemes** could provide a local focus for action to tackle nutrients; the Defra-funded catchment based approach and water company schemes include examples for P and nitrate and the use of Payments for Ecosystem Services approaches for nutrients was being considered in some catchments
- Improving farm nutrient management practices to mitigate P losses and improve efficiency: Defra is reviewing the current measures and mechanisms for controlling diffuse pollution from agriculture
- Review the potential for further source control: detergents (already underway through EU regulation), phosphate food additives (current 5-10% of P in sewage, relaunch of working group with industry to find replacements in some applications), phosphate dosing of drinking water (6% of P in sewage)
- Promoting a more sustainable diet, with a lower phosphorus footprint, and reducing food waste

Kim ten Wolde (ICL Fertilizers), explained that the company operates two plants manufacturing phosphate fertilisers in Europe (Amsterdam Netherlands, Ludwigshafen Germany). ICL has fixed the objective to use 15% secondary materials by end 2015 and 100% by 2025. Pilot testing shows that this is feasible and ICL's Amsterdam site was on track to replace 15% of its P-rock consumption by different ashes in 2014, but due to technical limitations the deliveries were halted. There are also issues to be resolved for scale-up:

Incineration ashes can be used as a raw • material in phosphate fertiliser production, by acidulation, so substituting phosphate rock. Wood ash has too low P levels to be useable. MBA (meat and bone ash) has proved a good raw material, but with variable reactivity in acidulation, so requiring specific mixing with appropriate grades of phosphate rock. However, sewage sludge incineration ash poses issues because of its variability, and particularly if iron and/or aluminium levels are too high because these elements tie up phosphorus which is not available for the fertiliser production process, so supply chains and long-term contracts need to be defined with the water industry to provide low Fe - low Al ash, by separate processing and

incineration of such sludges (e.g. from sewage works operating biological nutrient removal). Further R&D is necessary to optimise the acid treatment conditions for using different sewage sludges.

- Struvite has been tested. This is mixed (blended) with other fertiliser compounds, to produce an appropriately balanced product (nutrient contents, release rates). However, struvite as supplied to date has had a high free water content, incompatible with such blending into mineral fertiliser products. Work is underway by the struvite suppliers to try to produce a struvite with low water content. There are also questions to resolve concerning pathogens and organic contaminants potentially possible in struvite. Heavy metal levels have shown to be consistently within proposed EU Fertiliser Regulation revision limits.
- Scale-up at the Amsterdam site necessitates **construction of a specific ash storage and transport system**, because of the low particle size (dust, powder) of ash compared to phosphate rock. This c. 2 million €investment is currently pending funding. Ludwigshafen already has powdercompatible storage and handling installations, but is **currently delayed by permitting issues** (need for local authorities to grant permits to accept materials classified as "waste").

Tristan Eagling (Knowledge Transfer Network) presented the work of this organisation which is funded by UK government R&D funding (Innovate UK) and some of the RTD funding call opportunities offered by Innovate UK. TKN's objective is to **network between sectors to facilitate innovation and its uptake**. The organisation has specialists in areas including resource efficiency, EU Horizon 2020 project preparation and venture funding. TKN can facilitate "**Special Interest Groups**" to address themes sectors as offering major opportunities for job creation in the UK because of potential economic importance, UK R&D competence and development potential.

Lucinda Tolhurst (Lucid Insight) also summarised a proposed framework for roadmapping innovation opportunities and barriers in the UK, initially by consolidating existing data and drawing on the insight and knowledge of the network and other stakeholders. The emphasis would be on creating momentum for identifying areas for targeted support and facilitation, particularly where the network could help identify innovators and early adopters for collaborations, tackle market barriers, and create enabling environments.



Arnoud Passenier (European Sustainable Phosphorus Platform) underlined the importance of multi-stakeholder platforms, creating a broad enabling environment by bringing together industry, regulators, knowledge institutes and societal stakeholders, as a route for taking innovation through to implementation. Value chain actions, involving different industry sectors and end-users, enable projects to be taken forward which are positive for society and jobs, but which would not be viable for a single sector working alone. A shared vision across sectors is important.

Objectives for a UK nutrient platform

During the afternoon, participants discussed what they would see as objectives and actions of a UK nutrient platform, and how this could be funded and organised. **Proposals varied widely**, showing the rich mixture of participants from different sectors and types of organisation and the range of expectations of a UK nutrient platform.

Converging remarks suggested that a UK nutrient platform should

- Cover all nutrients, with a particular attention for phosphorus
- Promote **circular economy** thinking for nutrients address nutrient reduction measures, efficiency, reuse as well as recycling and recovery
- Develop a clear **common vision** and simple objectives
- Provide scientific evidence and data to support political and industry decision making
- Target a wide and **representative membership**, covering different industry sectors and activities and addressing the whole value chain through to consumers
- **Support innovation**, addressing opportunities with solutions, through to uptake and duplication
- Act to **improve regulation and incentives**, by providing mediation (concerted proposals) but not advocacy an enabling/facilitating approach
- Facilitate **demonstration projects and case studies** to form part of the evidence base.
- Function as a **network** for contacts, competence, experience transfer

Such a platform would require a significant budget to ensure moderation and information collection and circulation. In the absence of clear proposals for funding, it was suggested by several participants to continue networking to maintain impetus through regular meetings (which could self-fund their

organisation by a participation fee) and by looking for ad-hoc funding of specific projects. Start small if necessary but think wide/big and aim to build momentum.

The BioRefine project will fund one more UK nutrient platform meeting in the 3rd quarter of 2015.

Summary of UK nutrient platform meeting 2013 (London 24/9/2013), see SCOPE Newsletter n°98 on www.phosphorusplatform.eu Summary and slides of UK nutrient platform meeting 2014 (Leeds 24/10/2014) http://link2energy.co.uk/biorefine-nutrient-platform-event

Panel discussions summaries and speakers' slides from UK nutrient platform meeting London 29/4/2015 http://link2energy.co.uk/biorefine-nutrient-platform-event

Sustainability Meat and dairy in diets

Demand for meat and dairy products in developed and transition countries poses serious challenges for environmental protection, climate change, social justice and global food security. In the USA, livestock production accounts for around one third of nutrient emissions to surface waters.

Worldwide meat production has multiplied by +200% over the last 40 years and by +20% over the last decade, with huge global disparities: 117 kg meat per capita per year in the USA, 88 kg in Germany, compared to only 4 kg in India.

Environmental impacts

Livestock production today accounts for around 70% of agricultural land use (30% of total global

land surface). This pressure on land use (leading to deforestation and destruction of natural habitats), alongside intensification of pasture and monocultures for animal feed (e.g. soy bean) means that livestock is estimated to contribute one sixth to one third of planetary biodiversity loss.

Meat production also accounts for 18% of total world greenhouse emissions, through ruminant methane emissions, deforestation and use of nitrogen fertilisers for intensive feed crop production.

Food-related greenhouse emissions were calculated to be twice as high for a UK meat-eating diet than for a vegan diet.



Social and food security

It is estimated that if current crop production feeding livestock and biofuels were instead used for human food production, +70% more calories would be produced worldwide, potentially meeting the basic needs of an additional 4 billion people. Global food security is thus largely linked to meat and dairy consumption patterns.

Additionally, intensive monocultures of animal feed crops result in displacement of small farmers and concentration of land ownership (e.g. in Paraguay, Brazil, Argentina).

Also, preference for certain meat cuts result in from developed "dumping" to developing economies. The European poultry business sells chicken breasts in Europe, but exports the remaining meat pieces at very low prices to Africa, effectively killing local smallholder chicken production.

Meat and health

The authors note that only around 50g of meat per day to provide adequate dietary protein.

Current developed country diets with much higher levels of meat, dairy and eggs are considered to be obesity, coronary heart linked to disease, hypertension, diabetes, gout and cancer.

A non-meat diet is estimated to result in a 7-13% reduction in cancer risk and a 20% reduction in coronary heart disease.

Changing policies and choices

The authors underline that livestock production is heavily subsidised worldwide:



Subsidies for meat production from OECD member countries, estimates for 2012, in billion dollars (CC-BY-SA Heinrich Boell Foundation, Friends of the Earth).

The European Union subsidises animal feed (fodder) crops and new animal housing (up to 40% subsidies). Overall, over 12% of gross farm income for livestock production in Europe comes from subsidies. Other indirect public subsidies include costs of transport and port infrastructures, reduced VAT on meat products and low wage levels in abattoirs and meat processing.

The authors identify a range of social barriers to reducing meat consumption: benign ignorance (consumers do not realise the environmental consequences of meat), deliberate ignorance or cognitive dissonance (consumers fail to connect their knowledge of meat's consequences to their behaviour), cultural significance and symbolism of meat and economics (political influence of interest groups in the industrial animal agri-business).

Ways forward

The authors note that the first approach to reduce meat consumption should be to eliminate subsidies to livestock and add financial penalties to compensate for externalities (environment and climate impacts, social impacts). These approaches face however considerable political opposition from powerful agrointerest groups and need industry careful implementation to mitigate inevitable social impacts (farmers, meat related food products ...) and to avoid negative effects (e.g. loss of biodiversity in areas which still have extensive permanent pasture).

More promising is promotion of attitude changes. In Germany, for example, high meat consumption is already today more prevalent in "lower classes". Public communications should actively promote low meat diets as socially desirable, particularly targeting the young. Aspects such as taste quality and convenience are also important.

"The Sustainability Challenges of Our Meat and Dairy Diets", Environment: Science and Policy for Sustainable Development, 57:3, 34-48, 2015 http://dx.doi.org/10.1080/00139157.2015.1025644 (Open Access)

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Case study Phosphorus management in Denmark

Denmark is one of Europe's leaders in phosphorus loss mitigation, with specific policies including targeted action plans and a tax on P in animal feeds. The objective is to maintain the country's productive export agriculture activities whilst ensuring water quality. Agricultural phosphorus loads have been reduced by 50% over the last 15 years.

In Denmark, the phosphorus loading from point sources has decreased over the years. Of the diffuse sources, agriculture remains the main source of phosphorus loading. Agricultural phosphorus demand and the great potential for phosphorus recycling from manure make agriculture one of the key factors in phosphorus pollution reduction.

The third Action Plan for the Aquatic Environment (APAE III) focuses in reducing excess phosphorus from agriculture by 50% by 2015 compared to the 37,300 tonnes in 2001.

Fiscal policies and farmer information

There are neither controls nor penalties on the amount of P in manure and the P given to crops. However, Denmark imposed a tax of DKK 4 / kg on the use of added P in animal feed with a goal to reduce the Psurplus by 25%. The tax was introduced in 2005, the only such case in the EU, and it has generally resulted in reduced phosphorus excretion. The following regulations or recommendations are in effect in the agricultural sector:

- Average recommended rates of P use on major crops (kg P205/ha): Barley 16, maize/silage 25, wheat 17, potato 35, sugar beet 35, grassland 15 kg P205/ha
- Phosphorus from manure is restricted to 140-170 kg N/ha/y for the entire Danish territory
- Phosphorus application by organic fertilizers • consisting of less than 75% manure (mainly sludge) restricted to 30 kg P/ha/y over a period of 3 years and to a maximum of 7 tonnes dry matter/ha/year. The sewage sludge must be analysed for heavy metal and xenobiotic substances before application on farmland.

Sewage phosphorus

In wastewater treatment, Denmark has been able to reduce P pollution by 85% due to better methods, stricter regulations and decreased industrial discharges. Danish removal requirements are in line with the HELCOM recommendations. Danish wastewater treatment plants (WWTP) treat approximately 630 million m³ of waste water annually both from household and industry sources. There are about 1100 WWTPs that are treating water with tertiary treatment (nutrient removal) for communities of 30 people or more. Despite the very high level of wastewater treatment, the municipal wastewater treatment plants still remain the biggest point source of P pollution.

The treatment of waste water produces about 1.2 million tons of wet sludge, corresponding to about 160 000 tons of dry sludge annually. The content of the dry sludge reused as fertilizer in agriculture varies in municipalities. On estimate, half of the sludge is used in farming and the other half is incinerated, dumped or used for other purposes.

Constructed wetlands

Denmark is one of the pioneers of the constructed wetland systems that can be used both in wastewater and sludge treatment. Constructed wetland systems for wastewater treatment have been in operation in Denmark since early 1980s. There are about 170 constructed wetland systems and 100 willow-based evaporative systems for the household sewage treatment. In addition, there are roughly 50 restored wetland projects for nitrate removal from surface and drain water. The majority of the constructed wetland systems and willow-based evaporative systems are meant for treating domestic sewage from small villages in rural areas. Often in rural areas the sewerage systems are combined thus the reed beds are used for both rainwater and sewage treatment.

In general, the constructed wetland systems are easy to operate. They can be built in any area and they are simple to construct and maintain. The removal of nitrogen and phosphorus is roughly 30-50% and the phosphorus treatment performance seems to remain stable over time as the systems mature.

Biogas and P-recycling

Anaerobic digestion plants have proven to be suitable for wastewater treatment. With anaerobic digestion



technology, waste and sludge from different sources are blended, pasteurized and digested at 35°C. The end-products are digestate, which can be spread on land and used as a fertilizer, and biogas, which is used for producing electricity and heating.

Anaerobic digestion technology is in use in the Grindsted municipality. Built in 1996, the anaerobic digestion plant produced around 2.5 million m3 per year of biogas in 2010. With the initial investment of €8.5 million, the plant has reduced the waste by 60%and degrades the waste by the same amount. By combining different waste streams and using a technology that allows them to be handled together Grindsted municipality turned their waste into a resource.

Aquaculture

Aquaculture as an industry is an important and growing sector in Denmark which makes it significant in terms of phosphorus pollution although the rate of phosphorus loading from aquaculture is relatively low compared to agriculture. The aquaculture industry is regulated by national legislation and the EU Water Framework Directive. From aquaculture sources, phosphorus is discharged as both particulate and dissolved phosphorus into the environment. Especially rainbow trout production forms the biggest risk of phosphorus discharges. The four main technologies have different efficiency rates in phosphorus reduction.

In particular, Danish model fish farming and recirculation-based FREA/RAS technologies have decreased the phosphorus loading from aquaculture.

Baltic Sea

Phosphorus constitutes a major part of the nutrient pollution in the Baltic Sea region causing eutrophication. As phosphorus is a non-substitutable and non-renewable resource, it needs to be used, reused and recycled in an efficient way. As this report shows, Denmark as one of the major phosphorus polluters in the Baltic Sea region has been proactive in discovering ways to reduce, manage and recycle phosphorus more efficiently.

"Phosphorus Project: Sea Breeze IV Case Denmark", 33 pages, 2015, available for download on www.phosphorusplatform.eu

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Organic recycled nutrient products

Finland P-availability in manures and sewage sludge

8 week pot trials using rye grass (*Lolium multiflorum*) compared plant availability of mineral fertilisers, sewage recovered struvite, 3 dairy manure, 7 biological nutrient removal and iron-dosing chemical P-removal sewage sludges, with or without anaerobic digestion and at different application rates.

The levels of phosphorus in the dairy manure and sewage sludges used, the types of digestion and sanitation treatment applied to the sewage sludges and the fertiliser application rates included those typical of Europe and Finland. Each fertiliser was tested at three application rates, based on preliminary pot trials, with five complete replicates. Plants were harvested at 4 and 8 weeks, and **plant phosphorus availability** of the tested product assessed by comparing the proportion of phosphorus remaining in the soil and taken up by the plant.

P availability depends on sewage & sludge processes

Phosphorus plant availability in the sewage sludges was **significantly higher in sludges from biological nutrient removal (BNR) plants** or where iron was used as a secondary coagulant (Fe/P 1.6). Pavailability was low when lime-stabilized or when very high amounts of iron (Fe/P 9.8) were dosed in direct precipitation.

Anaerobic digestion of sludge statistically significantly reduced the plant availability of the phosphorus at a relevant application rate and showed a similar tendency for manure. This is thought to be to increased sorption and conductivity. due Composting of the digested manure improved its phosphorus availability, but this was less true for the digested sewage sludge where combined acid and oxidizer improved phosphorus availability.

The authors conclude that **organic input to soil can improve phosphorus availability** by reducing phosphorus sorption onto soil particles (competition with organic acids) as well as by direct release of phosphorus from the organic product. Phosphorus in recycled organic products can thus, if appropriately managed, provide better plant available phosphorus than application of mineral fertilisers only.



See also summary in the European Commission (DG Environment)'s "Science for Environment Policy", Issue 412, 30th April 2015, "Manure and sewage can provide crops with more phosphorus than chemical fertilisers". http://ec.europa.eu/environment/integration/research/newsalert/pdf/ manure_and_sewage_can_provide_crops_with_more_phosphorus_ than chemical fertilisers 412na2 en.pdf

"Phosphorus in Manure and Sewage Sludge More Recyclable than in Soluble Inorganic Fertilizer", Environmental Science & Technology 49(4): 2115–2122, 2015 http://pubs.acs.org/doi/abs/10.1021/es503387y

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Phosphorus availability Different phosphorus forms in biowastes

The EC-developed SMT procedure for assessing P in freshwater sediments showed to be applicable to biowastes. 15 biowastes were tested, including heat-dried sewage sludge, composted municipal solid waste, agricultural wastes, food industry waste and pig slurry. WSP (water soluble phosphorus), which is immediately plant available but also poses run-off risks, did not correlate well to total P, but was inversely related to iron + aluminium + calcium content.

The **SMT Protocol for phosphorus fractionation** in freshwater sediments was developed in the framework of the Standards, Measurements and Testing Programme of the European Commission and is frequently used in agriculture to obtain total P, inorganic and organic P, apatite P and non-apatite inorganic P. Additionally, the Hedley method was used to determine WSP (water soluble phosphorus): shaking for 16 hours at 25°C in demineralised water followed by 0.45 μ m filtration.

The **15 biowastes analysed** were municipal solid waste, municipal green wastes, sewage sludge (the article says "biosolids" please confirm this means sewage sludge), grape pomice, mushroom substrate, food industry waste, pig slurry, water treatment sludge, combinations of the above, after different treatments (dewatering, composting, digestion, heat treatment).

The results obtained, including the comparison between apatite and non-apatite inorganic P and analysed inorganic P confirmed the **applicability of the SMT protocol** to these products.

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Wide differences

Total phosphorus levels in the different biowastes tested varied considerably, from 0.4%P in grape pomace to 5.3%P for pig slurry compost.

Total phosphorus was not well correlated with WSP (water soluble phosphorus), suggesting that it would not provide a good indicator of readily plant-available phosphorus, nor of risk of phosphorus loss from soils. In particular, for composts, WSP was always <15% of total phosphorus, indicating that composts pose a low risk of soil P-loss. Over 80% of total P in fresh pig slurry, on the other hand, was water soluble.

Water soluble phosphorus showed a curvilinear **inverse relation to the total content of calcium** + **iron** + **aluminium**, indicating that the use of these salts for chemical nutrient removal in sewage works reduces water soluble phosphorus.

"Fractionation of phosphorus biowastes: Characterisation and environmental risk", Waste Management, 2012 Volume 32, Issue 6, June 2012, Pages 1061–1068, http://www.sciencedirect.com/science/article/pii/S0956053X12000451

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Composts and digestates Nutrient and contaminants

Recent publications show low levels of organic contaminants in digestates and composts

Garcia-Albacete et al. studied **phosphorus leaching from composts and digestates of municipal solid wastes**, using laboratory 20-day controlled leaching columns (21 cm height, 6 cm diameter, triplicated) and three different soils. Phosphorus losses after 22 days were c. 40 - 50 mgP/kg soil from an initial load of compost/digestate of c. 140 mgP/kg soil (equivalent to 100 kgP/hectare), that is a nearly 40% phosphorus loss in leaching after three weeks. Leaching losses were slightly lower from digestate.

The authors note that **WSP** (water soluble phosphorus) analysis of the digestate and compost are not a good indicator of leaching, in that WSP has higher but leaching was lower in the digestate. They suggest that leaching (in this type of test) is related to changes in the wettability of the organic material.



Suominen et al. analysed organic pollutants in digestates from ten large biogas production lines in Finland. These were using a range of different wastes as inputs: sewage sludge, sorted municipal biowaste, agri-food industry wastes, manures. Concentrations of pollutants in the digestates did not correlate to concentrations in the feedstuffs input.

The authors conclude that **although concentrations were low, certain highly persistent substances** (**brominated flame retardants PBDEs and HBCD, PFCs perfluorinated alkyl compounds) could accumulate in agricultural soils** if these digestates were used as fertilisers. Other substances tested were not considered to pose a risk of accumulation: dioxins and furans, poly aromatic hydrocarbons PAHs, phthalates, detergent surfactants LAS and NP + NPEO, TBBPA.

Comparing levels of the studied contaminants in the digestates to literature data for levels of atmospheric deposition and dietary intake, they suggest that levels of **most of the contaminants studied in digestates are not likely to impact food safety in Finland**, but that further research is needed into the possible risks for the brominated flame retardants PBDEs and HBCD and for PFCs.

Hemmerling analysed organic contaminants in 3 commercially available (in the USA) bio-based fertilisers, one composted animal manure, one organic compost and 2 non bio-based fertilisers. Micropollutants PFASs (perfluoroalkyls), hormones, parabens, pharmaceuticals and personal care chemicals were analysed. Certain of these contaminants were found in both bio-based and non bio-based fertilisers, at concentrations from 8 to 11 000 ppb (parts per billion), but with fewer of these organic contaminants and at lower levels in the non bio-based. The author emphasises that the detection of these contaminants does not indicate that there is any health or environmental risk.

"Risk of Leaching in Soils Amended by Compost and Digestate from Municipal Solid Waste", Scientific World Journal, vol. 2014, Article ID 565174, 8 pages http://dx.doi.org/10.1155/2014/565174

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"Hazardous organic compounds in biogas plant end products -Soil burden and risk to food safety", Science of the Total Environment, vol. 491-492, Sept. 2014, pages 192-199 http://dx.doi.org/10.1016/j.scitotenv.2014.02.036

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"Evaluating Contaminants of Emerging Concern in Commercial Biosolid-based Fertilizers", Summer Undergraduate Research Fellowship (SURF) Symposium, 7 August 2014, Purdue University http://docs.lib.purdue.edu/surf/2014/presentations/120/

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Sewage sludge Varying removal of pharmaceutical contaminants

23 pharmaceuticals were analysed in sewage sludge and digestate from Nykvarn municipal sewage treatment plant, Linkoping, Sweden (180 000 pe). 13 of these pharmaceuticals were then spiked at $100 - 1500 \mu g/l$ to sludge or digestate, before lab-scale controlled treatments to assess rates of reduction in sludge processes.

The spiked pharmaceuticals were selected to include a range of wastewater concentrations, sludge affinities and ecotoxicities. The pharmaceutical trimethoprim, known from literature to be broken down in sludge treatment, was also spiked as a control.

The sludge treatment processes tested were pasteurization, thermal hydrolysis (165°C, 6 bar, 30 mins, equivalent to the CAMBITM process), advanced oxidation process (AOP) using sulphuric acid and hydrogen peroxide, ammonia treatment, thermophilic digestion. anaerobic digestion dry at 55°C (thermophilic) and at 38°C (mesophilic).

Pharmaceutical concentrations in sludge

Background pharmaceutical concentrations in mixed sludge (c. 80% primary 20% secondary excess sludge) ranged from below detection (e.g. $< 10 \ \mu g/kg$ TS) up to > 200 μ g/kg TS for carbamazepine drug), neural (anticonvulsant sertraline (antidepressant), furosemide (heart drug), ketoconazole (anti-inflammatory). (anti-fungal) and naproxen Caffeine was also present at $> 1500 \,\mu g/kg \,TS$.

Lipophilic pharmaceuticals showed, as expected, to be present principally in the solid phase in sludge, for example the SSRIs (selective serotonin reuptake inhibitors) and estrogens. These pharmaceuticals were more persistent in anaerobic digestion, possibly because less accessible to degrading micro-organisms.



Anaerobic digestion

Anaerobic digestion (AD) proved to be the most effective process for reducing a range of pharmaceuticals, with little difference between the two tested temperatures, achieving an average c. 30% reduction. However, anaerobic digestion did not significantly reduce the SSRI drugs, carbamazepine or propranolol (β-receptor blocker) and only thermal hydrolysis (650°C) was effective in removing the potent ecotoxicological estrogens.

"Pharmaceutical residues in sewage sludge: Effect of sanitization and anaerobic digestion", Journal of Environmental Management 153 (2015) 1e10

http://www.sciencedirect.com/science/article/pii/S0301479715000572

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Sustainable aquaponics Fish production, hydroponics, recycling

An overview in 'Sustainability' summarises the challenges of "aquaponics", that is combining fish (aquaculture) and no-soil production crop production (hydroponics), in particular nutrient recycling advantages and knowledge gaps concerning nutrient forms and flows.

"Aquaponics" combines advantages of recirculating aquaculture and hydroponics, by using the nutrientenriched water from fish production as inputs to fertiliser plant growth. The principle dates back in history, for example to the Aztecs chinampas or introduction of fish into South-East Asia paddy fields 1500 years ago.

Through symbiosis of fish, microorganisms and **plants**, aquaponics enables the nutrient inefficiency and pollution issues of aquaculture fish production to significantly addressed, and reduces water be consumption.

Microorganism synergies

The **microorganisms** present in the aquaponics system are essential, because of their role in cycling nutrients in fish excreta and uneaten fish food, into soluble forms or forms which are plant available. At the same time, the microorganism community must be safe for the fish themselves and for their use as food.

Particularly important are the nitroso-bacteria and nitro-bacteria, generally present as a biofilm on solid surfaces, and which convert ammonia (toxic for fish) respectively into nitrites and nitrates. In some aquaponics systems, a specific nitrification biofiltration unit is included.

The balance of the aquaponics system must also be managed by:

- Appropriate selection of fish species and crops, for which the fish nutrient discharge – plant nutrient needs cascade is well balanced
- Selection of fish food, e.g. protein content and type impacts ammonia production
- **Population of fish, feeding frequency**
- Water parameters such as pH, temperature, mineralisation/ alkalinity
- Aquaponic system design, in particular correct sizing of filtration systems and water recycling
- Physical media used as no-soil substrate for plant growth
- Taking into account fluctuations in biomass of fish and plants due to different growth stages

The paper compares, from literature data, a range of parameters for different hydroponic bed types: media-based grow bed, deep-water culture, nutrient film technique, soil.

Additional installations such as anoxic digestion or earthworm composting can be installed to recover and recycle nutrients from the aquaculture solid wastes, e.g. from filters. Also, low trophic level fish can be preferred, in order to use plant-based and alternative naturally available foods such as insects, aquatic weeds or algae.

Different forms of nutrients

Hydroponic systems allow precision controlled dosage of both water and nutrients (macronutrients, in particular N, P and K, and micronutrients) to crops, as a function of their growth and needs. This is more difficult in aquaponics, where the nutrient supply is a function of the fish production. Nutrients and micronutrients therefore should be monitored and supplemented where necessary for plant needs.

In particular, the form of the nutrients in aquaponics is complex. Nitrogen and phosphorus, particularly, are present in a range of organic and inorganic forms, which may be more or less available for plants.

The authors' assessment of literature suggests that



data on macro- and micro-nutrients in aquaponics is currently inadequate, and that aquaponics concentrations of nutrients are often below what is considered the optimal level in hydroponics. However, nutrient monitoring data from aquaponics and hydroponics are largely non-comparable, because nutrients are in different forms, again indicating that further investigation and data collection are needed.

Phosphorus recycling

Phosphorus is identified as "deserving specific attention". 30 - 65% of P in fish food is present in solid fish excreta, so not readily transferable to aquaponics crops, and soluble phosphorus in the system can further be lost by precipitation as calcium or other phosphates. Aquaponics literature reports levels of 1-17 mgP-PO₄/l compared to aquaponics recommendations of $40 - 60 \text{ mgP-PO}_4/1$.

Solutions to access and reuse the fish tank discharge **phosphorus** therefore need to be investigated, e.g. by digestion of filter sludge using P-solubilising microorganisms.

significant challenges Other to aquaponics implementation are identified as: pest and disease management, regulation of nitrogen forms toxic to fish (ammonia, nitrate), energy consumption. Opportunities identified include nutrient and mineral recycling, water saving, possible use of renewable energies, socioecological pressures and food security, fishing supply pressures, urban farming and short supply chains.

"Challenges of Sustainable and Commercial Aquaponics", Sustainability 2015, 7(4), 4199-4224, http://www.mdpi.com/2071-1050/7/4/4199/htm

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Wastewater treatment Iron dosing and P-recovery perspectives

Iron dosing is the most effective method for Premoval in waste water treatment works. achieving low discharge consents economically, offering operating advantages, and compatible with future energy-positive wwtp configurations (Anammox - A-B). A better understanding of iron - phosphorus chemistry could enable phosphorus recovery for recycling.

Chemical phosphorus removal is the most widely used technology worldwide, with iron salts generally the preferred solution for cost reasons. Although biological nutrient removal (EBPR Enhanced Biological Phosphorus Removal) is often considered to be preferable, for reasons particularly of avoiding chemical use and lower sludge production, it involves higher investment (higher space use footprint) and is more difficult to reliably operate, so that iron dosing continues to be widely applied, including in new wastewater treatment plants (wwtps). Iron dosing is also widely used as a complement to biological phosphorus removal, to reliably ensure low discharge phosphorus consents.

Moreover, iron dosing offers other operational functions in sewage treatment, including prevention of hydrogen sulphide emissions during anaerobic digestion and acting as a coagulant to improve sludge dewatering. Iron is also dosed in wastewater pumping stations to reduce odours and corrosion. Also, iron is present at significant levels in raw wastewater, e.g. wwtp inflow concentrations of 1 - 10 mgFe/l in some plants in the Netherlands.

Tomorrow's wastewater treatment plants

The authors consider that iron dosing could play a major role in the wastewater treatment of tomorrow, where sewage treatment is optimised for energy production.

Future wwtp configurations using the A-B process may include Anammox (see SCOPE Newsletter n° 89) or low temperature Anammox. In both cases, the objectives are to reduce wwtp footprint and maximise the degradable organic matter transferred to sewage sludge, to feed methane production. It is estimated that such configurations could produce up to 86 J/person/day energy, compared to 158 J/person/day energy consumption in classical activated sludge sewage treatment.



The A-B process uses a first, high-load, biological adsorption step (A) followed by bio-oxidation to remove nitrogen (B). The nitrogen removal in this second step can be enhanced by application of Anammox processes so that an energy producing sewage treatment plant can be realized. In this setup phosphorus cannot be removed sufficiently by biological processes. Therefore chemical means for P removal are required. Iron dosing is the cheapest option to flocculate biomass, colloidal and particulate carbon in the A stage, as well as ensuring phosphorus removal.

P-removal and P-recovery

An issue for iron chemical P-removal is the recovery of the phosphorus for recycling. This requires separation of the phosphorus from the iron compounds in digested sludge to release the phosphorus into solution, from which it can be precipitated in a purer and more concentrated form.

The authors explain that iron bound phosphorus is cycled from iron compounds in nature by plants, bacteria and fungi. Natural P-release mechanisms include iron-reducing bacteria, sulphide production, excretion of carboxylate ions (which chelate Fe and release P), exudation of anions to desorb P from iron oxides (e.g. bicarbonate, hydroxide) and reduction of FePs by pH modification.

These examples show that iron bound phosphorus can be mobilized and should not a priori to be considered "lost". A better understanding of these processes may make it possible to design recovery processes for iron bound phosphorus. They suggest that further research is needed into possible mechanisms for release of phosphorus from iron compounds in wastewater and sewage sludge, including:

- identification of the **chemical form** in which iron and phosphorus are present: iron III or iron II phosphate, P adsorbed on iron oxides (at least 16 different iron oxides exist)
- impact of dosing ferric (iron III) or ferrous (iron II) salts
- making sewage sludge P more available by reduction from ferric to ferrous compounds, e.g. by iron reducing or iron oxidising bacteria
- using sulphur reduction to extract P from iron compounds in sludges, e.g. by using sulphide at low pH, or by addition of sulphate combined with microbial action
- impacts of humic substances, in particular on iron •

oxide phosphorus adsorption or possible formation of iron-humic-P complexes

- effects of **pH** on iron-phosphorus binding
- effects of different iron phosphate **crystal structures**

Iron-based P adsorbents

A different approach could be the engineering of ironbased phosphorus adsorbents. Already iron based materials like granular ferric hydroxides, iron coated sand (Blue PRO®), iron slags (EU project SLASORB), iron based resins (Lewatit FO36 ®) have been used or tested for P-removal in (small scale) sewage treatment (see references 71-75 in the review) but **further work is needed to develop adsorbents with effective regeneration for selective phosphorus release**. This could be achieved by optimising crystallinity, pore sizes and surface characteristics of iron oxide based adsorbents.

The authors conclude that **biomimetic processes for iron-based P-removal and recovery** could make a valuable contribution to development of the wastewater treatment plant of tomorrow, with optimised energy and nutrient recovery.

"The relevance of phosphorus and iron chemistry to the recovery of phosphorus from wastewater: a review", Environ. Sci. Technol., 2015, in print

http://pubs.acs.org/doi/pdfplus/10.1021/acs.est.5b00150

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Soil analysis New techniques for assessing soil P

Levels of soil phosphorus, the form in which P is present and the soil / microorganism / plant reactions are essential information for managing crop fertilisation, soil phosphorus runoff risks and soil P reserves. A number of innovative techniques provide more powerful tools than traditional soil extraction and analysis. This review summarises these different methods, their application and implications.

A 2-page summary of the **soil phosphorus cycle** is presented, covering inputs, soil P pools and reactions and soil P losses. Interactions and different forms of



inorganic and organic phosphorus in soil are discussed, including the small but important pool of soil solution inorganic P, which is readily available for plant or microorganism uptake. The traditional P extraction and analysis techniques for the different P pools in soils are indicated.

Innovative soil P analysis methods

Techniques for soil P assessment presented are the following:

- 13 **spectroscopic methods**, which enable identification of different P forms in soil or solution samples
- Soil P reaction methods: sorption isotherms, generally using batch equilibrium tests with different P solutions
- Quantum chemical modelling, looking at P binding to soil minerals or other reaction sites
- Microbial biomass and microbial P turnover. Soil microbial P (P_{mic}) is only a small proportion of total soil P (0.4 – 2% in cropland, up to 7.5% in grassland) but is an important labile P source for plants. Analysis of microbial P can be based on Prelease by cell lysis by biocides. Analysis of microbial P processes can be based on measurement of phosphatase or of inorganic and organic P breakdown products.
- **Diffuse gradients in thin films (DGT**, see Six et al. in SCOPE Newsletter n° 112), used to asses labile P fractions in (wetted or moist) soils. As indicated by Degryse et al. 2009, DGT is generally a better indicator of plant nutrient availability than traditional extraction methods where P diffusion within soil is a limiting factor for crop access
- ³³P isotopic exchange (radio-labelling), which is a powerful tool for analysing soil – plant – microorganism P cycling.
- **Stable oxygen isotope ratios**, using ¹⁸O / ¹⁶O ratios compared to a reference material.

Applications and specifications

A **detailed table** specifies applications, types of results, concentrations covered, sampling, advantages and disadvantages of 22 different methods.

The authors underline that these recently developed methods enable considerable progress in characterisation of P forms (and P-bonding) in soils, understanding of spatial distribution of P forms within the soil and of transformation processes. They conclude that all methods offer both advantages and disadvantages, so that no single method will

comprehensively characterise the wide range of P forms and pools in soils: multi-methodological approaches are essential. A multiple approach also limits the risk of simplistic considerations of soil phosphorus and crop availability and incites to take a wider phosphorus stewardship approach.

"Innovative methods in soil phosphorus research: A review", J. Plant Nutr. Soil Sci. 2015. 178. 43-88 http://onlinelibrary.wiley.com/doi/10.1002/jpln.201400327/abstract

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Food security Wastes to reduce soil nutrient deficits in Uganda

Material flow analysis in Uganda shows potential of human exxcreta to reduce soil nutrient deficits in agricultural soils.

A material flow analysis (MFA) on substance level was carried out for the Busia District in the east of Uganda. The soil nutrient balance of nitrogen (N), phosphorus (P), and potassium (K) were calculated, and also the potential of hitherto not utilized human excreta (urine and faeces) and municipal solid waste (MSW) to reduce soil nutrient deficits in farmland soils.

Like many countries in Sub-Saharan Africa, the country of Uganda faces a considerable soil nutrient deficit in agricultural soils. So far, a quantification of the potential of waste nutrient sources to overcome negative soil nutrient balances in Uganda has not been carried out.

Soil nutrient deficit

The results of the study show that there is a comparatively high soil nutrient deficit of major plant nutrients in agricultural soils in Busia District. Annual soil nutrient deficits have been determined at values of -33 kg of nitrogen per ha, -6 kg of phosphorus per ha, and -41 kg of potassium per ha of agricultural land.



High soil nutrient restoration potential by human excreta

The MFA further shows that the potential to reduce negative soil nutrient balances is small for hitherto not utilized urban MSW municipal solid wastes (1-3%), but much higher for human excreta (17-60%).

The low potential of MSW is due to the lower quantity of nutrients that accumulates in organic MSW, but also due to the fact that MSW from rural areas is already widely used on agricultural soils.

The higher potential of human excreta, which are currently not used as nutrient source for agricultural soils, is challenged by the **hygienic problems** which are associated with their utilization. This counts particularly for human feces. The problems of the low soil nutrient deficit reduction potential of urban organic MSW on the one hand and safe handling of human excreta on the other hand suggests that other measures (e.g. soil conservation, mineral fertilizer) should not be ignored in order to increase the agricultural productivity. This not only counts for Busia District, but also applies to other areas and countries in Sub-Saharan Africa.

"The potential of wastes to improve nutrient levels in agricultural soils: A material flow analysis case study from Busia District, Uganda", Agriculture, Ecosystems & Environment, September 2015, 207, 26-39 http://dx.doi.org/10.1016/j.agee.2015.03.024

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Anthropogenic P resources Evaluation of phosphorus stocks in Austria

As projections predict a shortage of some raw materials, the use of anthropogenic resources by concepts like recycling and urban mining receives an increasing attention by scientists, companies, and private and public stakeholders.

In order to assess and evaluated the availability of selected secondary raw materials from the anthropogenic stock, a concept for **categorizing** anthropogenic resources in a similar and thus comparable manner to natural resources, distinguishing between reserves, resources and other occurrences, is

needed. This article presents a conceptual framework for the evaluation of anthropogenic resources.

Anthropogenic resource evaluation concept applied to phosphorus

The concept presented is derived from the US Geological Survey standard procedure for resource identification. and reserve evaluation. and classification of natural stock resources (McKelvey diagram).

The framework was applied to a case study on phosphorus (P) stocks in Austria. To determine the size of the anthropogenic P stocks built up in Austria since the year 1960, material flow analysis (MFA) data from literature as well as own calculations based on government documents were used. After selecting technologies to extract and produce P fertilizer from the P stocks, an economic evaluation was performed. Based on that, the P stocks identified were finally classified due to their economic extractability and certainty of size.

Anthropogenic P stocks in Austria can currently not be classified as reserves

Results indicate that of the total anthropogenic P stocks in Austria of around one million tons, only 10% are extractable at subeconomic levels.

The production costs to produce mineral P fertilizer from this stock fraction, which is mainly located in landfills of municipal sewage sludge incineration ashes, municipal solid waste bottom ashes, and municipal sewage sludge, are 5-10 times higher than the current market price for P fertilizer.

Another 20% of P stocks have been found to be not technically extractable. This mainly counts for P in municipal solid waste landfills. Finally, 70% of the P stocks are of such a low grade that it is not practically feasible to recover P fertilizers from them, principally in soil phosphorus accumulation, iron & steel slag stockpiles and in buildings (materials).

Separate disposal of sewage sludge incineration ashes is recommended

The assessment results also show that the **extractable** quantity of P would have been much larger if Prich materials were not landfilled together with low-grade materials. This particularly counts for municipal sewage sludge incineration ashes which were mixed with municipal solid waste bottom ashes



in the same landfill.

The evaluation of anthropogenic P stocks in Austria presented in this article was performed on a first screening level. The application of this framework shows that a method for the evaluation of anthropogenic resources that is consistent with natural resource evaluation methods **can provide a solid basis** for enhanced utilization of some anthropogenic resources.

However, like comparable economic resource evaluation methods, the method at hand lacks some important evaluation aspects, like environmental, technological, and societal factors.

"A framework for the evaluation of anthropogenic resources: the case study of phosphorus stocks in Austria", Journal of Cleaner Production, 1 December 2014, 84, 368-381 http://dx.doi.org/10.1016/j.jclepro.2014.05.078

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Blog

Sustainable P Initiative blog

http://www.phosphorusplatform.eu/blog.html

Nutrient Platforms

Europe: www.phosphorusplatform.eu Netherlands: www.nutrientplatform.org

Flanders (Belgium):

http://www.vlakwa.be/nutrientenplatform/

Germany: www.deutsche-phosphor-plattform.de

America Partnership on Phosphorus North Sustainability NAPPS https://sustainablep.asu.edu

Upcoming events

- ✤ 26-29 May, Erfurt, Germany, ReUseWaste, FertiPlus, IneMad and Biorefine meetings and FIRe workshop: Innovative strategies to improve the recycling of energy, nutrients and organic matter from waste materials http://www.reusewaste.eu/events/register/
- ✤ 1st June, Toronto, Canada, Phosphorus recovery workshop and action plan *imogen.coe@ryerson.ca* within the Grev to Green Conference www.greytogreenconference.org

- 3-5 June 2015, York, England, RBB-11 11th International Conference on Renewable Resources & Biorefineries http://www.rrbconference.com/
- 6 June 2015, Leeds, England, Food Waste Reduction (AqueEnviro) http://www.aquaenviro.co.uk/view-product/A-New-Opportunity-for-Food-Waste-Reduction
- *7-10 June, Washington D.C., WEF IWA Residuals and Biosolids Conference 2015, http://www.wef.org/ResidualsBiosolids-WEFIWA /
- *11-12 June, WATERNET, Amsterdam, P-REX Final Workshop and technical visits http://prex.eu/
- 15-16 June, Skellefteå, Sweden, LIFE+ conference Resource Recovery and Water Protection http://www.outotec.com/en/About-us/Calendar-of-events/Life-Conference-Resource-recovery-and-water-protection/
- * 17-19 June, Prague: ARGUS FMB East Europe Fertiliser Conference http://www.argusmedia.com/Events/Past-Argus-Events/Europe/2014/Fert-East-Euro/Home
- 23 June, Brussels: REFERTIL& FERTIPLUS compost & biochar conference http://www.refertil.info/
- 24-25 June, Stuttgart, Germany, P-recovery P-ROC pilot plant visit & conference (in German) http://www.prueck-dwa-bw.de/programm_und_vortraege/
- 24 June, Brussels, ECN (European Compost Network) policy workshop: compost & digestate in the Circular Economy www.compostnetwork.info
- 25 June, Milwaukee, Wisc., USA, Resource Recovery from Effluent Workshop www.thenetherlands.org/news/2015/05/effluent-resource-recovery.html
- ✤ 30 June, Brussels, SPIRE Horizon 2020 brokerage event (Sustainable Process Industry through Resource and Energy Efficiency) www.spire2030.eu
- 19-22 August, Tampere, Finland: Global Dry Toilet Conference www.huussi.net/en
- ★ 30 Aug 2 Sept, Ghent, Belgium, Bridging towards the chemical industry1st IWA Resource Recovery Conference http://www.iwarr2015.org/
- 2 Sept, Ghent, BioRefine meeting www.biorefine.eu



- 8-10 September, Son, Norway (50 km from Oslo), 23rd Symposium Int. Sci. Centre for Fertilisers – Plant nutrition and fertilisers for cold climates http://www.bioforsk.no/ikbViewer/Content/118311/CIEC%208.-10.%20september%202015.pdf
- 28-30 Sept, Wexford, Ireland, Catchment Science 2015 http://www.teagasc.ie/agcatchments/catchmentscience2015.asp
- 17-18 September 2015 Toledo, Castilla-La Mancha Gastronomy School, Spain REFERTIL International Conference http://www.refertil.info
- 1-2 October, Vienna University of Technology, "Mining the Technosphere: Potentials and Challenges, Drivers and Barriers" http://iwr.tuwien.ac.at/mining-the-technosphere/home.html
- 11-14 October 2015, Ithaca, New York, USA, 2nd International Conference on Global Food Security www.globalfoodsecurityconference.com
- 30 October 2015, Berlin. DPP German national phosphorus plan meeting. www.deutsche-phosphorplattform.de
- 15-18 Nov. Minneapolis, US ASA-CSSA-SSSA-ESA soil science meetings www.acsmeetings.org including session 'Tracking Legacy Phosphorus in Lakes and Rivers' https://scisoc.confex.com/scisoc/2015am/webprogrampreliminary/Sessi on14624.html
- 18-19 November, Minneapolis, SERA-17 promoting promote innovative solutions to minimize phosphorus losses from agriculture http://www.cvent.com/events/2015-sera-17-meeting/eventsummary-4eb969f0be224a25821b4372c54c34a5.aspx
- 2-4 Dec 2015, Ghent, Belgium, ManuResource II (manure valorisation) http://www.manuresource2015.org/
- 10 Feb <u>2016</u>, Leeuwarden Netherlands, EIP Water Conference <u>www.eip-water.eu</u>
- 12-16 Sept 2016 Rostock, Germany, 8th International Phosphorus Workshop (IPW8), Phosphorus 2020 – Challenge for synthesis agriculture & ecosystems http://www.wissenschaftscampus-rostock.de/

