European Sustainable Phosphorus Platform

July 2015 n° 114

SCOPE NEWSLETTER

Public policy

Brittany
EU Investment Plan funds nutrient recycling

Methatrac – Cooperl 16 M€ manure recycling and TRAC new generation piggeries funded

Circular Economy
Benefits for society need tax changes

Studies show that circular economy can create jobs with tax shifts from employment to resources

Circular Economy
EU Commission conference & Ellen MacArthur Foundation

800 stakeholders hear that circular economy would bring € 0.9 trillion/year benefits

BSAG (Baltic Sea Action Group)
European Parliament meeting on nutrient circular economy

Sirpa Pietikaïnen, MEP Finland, hosted discussions on how to implement sustainable nutrient management in EU Circular Economy policies

EIP-AGRI
Agronomic use of recycled nutrients

Proposal to create an EU EIP-AGRI Focus Group

NAPPS launch
North American Partnership for Phosphorus Sustainability

70 stakeholders engage dialogue on p sustainability in North America and initiate a P sustainability partnership.

Workshop 3-4 Sept. 2016, Ghent, Belgium

Data on Nutrients to Support Stewardship project DONUTSS

Contact brusselsoffice@phosphorusplatform.eu

Nutrient recycling

Composts
Plant phosphorus availability

P is more labile in composts with low Ca, less impacted by Fe, Al

China
Contaminants in struvite from manure

Composition and heavy metal contaminants in struvite precipitated from pig manure digestate

P-recovery research
Selective P-adsorption

Mineral-organic composite tested for selective adsorption – desorption of P from wastewaters

Phosphorus industry

Applications
Phosphorus in pharmaceutical drugs

Uses of phosphorus is developing in anti-cancer, bone, antioxidant and antidiabetic drugs

Industry perspectives
Other resources present in phosphate rock

Recovery potential of different elements in phosphate rock

EU Circular Economy public consultation

http://ec.europa.eu/environment/consultations/closing_the_loop_en.htm

New ESPP members :

Biomasa Peninsular *SA. provides full management services for organic by-products recycling for 2 decades, the core of the circular economy.*

Suez Environnement *is active in the recycling of phosphorus in Wastewater Treatment Plants: Designing, building and operation of P recovery installation.*

Italmatch *is a leading innovative Chemical Group, specialized in Performance Additives for the Lubricant, Plastics, Water & Oil markets.*

The partners of the European Sustainable Phosphorus Platform

Public Policy

Brittany

EU Investment Plan supports nutrient recycling

The European Commission Investment Plan / European Investment Bank (EIB) has identified nutrient recycling and phosphorus management as a priority area for project funding. A first project has already achieved provisional approval, presented by COOPERL (Brittany, France, farmers' cooperative).

The METHATRAC project combines new generation piggeries equipped with TRAC scraping process, anaerobic digestion of the manure with slaughterhouse waste and municipal sewage to produce biogas and processing of the digestate to a valuable agricultural fertiliser product.

The 16 million € project will treat over 38 000 tonnes of pig manure (110 000 pigs). 55% of manure nitrogen (490 tonnes N/year) and 90% of phosphorus (430 tonnes P/year) will be captured and recycled as fertiliser. 7.6 million m^3/year of biogas will be generated. Process water will be purified and recycled (reverse osmosis).

Manure recycling and new generation piggeries

The **TRAC piggery system** reduces nitrogen climate gas emissions, improves animal and worker welfare (reduced NH4) and facilitates manure treatment for nutrient recycling. 40 such installations are already operational in Brittany. 125 tonnes/year of NH_3 volatisation will be avoided in the METHATRAC project piggeries and net emissions of nearly 28 000 tonnes CO_2 saved.

This project will **accelerate sustainability in Brittany's specialist intensive agriculture**. Already today Brittany's farmers process over 400 000 tonnes of manure per year (processed weight, 50 – 90% dry matter), producing organic fertilisers specifically adapted for different crop needs and transported to other regions of France. In total, Brittany's 1 100 farms generate livestock manure containing around 200 000 tonnes of nitrogen (N) and 120 000 tonnes of phosphorus (P).

EU Investment Plan / EIB loans are available for high-risk, market ready private investments of significant scale (generally > 15 million €). Nutrient recycling is identified as a target area for new project funding.

EU Investment Plan http://ec.europa.eu/priorities/jobs-growth-investment/plan/index_en.htm

For information about possible nutrient recycling project funding loans under this plan, contact ESPP.

Circular Economy

Benefits for society need tax changes

Studies by the Club of Rome for Sweden Ex'Tax group of fiscal experts for Netherlands and WRAP/Green Alliance for the UK confirm that the circular economy can create many jobs, distributed over both urban and rural regions and at all skill levels, but that to achieve results there must be a significant shift in fiscal burden from taxes on employment (income tax, contributions, VAT) to environmental, energy or resource taxation.

The study by the Club of Rome, with support of the MAVA Foundation and the Swedish Association of Recycling Industries, assesses potential societal benefits of the circular economy in Sweden, and the policy changes necessary to achieve this, in particular changes in taxation and VAT. Job creation, energy and climate change, balance of payments and investment costs are addressed. A further study is underway looking at the Netherlands and Spain.

3% of Sweden's workforce

The Club of Rome report estimates that a circular economy combination of energy efficiency measures, renewable energies and reorganising manufacturing around material efficiency and circular recycling could, in Sweden, **reduce carbon emissions by 70%, employ 3% of the workforce and improve the balance of payments by 3% of GDP**.

The report considers that this confirms conclusions of the recent **WRAP/Green Alliance study in the UK** which estimated that developing recovery, reuse, repair and remanufacturing could **reduce unemployment by 50 000 – 100 000 in the UK**.

The circular economy will also **reduce regional disparities (because circular economy jobs are local and distributed)** and create **jobs at all skill levels**

This scenario would imply **investments of c. 3% of GDP/year through to 2030**, so would necessitate significant fiscal policy changes for it to be achievable.

Tax and VAT policies

The report underlines that a shift in fiscal and VAT policies are necessary and feasible to achieve this. Tax in Europe is currently dominated by taxes on labour (contributions, VAT), whilst tax on natural resources consumption, waste and emissions are very low. **The circular economy, favouring reuse and recycling, is considerably more labour intensive than mining and manufacturing from virgin materials**.

In addition to moving the tax burden from labour to resources, the report recommends a **change in VAT policies**, to exempt goods produced from secondary materials, where VAT has already been paid once on the initial product.

Industry fiscal experts The Netherlands

The Ex'Tax study, 2014, carried out by tax experts from leading financial consultancies (Deloitte, EY, KPMG, Price Waterhouse) proposes a **34 billion € tax shift in the Netherlands (that is, 15% of total national tax revenue) from labour taxes and contributions to environment and energy taxe**s. This would generate over one million jobs (FTE full time equivalent).

The report shows that over 50% of EU tax revenue was derived from labour taxes and social contributions, plus 30% from consumption taxes, compared to only 6% environmental taxes (principally on energy and transport).

The tax experts consider reducing tax on employment by reducing income taxes, social contributions and VAT. In particular raising low-income allowances for income tax and employers' contributions would exonerate a number of workers from both, so **reducing administration costs for the tax authorities and employment-related bureaucracy for employers** (no pay-as-you-earn income tax and no social contributions for employees below the allowance level).

These tax revenue reductions would be compensated by **taxes on a range of polluting activities, covering greenhouse gas emissions (CO_2 and NO_x), electricity, fossil fuels, water and electronic wastes**. These are sectors where taxes or other mechanisms (carbon credits) are already in place, so avoiding new bureaucracy.

For electronic wastes, in order to avoid the considerable issues already known in this sector, with inadequately collected waste and current producers facing costs related to orphan legacy equipment**, a "deposit" system is proposed** which consumers would pay on new items and which would be partly refunded on return at end of life (e.g. c. 75€ on a TV set, 50 € returned at end of life, 25 € retained as a materials consumption tax and to fund recycling).

Zero-VAT is proposed for job-intensive circular economy sectors (all repairs and maintenance of e.g. machines, electronics, clothes, and also on energy-savings advice and installation).

Zero-VAT is also proposed on "**Best Practice**" products, to promote sustainable innovation, by analogy with Japan's "**Top Runner**" programme.

Other measures proposed include corporation tax advantages for activities related to circular economy of materials.

Netherlands Government proposals

The Netherlands Government has published proposals "for a new circular economy package" (30/4/2015). These proposals emphasise the need for a Natural Capital approach to sustainable primary resources, including agricultural commodities. Development and **integration of natural capital accounting should enable internalisation of environmental costs** in the production phase of both a-biotic and biotic resources.

The Netherlands underlines the need for **intelligence on resource security and support for the OECD biomass platform**, to ensure necessary data on bio-resources for developing stewardship and recycling. It is proposed to develop an EU "*uniform framework to monitors all flows within and lost from the food supply chain*". Relevant to this is the **ESPP "DONUTSS" initiative Data on Nutrients to Support Stewardship**: *www.phosphorusplatform.eu* under events.

The Netherlands Government proposals note the need to **review the concept of "waste",** in order to facilitate the use of waste as a resource and recycling, including in the Waste Framework Directive: defining better the term "to discard", aligning articles concerning end-of-waste and by-products, establishing an indicative list and data base of by-products and by-product / end-of-waste criteria.

Specifically, a "***Harmonised market for nutrients, recovered from organic waste***" is called for, with in particular revision of the EU Fertiliser Regulation to integrate recovered products (underway) and creation of coherent "end-of-livestock-manure" criteria to address the limitation of use of processed manure currently posed by the Nitrates Directive.

Concerning **food waste**, the Netherlands proposes to emphasise preventing food waste, but also to define food waste as a secondary resource not a waste.

The Netherlands also proposes to develop **dynamic standard setting**, with an "EU top-runner approach"

"The Circular Economy and Benefits for Society", A. Wijkman, K. Skånberg, Club of Rome, MAVA Foundation, Swedish Association of Recycling Industries, 4/2015
http://www.clubofrome.org/?p=8260

"Employment and the Circular Economy - Job creation in a more resource efficient Britain", J. Morgan, P. Mitchell, WRAP – Green Alliance, Jan 2015 http://www.wrap.org.uk/content/employment-and-circular-economy

Ex'TAX "New era. New plan. Fiscal reforms for an inclusive, circular economy. Case study the Netherlands", F. Groothuis et al., 27/11/2014 http://www.ex-tax.com/news/extax/ground-breaking-extax-report/

Netherlands Government, "Further proposals for a new circular economy package", 30th April 2015
https://zoek.officielebekendmakingen.nl/blg-536079.pdf

Circular Economy

EU Commission conference & Ellen MacArthur Foundation

Over 800 stakeholders attended the European Commission's circular economy policy workshop, Brussels, 25th June, twice the capacity of the conference hall, filling two additional rooms.

The conference confirmed the considerable expectations of **the European Commission's new Circular Economy proposals, currently open to public consultation to 20/8/15**
http://ec.europa.eu/environment/consultations/closing_the_loop_en.htm

Vice-President of the European Commission, Frans Timmermans, stated that we know we must move to a circular economy, which represents a long-term profitable economic model, and that the question is not "if" but "how". The EU has the smallest income gaps in the world and ***"the future lies not in low cost production but in services"***. The circular economy can make Europe competitive, without sacrificing wage levels or quality of life.

Environment Commissioner, Karmenu Vella, emphasised that Europe is world leader in eco-industries and green technologies. The circular economy can deliver both jobs and economy and is resilient to economic crises. It must be "***led by European regulatory targets for wastes, water and energy***".

Carsten Bermig, cabinet of Elżbieta Bieńkowska, Commissioner for Internal Market, Industry, Entrepreneurship and SMEs, underlined that R&D and innovation are needed for Europe to stay world leader in "clean industry". EU policies should ensure better adapted regulation, a stable regulatory context necessary for industry investment, and market incentives including through GPP (green public purchasing).

Proposals made by conference participants and panellists in discussion included:

- Need for **binding waste targets**
- Remove subsidies for **incineration**
- **Ban landfill on recoverable or recyclable materials**
- Higher **recycling targets**
- Need for **quality targets** for material recovery, not only quantity targets
- **Prescriptive measures** to ensure that targets are achieved
- **Certification** of recycling plants
- Use **differential VAT** levels to support circular economy, in particular zero VAT on repair and recycling
- Importance of **reliable indicators** to measure progress
- Value of **traceability** for recycled materials to ensure upstream confidence
- **Chemical safety** of recycled materials
- Facilitate market access for recovered materials (the current **proposed modification of the EU Fertiliser Regulation** was cited as a frontrunner initiative which could become a model for other sectors)

0.9 trillion €/year benefits

In an inspiring address to the European Commission conference, **Ellen MacArthur** told of her personal journey from sailing solo round the world to trying to understand how to change society from linear consumption to the circular economy. Her foundation's 4th report ("*Growth Within*", 2015) takes the challenge bottom-up, looking at **how to sustainably meet our principal needs: food, clothes, buildings**.

Recycling is only the outer loop of the circular economy: **the priorities should be keeping materials at their highest value (not down-cycling), durability and efficient use, repair, reuse**. For food, a key challenge cited is moving nutrients back from cities to farms.

Martin Stutchtey, McKinsey & Co., presented key conclusions of the Ellen MacArthur Foundation reports. Current EU household spending on food, housing and mobility represent 60% of household costs and 80% of resource use for a total of 7.2 trillion €/year (2 trillion € externalities, 1.8 tr€ resource costs and 3.4 trillion € processing). **The circular economy could benefit 0.9 trillion €/year**, additional to similar levels of benefits from digital and technology development (e.g. online sharing such as AirB&B, ZipCar). He underlined **the need to develop closed nutrient loops in food production**, pointing to current inefficiency "*only 5% of nutrients applied to the field reach our bodies, not all with health benefits*".

Ellen MacArthur circular economy report IV

The Ellen MacArthur report, "*Growth Within*", June 2015, is supported by signatures from **Philips, Deutsche Post Foundation, Véolia, Acatech, Renault, Redisa, Kingfisher, Arup, UNEP**.

One of four thematic chapters addresses "**Reinventing a regenerative food system**", considering that the current food system "*occupies 40 percent of European land, meets such vital societal needs as nutrition, and provides such ecosystem services as pollination and energy … but is wasteful, causes environmental externalities and does not produce healthy outcomes for the entire population*". Over half of the EU population is overweight or obese.

Around one third of all food produced in Europe is thrown away as waste and only 5% of fertilisers applied to land finally provide nutrients to the human body.

The report considers that a circular economy system for food production could **cut food cost per person by 30%.** This assumes that the 16 million tonnes of synthetic fertiliser used today in the EU would be reduced by 80% by 2050 by reducing wastage and closing nutrient loops. Water consumption by agriculture could be reduced by 70% and CO2 emissions by 60%. **Phosphorus recovery is top of a list of possible circular economy pilots** (fig. 20).

Nutrient losses

Reducing losses of phosphorus and nitrogen from agriculture are noted as important to reduce system risk, costs and **improve environmental water quality**.

The report cites Kimo van Dijk et al. at SPS 2014 (*Present and future phosphorus use in Europe: food system scenario analyses, 2014*) that **recycling/reuse of sewage sludges, meat and bone meal ash and other biowastes already today represents around 30% of Europe's mineral phosphate fertiliser use** (not including manures)

Examples of new actions cited are:

- separate urine collection, market scaling for recovered fertilisers (the e-Market *http://e-market.phosphorusplatform.eu/* is cited)
- separate food waste and garden waste collection
- synergies in bio-refineries where one organic by-product is used as feedstock for another process
- peri-urban farming to close loops
- research into soils
- digital solutions to reduce food supply chain wastage.

The report states that to move to a circular economy for food production requires **systemic change and policies which address the barrier posed by the current lack of pricing of resources and externalities**, which results in undervaluation of natural capital and prevents recovery of nutrients reaching large scale. **Redesigning of processes** for collecting, separating and processing bio-wastes, manures and sewage / waste water will be necessary.

The Foundation proposes to price externalities to resource consumption, to reduce taxes on secondary materials such as recovered nutrients, and to shift taxes away from labour to finite resources.

A combination of a healthier, more varied, more locally produced diet (including 40% reduced calorie intake) and an 80% reduction in food waste could reduce household spending on food by 40% by 2050.

Overall, the Foundation estimates that a circular economy for nutrients and food production could bring **320 billion €/year benefits** (compared to development otherwise), as well as reducing negative externalities by 130 € billion/year.

"Growth Within: a circular economy vision for a competitive Europe", 100 pages, 25th June 2015, Ellen MacArthur Foundation, McKinsey Center for Business and Environment, SUN (Stiftungsfonds für Umweltökonomie und Nachhaltigkeit) http://www.ellenmacarthurfoundation.org/news/latest-research-reveals-more-growth-jobs-and-competitiveness-with-a-circular-economy

BSAG (Baltic Sea Action Group)

European Parliament meeting on nutrient circular economy

A meeting at the European Parliament, co-organised by BSAG and chaired by Sirpa Pietikaïnen, MEP, Rapporteur for the EU Circular Economy package, discussed how to integrate sustainable nutrient management into the new EU proposals for a Circular Economy strategy.

Sirpa Pietikaïnen opened the meeting, underlining the need to change our society and economy from a consume-and-dispose flow-through system, in which **planetary boundaries are exceeded for many resources, in particular, for phosphorus and nitrogen** (see e.g. SCOPE Newsletter 103), to a sustainable circular economy. This needs a paradigm change and a systematic approach throughout society, and will offer important opportunities for new business and job creation.

Mathias Bergman, BSAG (Baltic Sea Action Group), considers that **nutrient cycling and nutrient reuse are key to addressing Baltic eutrophication issues** with sustainable and economic solutions. Business involvement is essential for the transition to a circular economy for phosphorus, nitrogen and carbon.

Arnoud Passenier, ESPP (European Sustainable Phosphorus Platform), explained how **networks and stakeholder dialogue** through the value chain can contribute to promoting innovation and demonstrating success stories.

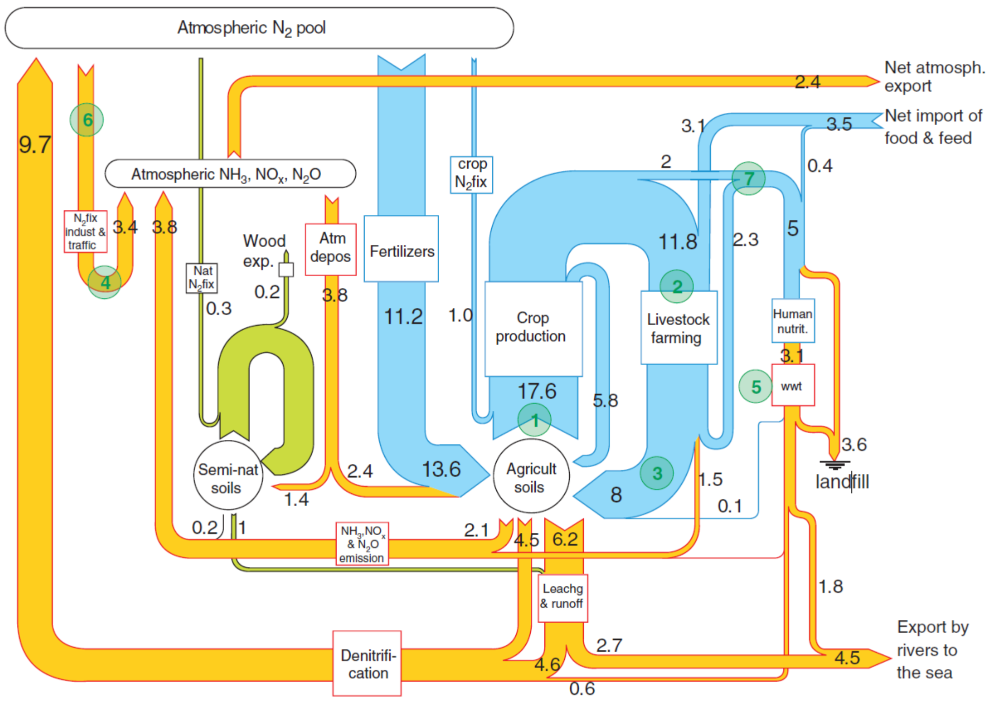
Costs and benefits of nutrient management

Mark Sutton, CEH (UK NERC Centre for Ecology and Hydrology), presented the European Nitrogen Assessment *http://www.nine-esf.org/ENA* and global nitrogen policy perspectives. **Without mineral nitrogen fertiliser, we could today feed only around half of the world's population**, but nitrogen use brings *important "WAGES", that is costs to Water, Air, Greenhouse, Ecosystem and Soil*.

In Europe, nitrogen losses are estimated to cost 70 – 320 billion €/year, with the biggest cost being health impacts of particulate matter air pollution caused by nitrogen-emissions. **The fertiliser value of nitrogen losses in Europe is c. 18 billion €/year**.

Several recent publications have identified options for taking action on the nitrogen cycle. These publications include "**Our Nutrient World**" (2013, published by CEH for UNEP on behalf of the Global Partnership on Nutrient Management and the

Nitrogen fluxes in the EU27, year 2000, from Sutton et al., European Nitrogen Assessment 2011. Green flows are natural, blue are intended anthropogenic flows, yellow are losses and unintended flows



International Nitrogen Initiative, www.unep.org/gpa/documents/publications/ONW.pdf "Options for **Ammonia Mitigation**" and "**Nitrogen on the Table**", both prepared by the UNECE Task Force on Reactive Nitrogen (www.clrtap-tfrn.org/webfm_send/553; http://www.clrtap-tfrn.org/).

Options proposed are:

- **Crop nitrogen efficiency**, e.g. by more precise fertiliser use, new crop types, reducing disease …
- **Improving recycling of manures**
- Centralised **recycling of NO_x** from fuel combustion to produce nitrogen fertilizers
- **Changes in human diet**: halving EU meat and dairy consumption would cut nitrogen fertiliser use by 40% and double nitrogen efficiency

Prof. Sutton outlined **proposals for Europe's role in global policy action on nitrogen**:

- Bring a positive approach based on the economic returns of reducing nitrogen losses (WAGES)
- Demonstrate the win-win synergy with energy efficiency
- Develop the circular economy and local job creation

Paulo Gouveia, COPA-COGECA (European federation of farmers organisations and agricultural cooperatives), reminded that **the circular economy is natural for agriculture, but that it can only function if the economic price is right and if added-value is generated and returned to farmers**. It is essential to guarantee food quality and safety, to ensure consumer confidence. If this is ensured, then the circular economy can generate local jobs in collection, sorting and transformation of agri-food products. His proposals for developing the nutrient circular economy in agriculture include:

- Local networks to recycle nutrients back to the field
- Integrated farming, where animal manures can be used efficiently locally
- R&D and knowledge transfer to disseminate innovation
- Access to risk financing for entrepreneurs

Industry and regulation

Ludwig Hermann, Outotec, presented the group's role as a leading technology company in minerals, metals and nutrients (1.9 billion € turnover). The current cost of technical recovered nutrients is significantly higher than mineral phosphate fertiliser, but generalised P-recovery from wastewater would only cost a few €/person/year.

A number of technologies for P-recycling are already operational, but these cost issues, along with logistics and market questions (variable characteristics of recovered products), mean that widespread implementation will not occur without appropriate regulatory or incentive drivers.

The regulatory context needs to be reliable and stable over the long term to drive industry investment. He proposed as options to support the nutrient circular economy:

- Nutrient recovery or recycling targets, as currently proposed in Switzerland or Germany
- Contaminant limits
- Implementing spreading limits for manures
- Establish harmonised quality criteria for recycled nutrient products

Claudia Olazabal, European Commission DG Environment (Head of Unit, Agriculture, Forests and Soil) highlighted the importance and challenges of nutrient management. She stressed the fact that closing a nutrient cycle involves **many actors in many different areas at large geographical scale**.

She focused in particular on the agricultural sector, where despite the improvements in farm management a lot remains to be done, both on **balanced fertilization** and in **nutrient management in areas of surplus**. Avoiding nutrient losses in areas of intensive livestock rearing entails often some pollution prevention costs, which some farmers claim they might have a difficulty to bear, because of the low margins of profitability. This would point to the need to ensuring a more equitable share of the profit across the value chain. Particularly as the societal costs of agricultural pollution are very often paid by the citizens; even if they have access to food at low prices, **the consumer will pay much higher costs through water bills** for the costs of water decontamination. These economic issues must be addressed to take forward the nutrient circular economy.

Existing EU regulations offer opportunities to improve phosphorus management, including the Water Framework, Nitrates, Urban Waste Water Treatment and Marine Strategy Framework Directives. The Nitrates Directive, for example, although it does not refer to phosphorus, has been effectively used by Member States to address agricultural phosphorus pollution and has led to significant gains in nutrient use efficiency and to "smart" farming.

The European Commission's Consultative Communication on Sustainable Phosphorus (see SCOPE Newsletter 107) concluded that closing the loop for phosphorus is both feasible and desirable, offering important opportunities both for environmental progress and economic benefits and jobs. Key issues to be addressed include:

- **Ensuring safety**: limit levels and monitoring of contaminants both in mineral fertilisers and in recycled nutrient products, in order to support farmer and consumer trust and market harmonisation
- **P-recycling** is already operational: how to scale up and generalise?
- The EU is an **international frontrunner** in nutrient recovery and recycling: how to maintain this advantage and facilitate business and job creation?

Heidi Jern, Cabinet of Jyrki Katainen, Vice-President of the European Commission for Jobs, Growth, Investment and Competitiveness, indicated that the Commission has launched a public consultation on the proposed new Circular Economy strategy for Europe. Stakeholders interested in phosphorus sustainability are strongly invited to contribute with concrete proposals for policies to move forward implementation of the nutrient circular economy.

EU Circular Economy consultation:
http://ec.europa.eu/environment/consultations/closing_the_loop_en.htm
Closing date 20th August 2015

"Nutrient cycling in a circular economy", European Parliament, 27th May 2015, co-organised by BSAG (Baltic Sea Action Group) and chaired by Sirpa Pietikaïnen, MEP, Rapporteur for the EU Circular Economy package.

The following BSAG www.bsag.fi *documents and the meeting presentation slides are online at* http://www.bsag.fi/en/News/News%20Archive%202015/Pages/Nutrient-cycling-in-circular-economy%E2%80%93meeting-at-the-European-Parliament.aspx

➔ *BSAG leaflet "Nutrient cycling at the core of circular economy", 6 pages*

➔ *BSAG position paper and study: "The role of nutrient cycling in circular economy*

This includes a 2 page position paper, May 2015, with five proposals for "**Key elements for possible Nutrient Framework Policy**"

- Policy planning and market creation, e.g. proposal for "feed in tariffs" for recycled nutrient fertilisers
- Regulatory coherence: EU-wide phosphorus application regulation, comparable to the Nitrates Directive
- Stakeholders, research, data and best practice
- Communication and public awareness
- Reforming CAP to support nutrient cycling and enable consumer choice

This document also includes the BSAG report "Study: nutrient cycling at the core of circular economy": 12 page compilation of data on supply and demand for phosphorus and nitrogen, links to energy, nutrient mass flows, nutrients in organic materials and wastes, possible policies and solutions to develop the nutrient circular economy.

BSAG press release "Three ways to create economic growth from nutrient cycling" 11/5/2015
http://www.bsag.fi/en/News/News%20Archive%202015/Pages/PRESS-RELEASE-Three-ways-to-create-economic-growth-from-nutrient-cycling.aspx

EIP-AGRI

Agronomic use of recycled nutrients

With support of 60+ organisations, ESPP has submitted to EIP-AGRI (European Innovation Partnership for Agriculture) a proposal to create a "Focus Group" on agronomic use of recycled nutrients.

EIP-AGRI is a European Commission funded organisation (linking DG Agriculture and Horizon 2020 R&D) with objectives of **helping agricultural and forestry become more productive, sustainable and competitive by facilitating innovation** through partnerships and networks.

If accepted, this proposal will lead to the establishment and moderation by EIP-AGRI of an 'officially recognised' expert group to **facilitate innovation towards a circular economy for nutrients** by assessing needs for information dissemination, research, implementation and networking. Focus Group themes are selected by EIP-AGRI from ideas submitted by stakeholders. See *http://ec.europa.eu/eip/agriculture/en/content/focus-groups*

The 3rd March 2015 **DG Research & Innovation workshop identified as an R&D need "*agronomy research into phosphorus use efficiency in farming practices and crop availability of recovered nutrient products*"** and identified the need to better coordinate and disseminate the many different R&D projects and networks related to nutrient recycling. Workshop co-organised by the European Commission DG Research and Innovation, ESPP and P-REX (see SCOPE Newsletter 112), see *http://bookshop.europa.eu/en/circular-approaches-to-phosphorus-pbKI0115204/*

If you are interested in this topic and wish to be informed of future developments, contact **info@phosphorusplatform.eu**

Agronomic use of recycled nutrients

The proposal submitted by ESPP aims to accompany development of the **circular economy for nutrients**, looking at agronomic use of recycled nutrients (biosolids [inc. manure], digestates, composts, biochars, recycled fertiliser products, on-farm recycling) and covering short / long term fertiliser value; nutrient loss mitigation; macro- and micro-nutrients; contaminants; impacts on soil (organic matter, chemistry, biology, erosion risks); BMPs for handling and application; circular economy and farm added-value.

Considerable knowledge exists, but this needs assembling and updating to address e.g. long term approaches to soil carbon and microbiology; nutrient loss risk and soil erosion; new and emerging contaminants; quality standards for a harmonised market for recycled nutrient/fertiliser products; new nutrient recycling routes.

Key questions to be addressed are proposed as follows:

- **Fertiliser value** (and adapting recycling to optimise): availability of recycled nutrients to crops, impact on soil quality (biology, chemistry, organics, fertility, crop-availability of nutrients in soil) short term and across seasons …
- **Impacts on soil** erosion, nutrient losses (leaching and run-off, N air emissions) and environmental aspects (ecosystem services, LCA …)
- **Contaminant risks**: food safety; health and environment; farmer, food industry, retailer, consumer confidence; monitoring, testing, bioassays, standards
- Characterisation of products depending on the feedstock and treatment processes, **identification of future developments and innovations**, market, regulatory, logistics and economic considerations for widespread implementation
- **BMPs (Best Management Practices)** for storage, handling, application, nutrient management
- **Dissemination**: accessible and adapted to farmers and land managers, advisers, regulators, recycling industry, process developers, general public and end-use perception.

Implementing nutrient circular economy

ESPP's proposal underlines that **nutrient recycling is evolving and increasing (value, quantity)** with agronomic efficiency, food safety and consumer confidence as key objectives. However, maintaining current levels of nutrient recycling and developing the nutrient circular economy face challenges because of **pressures such as spatial redistribution, societal concern about "wastes" or contaminants**.

Yet bio-nutrients should be a key aspect of EU Circular Economy policy, with **opportunities for local job creation and farm added-value**, and for international business (the EU is a world frontrunner in nutrient recycling).

Stakeholder dialogue

To implement the nutrient circular economy, there is a need for information dissemination and stakeholder dialogue between science, farmers, advisers, regulators, water/waste industries, food industry, environmental NGOs, consumers and supermarkets. This should **address issues around contaminant risks** (health, environment) and monitoring.

EIP Focus Group can facilitate dialogue; identify R&D needs, end-users' knowledge and skills gaps; improve dissemination to accompany new markets, **new opportunities for farmers**.

Regulatory and standards links

There are many **links to EU policies**, including Circular Economy, Nitrates and Water Framework Directives, Sludge Directives, CAP (Common Agricultural Policy) and RDF (Rural Development Funds), Circular Economy and Critical Raw Materials policies Critical Raw Materials List, Consultative Communication on Sustainable Phosphorus, policies on biorefineries, renewable energy, Fertiliser Regulation update, EU draft End-of-Waste criteria for composts and digestates, as well as national / regional policies.

There are also **interactions with standardisation** processes: CEN and ISO standards for biosolids management, eg. ISO 275 pr, CEN/TC 308, CEN/TC 223, CEN/TC 400: HORIZONTAL, CEN/TS 13714.

Supporting organisations

The proposal submitted has registered the **support of 60+ organisations** and is relevant to a number of existing networks:

- COPA-COGECA (European Farmers – European Agri-Cooperatives)
- Fertilizers Europe *www.fertilizerseurope.com*
- International Water Association (IWA) *www.iwa-network.org*
- UNIFA (Union des Industries de la Fertilisation, France) *www.unifa.fr*

- EUREAU (Europe's drinking & waste water service operators federation) http://eureau.org/
- European Compost Network www.compostnetwork.info
- European Biogas Association http://european-biogas.eu/
- VCM (Flemish Coordination Centre for Manure Processing) www.vcm-mestverwerking.be
- Northern Ireland Environment Agency (NIEA) http://www.doeni.gov.uk/niea/
- Denmark EPA (Environmental Protection Agency)
- Swedish EPA (Naturvardsverket)
- Environment Agency (England & Wales)
- Käppala Waste Water Treatment Plant, Sweden
- International Nitrogen Initiative and Task Force for Reactive Nitrogen
- Baltic Sea Action Group www.bsag.fi
- Countryside and Community Research Institute (stakeholder engagement) , UK www.ccri.ac.uk
- Bundesamt für Landwirtschaft BLW, Switzerland
- C.A.S (French federation of organic fertilisers and growing media)
- Central Union of Agricultural Producers and Forest Owners (MTK), Finland http://www.mtk.fi/en_GB/
- WssTP (European Water Platform) http://wsstp.eu/
- Instituto Politécnico de Castelo Branco, Escola Superior Agrária, Portugal http://www.ipcb.pt/ESA/
- AWEL, Baudirektion Kanton Zurich, Switzerland
- Chemische Fabrik Budenheim KG, Germany
- University of Hohenheim in Stuttgart, Germany
- ILVO, Institute for Agricultural and Fisheries Research, Flanders, Belgium www.ilvo.vlaanderen.be
- Biorefine Cluster Europe http://www.biorefine.eu/cluster
- Centre for Ecology & Hydrology (UK Natural Environment Research Council NERC)
- University of Ghent, Belgium
- Agri-Food and Biosciences Institute (AFBI), Northern Ireland www.afbini.gov.uk
- University of Helsinki Department of Agricultural Sciences http://www.helsinki.fi/agriculturalsciences/
- Norwegian institute for agricultural and environmental research (Bioforsk)
- SEGES (Denmark Knowledge Centre for Agriculture and Danish Pig Research Centre) http://www.seges.dk/
- Fachhochschule Nordwestschweiz (FHNW), Switzerland
- Instituto Superior de Agronomia, Universidade de Lisboa
- IRSTEA (National Research Institute of Science and Technology for Environment and Agriculture), France www.irstea.fr
- Royal Agricultural University, Cirencester, UK
- Gruppo Ricicla DISAA Università degli Studi di Milano http://users.unimi.it/ricicla/
- Cranfield University, UK
- Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, Germany
- Terra Humana Ltd www.3ragrocarbon.com
- ICL Fertilizers www.iclfertilizers.com/
- Lancaster University, UK
- VTT, Technical Research Centre Finland
- Universidade de Trás-os-Montes e Alto Douro, Portugal http://www.utad.pt/
- Bauhaus-Universität Weimar (Germany) www.uni-weimar.de/en
- INRA France
- CNP-Technology Water and Biosolids GmbH
- Natural Resources Institute Finland (Luke)
- NuReSys (nutrient recycling technologies), Belgium http://nuresys.be/
- Rothamsted Research, UK
- Aarhus University, Denmark
- Umweltcluster Bayern (Cluster of Environmental Technology Bavaria) www.umweltcluster.net
- Stockholm Environment Institute www.sei-international.org
- Alterra Wageningen UR (the Netherlands) http://www.wageningenur.nl/en/Expertise-Services/Research-Institutes/alterra.htm
- FHNW (Fachhochschule Nordwestschweiz) www.fhnw.ch
- Queen's University Belfast (QUB)
- University of Copenhagen, Denmark
- Vienna University of Technology (TUW)
- The James Hutton Institute www.hutton.ac.uk
- Leibniz ScienceCampus Phosphorus Research Rostock, Germany
- Ricarod-AEA http://www.ricardo-aea.com/cms/agriculture-services
- Montanuniversitaet Leoben, Austria
- KWB (Kompetenzzentrum Wasser Berlin) www.kompetenz-wasser.de
- EIP Water Action Group "ARREAU Accelerating Resource Recovery from Water Cycle" http://www.eip-water.eu/ARREAU
- WssTP (European Water Platform) Resource Recovery WG http://wsstp.eu/
- P-REX (FP7) www.p-rex.eu
- SmartSoil (organic carbon) http://smartsoil.eu/
- PROMISE (EU Bonus) http://www.bonusportal.org/projects/innovation_projects/promise
- REFERTIL (FP7) www.refertil.info
- Development of a suite of novel land conditioners and plant fertilizers from waste streams of biomass energy generation (UK NERC Resource Recovery from Wastes Program), lead Lancaster University
- Fertiplus (FP7) www.fertiplus.eu
- PProduct and PRecover (Finland Ministry for Agriculture)
- IMproveP (Core organic II ERA-NET) https://improve-p.uni-hohenheim.de
- End-o-Sludg (FP7) www.end-o-sludg.eu
- ROUTES (FP7) www.eu-routes.org
- UK sewage sludge index / Biosolids Nutrient Management Matrix http://www.adas.uk/Downloads/Biosolids_Nutrient_Management_Matrix.pdf (Water UK)
- SuWaNu (FP7) http://suwanu.eu/
- PhoReSE (ERDF, NIE) www.phorese.gr
- DIGESMART (Eco-Innovation) www.digesmart.eu
- ARBOR (Interreg IVB NWE) http://arbornwe.eu/
- ReUseWaste (FP7, MC-ITN) www.reusewaste.eu/
- Biorefine Cluster Europe and BioRefine (Interreg IVB NWE) http://www.biorefine.eu/biorefine
- INEMAD www.inemad.eu
- OPUS Organic P Utilisation in Soils) (BBSRC) http://soilorganicp.com/
- BioEcoSIM http://www.bioecosim.eu/
- PhosFarm http://www.phosfarm.eu/
- InnoSoilPhos (German BMBF)
- PHORWater (LIFE+) www.phorwater.eu
- RecoPhos (FP7)
- ManureEcoMine www.manureecomine.ugent.be
- Revaq Sweden, see http://www.iea-biogas.net/case-studies.html
- UKWIR projects related to use of biosolids and biosolid products applied to agriculture http://www.ukwir.org/site/web/content/reports/reports?FolderId=90078

The **number of interested organisations and existing networks relevant to agronomic use of recycled nutrients confirms the interest to better coordinate innovation actions**, improve networking and define R&D and dissemination needs to support implementation of innovation.

EIP-AGRI (European Innovation Partnership for Agriculture)
http://ec.europa.eu/eip/agriculture/

NAPPS launch

North American Partnership for Phosphorus Sustainability

North America stakeholders from industry (fertilisers, phosphate mining, chemicals, farm services, recycling …), regulators (including USDA, US EPA, Canada Agriculture and State representatives …) knowledge institutes, NGOs, came together on 19th May in Washington DC to discuss phosphorus sustainability issues and solutions and societal transition pathways.

The meeting confirmed the value of such stakeholder dialogue and the broadening interest in improving nutrient management.

The incipient North American Partnership (NAPPS) plans to move forward by organising **thematic workshops to further develop this dialogue** in practice, to construct a working network and to identify and initiate joint phosphorus management actions.

Nutrient management challenges

Nancy Rabalais, Louisiana Universities Marine Consortium, presented the challenge posed by nutrient inflow to the **Gulf of Mexico** from the Mississippi River basin. Since the 1950s, a 'dead zone' (hypoxia or low oxygen) as large as 22 000 km^2 has developed as a result of nitrogen and phosphorus discharge, resulting in a decrease in fisheries and shrimp production and a social/economic dynamic among fishers and farmers.

The data presented showed that fertiliser use increased considerably from the 1950s to the 1980s, but since then has been fairly stable. **Despite the fact that nutrient runoff is not increasing, the hypoxic zone continues to get bigger because of accumulation of legacy nutrients** in the watershed and nutrient and carbon legacies in the offshore coastal waters.

Dr. Rabalais underlined the failure of policy. The federal/state Mississippi River/Gulf of Mexico Watershed Nutrient Task Force Gulf "**Hypoxia Action Plan 2001 and 2008**", called for a reduction to 5 000 km^2 of the 'dead zone' area by 2015, but no reduction has been achieved. This Plan considers that a -35% reduction in nitrogen and a -45% reduction in phosphorus discharge are necessary. However, the Task Force is in the process of extending the deadline to 2035.

Dr. Rabalais noted that the source and loads of nitrogen and phosphorus vary by activity and location across the Mississippi River watershed. The solutions to losses of nitrogen and phosphorus also vary, but can be integrated in some forms of mitigation. The goal is a reduction in nitrogen and phosphorus loads with a balanced nitrogen:phosphorus ratio.

She concluded by noting that the **P-RNC initiative and the North American Nitrogen Center** should enter into a mutually beneficial dialogue and emphasised that she was impressed by the strong stakeholder commitment.

Melodie Naja, Everglades Foundation, Florida: scientists need to dialogue with policy makers to develop feasible and reasonable nutrient restoration targets and avoid false expectations. For **Lake Okeechobee watershed (South Florida),** agricultural Best Management Practices (BMPs) have been made mandatory but nutrients remain 3x higher than the Lake TMDL (Total Maximum Daily Load). Lake recovery is not meeting expectations because of the lack of BMP implementation verification mechanisms (enforceability), lack of funding, and because of legacy phosphorus stored in the soils of the watershed. She presented the **US$ 10 million Phosphorus Grand Challenge to be launched in 2016** and to be awarded to cost effective technologies removing and recycling phosphorus from eutrophied surface waters (see SCOPE Newsletter 111).

Samuel Williams, Economic Empowerment Committee of the Maryland Southern Christian Leadership Conference: the **Conowingo dam, Maryland**, offers a critical challenge and opportunity of this nature. The three Susquehanna river dams, including Conowingo, are estimated to have retained around 40% of the river's phosphorus flow towards the Chesapeake Bay over the last century. But this phosphorus is now held in the accumulated dam sediments. **Their release would massively set back eutrophication restoration of the Chesapeake Bay**. The phosphorus accumulated in Conowingo alone is estimated to have a fertiliser value of 27 billion dollars, so also represents a major potential opportunity.

Helen Jarvie, CEH England: Europe also faces major challenges to achieve the very demanding water quality and ecological status objectives of the **Water Framework Directive**, where phosphorus is in many cases the main chemical cause of non-compliance. Current monitoring data indicate that these objectives will not be achieved by the upcoming deadlines in much of Europe.

Difficulties are accentuated for phosphorus because of the delay between action and response (legacy P and recovery delay).

Achievements and progress

Doug Myers, Chesapeake Bay Foundation: positive achievements have been made, for example Washington DC success in reducing stormwater runoff and waste water treatment nutrient discharges, reduction in impermeable surface extension and restoration of stream morphologies.

Positive signs include the return of submerged vegetation in the Potomac River. Other areas for action recently identified include preventing loss of sediments during construction site works.

Andrew Sharpley, University of Arkansas: knowledge exists to reduce phosphorus losses from farming, with a range of **Best Management Practices** and an understanding of the importance of targeting hotspot areas: 20% of watershed area generally accounts for 80% of phosphorus discharge.

Mark Walbridge, USDA Agriculture Research Service: to implement nutrient Best Management Practices on the farm, more dialogue is needed with farmers to **communicate the details of BMP costs and benefits, and address farmers' concerns about changing practices** that may have been in use for quite some time, and ensure that nutrient mitigation installations are properly maintained so that they continue to function effectively.

Joe Bartenfelder, Maryland Department of Agriculture: phosphorus management is critical and political in the Chesapeake Bay. Phosphorus is essential for agricultural production, but eutrophication problems lead to deterioration of water quality for recreation and fisheries. Dialogue with science and industry is important to communicate with farmers and to support regulatory action. Maryland is currently developing phosphorus management tool regulations which **apply the most recent body of science in assessing the risk of phosphorus loss from the agricultural landscape and require appropriate adjustments in phosphorus applications** Maryland is also supporting the implementation of new, alternative technologies for managing animal wastes and improving water quality. Agriculture and phosphorus sustainability

Tom Bruulsema, IPNI (International Plant Nutrition Institute) presented the **4 R's approach developed for nutrient stewardship by the fertiliser industry: the Right source, at the Right rate, at the Right time and in the Right place**. Through this action, industry is investing considerable resources to support farmers in using phosphorus appropriately, so reducing losses to surface waters. Stakeholder partnership and dialogue is central to this approach because the 4 R's approach is always site specific, with differing local agronomy and environmental end-points.

Joe Nester, Nester Ag. Consultants: in response to the eutrophication issues of Lake Erie, **farmers are showing their capacity to improve phosphorus stewardship, implementing the 4 R's**. Soil phosphorus testing has increased by a factor of five, enabling reductions in fertiliser use. However, agronomic research is needed to address changing conditions, for example **with the reduction in acid rain soil sulphur is decreasing and soil pH is increasing. This seems to lead to increasing availability of phosphorus particularly on the soil surface**, and thus risk of runoff (to simplify, P is only 15-20% soluble at pH 6 due to bonding with Fe and Al, and is more soluble at pH 6.5).

Eileen McLellan, Environmental Defense Fund: the food industry and supermarket supply chain increasingly **perceive unsustainable agriculture practices as a business** risk that both threaten their license to operate and leave them unprepared to deal with climate change. To support this, sustainability metrics for farmers, with feasible monitoring systems need to be defined and developed, with the support of federal agencies and others.

Steve Slater, Mid-Western BioAg: farmers are changing, and a new generation of "Smart Farmers" will achieve improved nutrient management. **Soil is increasingly being considered as a living medium, and the importance of organic matter and soil micro-organisms is being recognised**. Agronomic science and research is needed to support this.

Galen Mooso, J. R. Simplot: the 4 R's approach is recognised as an effective way to improve farm phosphorus management by the agri-industry supply chain. New agronomic products are coming onto the market, which improve crop availability of phosphorus in soil - and thus phosphate recommendations can be reduced. **Partnership between industry, farmers, research and regulators can help implement phosphorus Best Management Practices (BMP)** and disseminate new products and techniques.

Opportunities for phosphorus recycling

Chris Haug, TRIEA Technologies: the feasible recycling of 60% of P in the USA's annual manure production would represent around 30% of mined and imported phosphorus which, with the appropriate infrastructure, could be reclaimed and recycled.. Intensive livestock production (CAFOs confined animal feeding operations) offer a priority opportunity, but **a value-chain and complete collaboration between regulators, industry and farmers is needed to move forward.**

Ying Wang, Dairy Innovation: the US dairy sector wants to develop nutrient recycling, but needs guidance from knowledge centres and relevant resources to select appropriate systems and technologies. The **development of anaerobic digesters and other efficient manure handling approaches** offer potential synergy with development of recycled nutrient products, which could become a revenue stream for dairy farmers.

Ariel Szogi, USDA-ARS Agricultural Research Service: there are about 2,500 farms using anaerobic lagoons to manage liquid swine manure in North Carolina. The cost of moving from this existing technology, in which investments have been made, is an obstacle to adopting more advanced nutrient recycling technologies. Regulators have however already placed a moratorium on the construction of new lagoons. **Currently, new swine farms or expansion of existing swine farms in North Carolina are required to follow strict environmental standards called "environmentally superior technology."** Although the government established a lagoon conversion program that provides financial incentives to assist producers, economic incentives are still needed for early movers and the market needs to be structured for recovered products: composts, concentrated recycled phosphorus products, and energy.

Policy coherence

Participants underlined the importance of critical events in raising awareness and taking policy and action forwards, such as the **2014 Lake Erie toxic algae incident** which led to interruption of drinking water supply to Toledo (see e.g. *http://www.wateronline.com/doc/should-the-u-s-get-an-algae-czar-0001*).

The need for policy coherence was emphasised: food security and biofuel security, nutrient policy, water quality. Funding mechanisms and regulation need to be adjusted so that the costs of phosphorus environmental impacts are not "externalised", to ensure that subsidy programmes do not encourage practices which accentuate phosphorus losses and that they make farm nutrient BMP's cost-effective. Nutrient trading can optimise overall costs of such policies.

US P-RCN (Phosphorus Research Network)

The NAPPS stakeholder meeting organised in parallel to the third annual meeting in Washington DC of the US P-RCN (2013 – 2017, **Phosphorus Sustainability Research Coordination Network**, funded by US National Science Foundation, see SCOPE Newsletter 100).

P-RCN aims to **facilitate networking between scientists interested in phosphorus sustainability** (if interested, contact Helen Rowe *hirowe@asu.edu*)

P-RCN has already facilitated the production of a number of joint papers and resources:

- WETSUS inventory and summary of technology assessments of phosphorus recycling technologies, produced by WETSUS and updated on the ESPP website *www.phosphorusplatform.eu* under 'Downloads'
- Doody, D.G.; Withers, P.J.A.; Dils, R.M. Prioritizing waterbodies to balance agricultural production and environmental outcomes. Environ. Sci. Technol. 2014, 48(14), 7697-7699.
- Elser, J.J., T.J. Elser, S.R. Carpenter, and W.A. Brock. 2014. Regime shift in fertilizer commodities indicates more turbulence ahead for food security. PLoS One 9: e93998. doi: 10.1371/journal.pone.0093998
- Gifford, M., J. Liu, B.E. Rittmann, R. Vannela, P. Westerhoff "Phosphorus Recovery from Microbial Biofuel Residual Using Microwave Peroxide Digestion and Anion Exchange" Water Research, 70:130-137 (2015)
- Haygarth, Philip; Jarvie, Helen; Powers, Steve; Sharpley, Andrew; Elser, James; Shen, Jianbo; Peterson, Heidi; Chan, Neng; Howden, Nicholas ; Burt, Tim; Worrall, Fred; Zhang, Fusuo; Liu, Xuejun. 2014. Sustainable phosphorus management and the need for a long-term perspective: The legacy hypothesis. Environ. Sci. Technol., 2014, 48 (15), pp 8417–8419
- Webeck, E; K Matsubae; T Nagasaka. 2014. Phosphorus requirements for the changing diets of China, India and Japan, Environmental Economics and Policy Studies, (DOI 10.1007/s10018--014--0088--8)
- Webeck, E; K Matsubae; K Nakajima; K Nansai; T Nagasaka. 2014. Analysis of Phosphorus Dependency in Asia. Sociotechnica, 11:119--126.
- Withers, P., J. Elser, J. Hilton, H. Ohtake, W. Schipper, and K. C. van Kijk. 2015. Greening the global phosphorus

cycle: How green chemistry can help achieve planetary P sustainability, Green Chemistry, DOI: 10.1039/C4GC02445A

The P-RCN identified the need to **develop overall systems analyses** of phosphorus stewardship and of pathways towards implementation in society.

Vision and transition

A process for producing a **roadmap for phosphorus sustainability for North America** (in a global context) was initiated, led by Dana Cordell and Brent Jacobs (University of Technology Sydney) drawing input from and debated with the participants at the NAPPS stakeholder workshop and the scientists at the P-RCN meeting. The definition of an outline vision for sustainable phosphorus management in 2040 was initiated, drivers and challenges associated with the current system articulated, and a set of transition pathways identified to move from today's situation towards this sustainable phosphorus future.

P-RCN projects to take forward

A number of **candidate research projects defined by the P-RCN group** will over the next two years look at different systemic aspects of phosphorus sustainability in society, grouped under four objectives: metrics, futures & technologies, transitions (behaviour, policy and communications) and ecosystems services and water – energy – nutrients nexus:

- Synthesis of integration of nutrient management in **sustainability indicators.** Case studies of application of nutrient sustainability indicators / footprints
- Research project for North America addressing sustainable **phosphorus recycling**
- Analysis of **regulatory drivers** for nutrient removal and recovery in North America
- Assessment of **potential of technologies for P-recovery from diffuse sources** (cf. Everglades Foundation Phosphorus Grand Challenge, see SCOPE Newsletter n°111)
- Concept for **cradle-to-cradle** phosphorus reuse
- **Pathways to phosphorus sustainability** model
- Model for optimisation of **farm nutrient practices** at the system level
- Case study of cost effectiveness of point vs. non-point **phosphorus source policies**
- Comparison between several regions **urban nutrient Circular Economy** opportunities
- **Educational and teaching tools** on phosphorus sustainability
- Overview of **phosphorus ecosystem services** at the watershed level
- Model of **soil phosphorus management** linking carbon, nitrogen, geochemistry, soil biology
- Assessment of **need for updated nutrient fertilisation recommendations** linking to water quality

ESPP projects with P-RCN

- analysis of **importance of long-term agricultural research** into P in fields, soils, including testing of nutrient products (e.g. biosolids) over several years' application
- **update existing farm P BMP (best management practice) factsheets** (e.g. COST, SERA17, USDA, Baltic …) and provide a single access point to present all sources of such BMP information (see article in this SCOPE Newsletter)
- initiate research to **support integration into norms and standards**, BAT, etc (ISO, CEN …) of P sustainability
- **phosphorus footprints for the agri-food industry**: how to integrate phosphorus into existing industry sustainability metrics ?
- in coherence with the European DONUTSS project on phosphorus stocks and flows, development **of P stocks and flows studies for North America a**nd for certain nutrient hot-spot states or for certain industry sectors (North America proposal led by David Vaccari, coordination with ESPP's DONUTSS project, workshop 3-4 September 2015, Ghent)

NAPPS and P-RCN contact Helen Rowe hirowe@asu.edu and website https://sustainablep.asu.edu/

Nutrient recycling

Composts
Plant phosphorus availability

Three different composts were tested for labile P and in rye grass pot trials for P-uptake

1. Composted dry digested household waste
2. Composted municipal solid waste
3. Composted solid fraction maze anaerobic digestate

Sequential extraction of phosphorus was tested with: deionised water, 0.5M sodium carbonate ($NaHCO_3$), 0.1M sodium hydroxide (NaOH), 1M hydrochloric acid (HCl), then finally residual phosphorus by hot digestion with sulphuric acid and H_2O peroxide. Composts were also analysed for different element and organic carbon concentrations, and using X-ray diffraction for mineral crystalline structure.

Pot trials were carried out in 2 litre pots using soil from the Po Valley Italy, with application rates of the composts each at 30 mgP/kg soil. Nitrogen was applied to be non-limiting. Rye grass (*Lolium multiflorum* subsp. *Italicum*) was grown for 112 days after sowing, with harvests at 28, 56, 84 and 112 days. A **control treatment with calcium monophosphate** (and no compost) was also grown.

Each treatment was grown in four replicate pots. Plant P-uptake was assessed by comparing P-content of shoots and roots to that of the control pot plants.

Different composts

The TOC (total organic carbon) was significantly higher composted maize based digestate, and was higher in the compost from digested household waste than from than non digested. Iron and aluminium were significantly higher in the two municipal-waste derived composts than in the maze-derived compost. Nitrogen contents (TKN) varied from 13 to 20 g/kg and phosphorus from 3.7 – 6.7 TP g/kg.

Phosphorus plant availability

The maize digestate compost showed the highest labile P (c. 60%), and also the highest P-uptake in the pot tests. Pot trail calculated plant P-availability was around twice as high for the maize digestate compost as for calcium monophosphate, whereas the two municipal waste derived composts were somewhat lower than calcium monophosphate. The compost from the digested municipal waste showed somewhat higher pot trail P-availability than that from the non-digested municipal waste.

Labile P and plant P-availability showed correlation to compost calcium content (conform to previous work by He et al. 2010 and Nanzer et al. 2014), and also to XRD crystallinity, but **not to iron or aluminium content**,.

Overall, these results suggest that composts from municipal waste sources are likely to show lower labile P and crop P-availability, probably related to calcium content, and that **prior digestion may increase the crop P availability**.

"Phosphorus in Digestate-Based Compost: Chemical Speciation and Plant-Availability", Waste and Biomass Valorization, May 2015 http://link.springer.com/article/10.1007/s12649-015-9383-2

M. Grigatti (1), E. Boanini (2), L. Cavani (1), C. Ciavatta (1), C. Marzadori (1), 1 = Dept. Agricultural Sciences, and 2 = Dept. Chemsitry, Alma Mater Studiorum - University of Bologna, Viale, G. Fanin, 40 - 40127 Bologna, Italy marco.grigatti@gmail.com

China
Contaminants in struvite from manure

Struvite was precipitated from swine manure anaerobic digestion liquor, in the laboratory using industrial grade (IG) magnesium oxide MgO and hydroxide Mg(OH)2 as low-cost magnesium sources. Heavy metal contaminants were analysed in the recovered struvite. Copper and zinc were found in the struvite at levels higher than China fertiliser limits.

Swine wastewater discharges large amounts of nitrogen and phosphate in China each year, offering great potential for nutrient recovery. However, **the quality of the recovered phosphate products is essential for uptake and market development** of nutrient recovery.

Contaminants and impurities

In the laboratory, using 400ml, 12 hour, stirred batch experiments, IG-MgO and IG-$Mg(OH)_2$, supplied by Laizhou Zhonghao Magnesium Company (Shandong Province, China) were tested as **magnesium sources** for struvite precipitation in real swine manure digestate wastewater (screened 0.5 mm mesh) from an anaerobic digester operated at an intensive pig farm by Yinxiang Group (Xiamen City). The influences of Mg/P molar ratio (1.4-3.8) and mixing time (0.5-12 h) were tested.

The industrial grade magnesium chemicals contained 50 – 80% MgO equivalent, 15 – 40% organics (LOI 1 100°C), low levels (1 – 3%) of iron, calcium, aluminium and silicon and traces (0.3 – 12 µg/g) of chromium, lead, cobalt, nickel, vanadium. Cadmium was 0.01 µg/g. Copper and zinc were below detection limit.

The **manure digestate** contained approx. 1 000 mg/l COD, 540 mg/l N-NH4 and 86 mg/l P-PO4 but 2.4 g/l of copper and 12 g/l of zinc.

Struvite impurities

The recovered precipitate products were analyzed by the following methods XRD, FTIR, elemental composition and mass balance analyses.

Results revealed that **struvite made up only 34-40% (weight)** along with amorphous calcium phosphate (8-10%), residual MgO or Mg(OH)2 (9-19%), 14-21% organics and 19-24% refractory materials (mainly SiO2).

Heavy metals are a concern in struvite recovery and thus, are seen as a potential hazard. In the study, **Cu and Zn in the recovered solids were detected significantly higher than the ruling standards of chemical fertilizer in China**, with concentrations of c. 800 µg/g and 5 000 µg/g, respectively – these clearly have their origin in the manure digestate. Cu and Zn are easily complexed to organic colloids. It was not analysed here whether these elements were present in the organic fraction of the recovered product or in the struvite.

It should be pointed out that **zinc oxide (ZnO) and copper sulfate (CuSO4) are commonly used as growth promoters in Chinese intensive swine farming**, and the major fraction of Cu and Zn are discharged into the wastewater.

Cadmium (c. 0.3 µg/g), lead (7-8 µg/g) and **nickel** (9-11 µg/g) were also present in the recovered product, but at much lower levels – it is not clear whether these come from the manure digestate, for the industrial magnesium compounds or from both.

"Phosphorus recovery from swine wastewater by struvite precipitation: compositions and heavy metals in the precipitates", Desalin. Water Treat., 2015 http://www.tandfonline.com/doi/abs/10.1080/19443994.2015.1035342

Y. Shen, Z-L. Ye, X. Ye, J. Wu, S. Chen, Institute of Urban Environment, Chinese Academy of Sciences, China

P-recovery research

Selective P-adsorption

This research article reports on lab-scale experiments using adsorption for selectively removing phosphate from a complex aqueous solution, including testing in real wastewater (biogas plant slurry).

Selective P adsorption followed by desorption (P release) could provide a route for producing a relatively pure phosphate solution for P-recovery.

Although articles involving phosphate adsorption are common, they often do not report on the synthesis of a selective adsorbent.

Selectivity for phosphorus

Selectivity is an important parameter especially in complex industrial waste streams where other anions can compete with phosphate for the adsorbent sites and hence affect the phosphate adsorption capacity.

Selective adsorption of phosphate also implies that **phosphate recovered by desorption will be purer**. Hence it is important to consider adsorbents that are highly selective for phosphate.

The adsorbent used in this research was an **organic-inorganic composite**, which consisted of intercalating pyromellitic acid (PMA, an aromatic carboxylic acid) in layered double hydroxides (LDHs). LDHs are materials comprising of cationic layers balanced by anions in between the layers. Hydrotalcite is a well-known example of an LDH. They have a strong anion exchange capacity and hence have been used extensively for phosphate adsorption. However their selectivity towards phosphate has usually been low and this presents a challenge in removing phosphate in industrial waste streams which have competing ions like carbonate, chloride, nitrate and sulphate amongst others.

The authors suggest that the selectivity of a Zn_2Al-LDH (comprising zinc and aluminium as the cations) towards phosphate adsorption is improved by introducing PMA as the interlayer (the resulting adsorbent is denoted Zn_2Al-PMA-LDH). For comparative studies, a similar LDH having chloride in the interlayer (Zn_2Al-Cl-LDH) was used.

Layered double hydroxides

The authors confirmed the presence of PMA in the Zn_2Al-PMA-LDH using powdered X-ray diffraction (XRD), thermogravimetric (TG), differential thermogravimetric (DTG) analysis. The selectivity of Zn_2Al-PMA-LDH and Zn_2Al-Cl-LDH was evaluated in an artificial wastewater solution containing 100 mg P/l and an equimolar mixture of common anions in wastewater: sulfate, nitrate, carbonate and chloride. The selectivity was defined as the mole ratio of phosphate adsorbed to all adsorbed ions.

Zn_2Al-PMA-LDH had a higher selectivity than Zn_2Al-Cl-LDH though a pH range of 3 to 10, with a highest selectivity of 97.4% at pH 7 by the Zn_2Al-PMA-LDH as compared to around 40% selectivity at pH 7 by the Zn_2Al-Cl-LDH. At pH 7 and 30°C, the Zn_2Al-PMA-LDH showed a phosphate adsorption capacity of up to 64.8 mg/g as compared to the Zn_2Al-Cl-LDH which showed a phosphate adsorption capacity of about 30 mg/g. This was due to the lack of selectivity of the Zn_2Al-Cl-LDH which led to competitive adsorption of carbonate ions by it.

Fourier transform infrared (FTIR) spectroscopy and X-ray photoelectron spectroscopy (XPS) analysis showed that the hydrogen bond between the hydroxyl group of phosphate and oxygen of aromatic carboxyl group present in the Zn_2Al-PMA-LDH, played a key role in selective phosphate adsorption. The hydrogen bond formation is affected by pH, which explained the high selectivity of Zn_2Al-PMA-LDH at the pH range of 3 to 9, whereas the **selectivity decreased at higher pH**.

Between pH 3 to 9, the phosphate species is present dominantly as either $H_2PO_4^-$ or HPO_4^{2-} which can form hydrogen bonds with the carboxyl group of PMA. At higher pH, the phosphate is not protonated and hence not able to selectively adsorb onto the Zn_2Al-PMA-LDH.

Thermodynamic parameters were obtained by running adsorption isotherm experiments at different temperature. Phosphate adsorption onto Zn_2Al-PMA-LDH was found to be an endothermic and spontaneous process. Adsorption was found to fit best with the Langmuir adsorption model.

Testing in biogas plant slurry

The adsorbent was also evaluated in supernatant from a sludge slurry from a biogas plant. The phosphate concentration in this wastewater was 44 mg P/l. Important competing anions in the water were ammonia (3470 mg N/l), chloride 156 (mg/l), sulfate (61 mg/l) and nitrate (26 mg N/l).

Under these conditions a **maximum phosphate adsorption capacity** was found of 48.4 mg/g at 30°C. The selectivity to phosphate under these conditions was not reported and the article does not explain the lower capacity of the adsorbent when using real wastewater. Desorption of phosphate from the Zn_2Al-PMA-LDH used with this wastewater was studied using a sodium hydroxide solution. It was found that the **desorption percentage varied between 60 to 80%** within 5 subsequent adsorption-desorption cycles.

"Highly selective adsorption of phosphate by pyromellitic acid intercalated Zn-Al-LDHs: Assembling hydrogen bond acceptor sites", Chemical Engineering Journal, 260 (2015), 809-817
http://www.sciencedirect.com/science/article/pii/S1385894714012455

Q. Yu, Y. Zheng, Y. Wang, L. Shen, H. Wang, Y. Zheng, N. He, Q. Li (*), Department of Chemical and Biochemical Engineering, College of Chemistry and Chemical Engineering, Xiamen University, Xiamen 361005, PR China (*) = also College of Chemistry and Life Science, Quanzhou Normal University, Quanzhou 362000, PR China wypp@xmu.edu.cn

Phosphorus industry

Applications

Phosphorus compounds in pharmaceutical drugs

Current and developing uses of phosphorus compounds, in particular phosphonates, as pharmaceuticals, antioxidants and antidiabetics are reviewed.

Including the element phosphorus in organic molecules imparts **specific and valuable biological and pharmaceutical properties**. In particular, phosphonates and phosphonic acids (which contain C-$PO(OH)_2$ or C-$PO(OR)_2$ groups where R = alkyl or aryl) can show antifungal, antibacterial, anti-inflammatory or anticancer activities. Widely used commercial phosphonates include Glyphosate (sold as "Roundup"), the world's most used herbicide, and Ethephon, a plant growth regulator.

Phosphonates also occur in nature, e.g. 2-aminoethylphosphonic acid which is found in plant and animal membranes, where their biological role is still poorly understood.

Bone and cancer drugs

Bisphosphonates are widely used in treating bone metabolism disorders such as osteoporosis, osteitisdeformans ("Paget's disease of bone"). Depending on the specific compound, they can impede dissolution of hydroxyapatite crystals, enhance bone mineral generation or prevent bone erosion by encouraging bone break-down cells (osteoclasts) to undergo apoptosis (destruction). They have also been shown to **prevent cancer cells from adhering to bone matrix, to inhibit cancer cell migration and invasion and to cause cancer cell apoptosis (destruction).**

The bisphosphonates clodronate and pamidronate are very effective in treating hypercalcaemia of malignancy, associated with myeloma and bone metastases, and are used for the prevention of skeletal related events associated with a variety of cancers.

Aminophosphonates (which include both N and P) can act as enzyme inhibitors, antimicrobial agents, anti-cancer drugs.

Antioxidants

Antioxidants are known to reduce reactions which deteriorate cells and biological functions and facilitate disease and ageing, although the mechanisms linking this to long-term health are not yet clear. **Organophosphorus compounds, in particular both phosphonates and phosphites, can act as either primary and/or secondary antioxidants**. Primary antioxidants trap peroxyl radicals (radical scavengers), whereas secondary antioxidants act as hydroperoxide decomposers (synergists, transforming radicals to non-radical substances).

Antidiabetics

Heterocyclic phosphorus esters are known to act as both hyperglycemic and hypoglycemic agents. Certain **phosphonates** have also been shown to reduce blood glucose levels in diabetes mellitus rats.

The author concludes that **phosphorus compounds are already widely used as drugs** in treating bone-related disorders, and that **significant development is possible in other applications including anti-cancer treatments, antioxidants and antidiabetics**, subject to further research and development.

"Phosphorus Compounds in Pharmaceutical Drugs and Their Rising Role as Antioxidants and Antidiabetics: A Review", International Journal of Chemical and Biomedical Science (AASCIT American Association for Science and Technology), Vol. 1, No. 3, 2015, pp. 56-69 http://www.aascit.org/journal/ijcbs

A. Kamel, Chemical Industries Division, National Research Centre (NRC), Dokki, Cairo, Egypt azza_kamel@yahoo.com

"Design, Synthesis, and Antioxidant/Antidiabetic Activity of Nucleic Acid Bases Bearing Fused N,S-Heterocyclic Phosphor Esters", Heterocyclic Chemistry, 2014, M. Wafaa Abdou, M. Khidre, A. Kamel
http://onlinelibrary.wiley.com/doi/10.1002/jhet.2260/abstract

Industry perspectives

Other resources present in phosphate rock

Phosphate rocks are well known to contain various other elements which may one day be extracted for industrial use. This overview, from Florida, looks at the different potentially valuable elements present in phosphate ore, as well as at possible technologies for improving P-extraction from rock and for using mining byproducts.

Elements present in sedimentary phosphate rock deposits (which currently produce over 85% of the world's phosphate) include uranium, thorium and rare earth elements. Two recent papers summarise potential and **possible technologies for recovery of these elements**.

Uranium

In the first paper, Zhang indicates that in sedimentary phosphate rock, after simple beneficiation (e.g. washing), uranium concentrations vary from 50 – 150 ppm, and thorium 8 – 23 ppm.

Research and testing has been undertaken over the last 40 years to try to develop a process to economically recover uranium from phosphate rock, for use as nuclear fuel, and pilot plants have been tested. Uranium in phosphate ores is estimated to represent 80% of the world's non-conventional uranium reserves, but as indicated above, **uranium concentrations are very low making recovery difficult**.

Most technologies tested to date are based on **solvent extraction** (using reagents such as DEPA di(2-ethylhexyl) phosphoric acid and TOPO trioctyl phosphine acid). These technologies face issues with emulsion, solvent loss and crud formation and costs to date are not economic. Current developments are looking at **ion exchange** technologies which do not face these problems but are still not economic.

Thorium

Thorium represents a possible future technology for nuclear energy production, where it is promised as clean and safe. Thorium levels in phosphate rocks are lower than uranium, and would again pose economic challenges. However, **thorium recovery may be combinable with rare earth element recovery**. Possible thorium recovery technologies include low temperature roasting (230 – 300°C) followed by water leaching, solvent extraction and separation.

Rare earths

Rare earths in the world's annual phosphate rock production are estimated at around 100 000 tonnes. However, again, **rare earth elements are present at very low concentrations**, with figures quoted from Florida of 90 ppm neodymium, 70 ppm cerium, 60 ppm yttrium, 50 ppm lanthanum. Only around 30% of the rare earths in phosphate rock reach the phosphoric acid after processing, the remainder going to phosphogypsum and other rock processing streams.

Improving phosphate extraction in rock processing

Today, **around 20% of phosphorus in phosphate rock is estimated to be left at the mine** (lost in the mining process). This rate can be improved by improving instant information regarding deposit quality and characteristics during the mining operation. Laser based analysis (LIBS) is currently being developed and tested to enable real-time analysis of phosphorus and magnesium content of mine dragline samples.

Phosphorus is further lost in the clays and slime generated during the **rock beneficiation process, with in some cases up to 30% losses**. These can be reduced by improving beneficiation and separation technologies, or by phosphate extraction from the waste clay/slimes.

Phosphate clay/slimes from mining processes and phosphogypsum (the calcium sulphate based byproduct stream generated in phosphoric acid production from rock by the sulphuric acid route) are both considered by industry as **potentially reusable materials**. Proposals include:

- **improving drying and thickening** of clays/slimes to extract a higher proportion of the phosphorus and reduce the waste byproduct, as well as avoiding the need for space-consuming and pollution-risk settling ponds
- processing of the clays/slimes or of phosphogypsums to manufacture **construction materials**, in combination with e.g. fly ash, polymers, grog
- **use as fertilisers**, but this poses questions regarding contaminants, and regarding the plant availability of the phosphorus present
- use as a **chemical industry input material**, for example for sulphur recovery, leaving a material with low sulphur content which can be used in the cement industry

Alternative phosphate ores

Around 75% of the world's phosphate reserves are **carbonaceous deposits (dolomitic ores, containing magnesium oxide),** e.g. the Florida pebble-fraction. These cannot by economically exploited using current phosphoric acid production processes because the magnesium is transferred into the acid where it poses processing problems. New rock processing systems (direct-reverse flotation) currently being developed could enable economic extraction of phosphoric acid from carbonaceous ores.

Zhang concludes that **sustainability of phosphate mining** can potentially be improved by focusing on increasing recovery of phosphorus in the mining and beneficiation process, developing use applications for waste streams (beneficiation clays/slimes, phosphogypsum) and recovery of radionuclides or rare earth metals.

Overview of recovery potential

In the second paper, **Chen & Graedel also analyse potential for recovery of uranium and trace elements from phosphate rock**. They particularly note that most of the rare earth elements (REEs) end up in the mining / rock processing waste streams (overburden, mine spoil, sands, slags, tailings and phosphogypsum) from where recovery is problematic. The most likely point for REE recovery would be from the phosphoric acid product (**green or merchant grade acid, MGA**), because recovery could then be combined with purification (e.g. cadmium removal).

They note that 8 plants were operating **recovering uranium from phosphoric acid** in the USA in the 1980's, plus plants in Canada, Spain, Belgium, Israel and Taiwan, but that all these plants closed by 2000 because of falling uranium prices.

The only current technology identified by Chen &

Graedel as effective for recovery of uranium and REEs is solvent extraction (which is today widely used for acid purification for food and industry applications), but this is **expensive and has high environmental impacts**.

These authors indicate that **16 of the trace elements present in phosphate rock (Li, Na, Mg, S, Cl, K, Ca, Cr, Mn, Fe, Co, Cu, Zn, Se, Mo, and I) are essential macronutrients or micronutrients for plants, animals, and humans** whereas Be, As, Cd, Hg, Tl, and Ra are highly toxic.

They calculate that **11 REEs have mining potential ratios (content in P-rock mined annually / annual commercial production) > 10** (Y, Sm, Eu, Gd, Hf, Tb, Dy, Rb, Sc, Tm, and Yb) and 7 have MPRs > 1 (La, Ce, Pr, Nd, Ho, Er, and Lu). Taking into account other sources and industrial requirements, the authors suggest that the more promising trace element candidates for extraction from phosphate rock are scandium (Sc), hafnium (Hf), beryllium (Be), gallium (Ga), germanium (Ge).

"Comprehensive Recovery and Sustainable Development of Phosphate Resources", "SYMPHOS 2013" 2nd International Symposium on Innovation and Technology in the Phosphate Industry, Procedia Engineering 83 (2014) 37 – 51
http://dx.doi.org/10.1016/j.proeng.2014.09.010

P. Zhang, Florida Industrial and Phosphate Research Institute, 1855 West Main Street, Bartow, FL 33830, USA
pzhang@admin.usf.edu

"The Potential for Mining Trace Elements from Phosphate Rock", J. Cleaner Production JCLP 5013, in print 2015
http://dx.doi.org/10.1016/j.jclepro.2014.12.042

M. Chen (1) and T. Graedel (2). 1 = Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, Beijing, 100081. 2 = Center for Industrial Ecology, Yale University, New Haven, 06511
thomas.graedel@yale.edu

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***

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

Upcoming events

- 6 July, Milan, EU JRC & DG ENVI workshop **Best Practices in improving the sustainability of agriculture** (EMAS BEMP) *https://ec.europa.eu/jrc/en/event/conference/best-practices-improving-sustainability-agriculture*
- 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** final conference *http://www.biorefine.eu/biorefine/news/save-date-biorefine-final-conference*
- 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 *brusselsoffice@phosphorusplatform.eu*
- 5-9 Sept., Windermere, Lake District, England, **International Organic Phosphorus Workshop 2016** *http://soilpforum.com/*
- 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*
- 18 Sept. Milan (San Rocco wwtp) **Resource Recovery in Wastewater Treatment Plants** *www.metropolitanamilanese.it*
- 16-17 Sept, Padeborn, Germany "**Sewage sludge handling**", 17 Sept. P recovery workshop (in German) *www.vdi.de/klaerschlamm*
- 17-18 September 2015 Toledo, Castilla-La Mancha Gastronomy School, Spain **REFERTIL International Conference** *http://www.refertil.info*
- 23 Sept, Milan EXPO, **RISE Sustainable Intensification and Nutrient Recovery and Reuse in Agriculture** *http://www.risefoundation.eu*
- 28-30 Sept, Wexford, Ireland, **Catchment Science 2015** *http://www.teagasc.ie/agcatchments/catchmentscience2015.asp*
- 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*
- 5-8 October, Karlsruhe, Germany, **CMM (Materials Processes Systems)** DPP P-recovery session (8/10) *www.cmm.kit.edu*
- 11-14 October 2015, Ithaca, New York, USA, 2nd International Conference on **Global Food Security** *www.globalfoodsecurityconference.com*
- 12-13 October, Manchester UK, 9th European **Waste Water Management Conference** *http://www.ewwmconference.com/*
- 30 October 2015, Berlin. **DPP German national phosphorus plan meeting**. *www.deutsche-phosphor-plattform.de*
- 2-6 Nov, **Amsterdam International Water Week** *http://internationalwaterweek.com/*
- 9-11 Nov, Manchester UK, 20th European **Biosolids & Organic Resources** Conference *www.european-biosolids.com*
- 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/Session14624.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/event-summary-4eb969f0be224a25821b4372c54c34a5.aspx*
- 25-26 Nov., Berlin, Germany, Global BioEconomy Summit 2015 *http://gbs2015.com*
- 2-4 Dec 2015, Ghent, Belgium, **ManuResource II** (manure valorisation) *http://www.manuresource2015.org/*
- 14-18 December, San Francisco, AGU (Am. Geophysical Union) Conference, Workshop '**Human alteration of the P cycle**' *https://agu.confex.com/agu/fm15/preliminaryview.cgi/Session8517*
- 10 Feb2016, Leeuwarden Netherlands, **EIP Water Conference** *www.eip-water.eu*
- 13-15 March 2016, Paris, Phosphates 2016 (the phosphate industry conference) *http://www.crugroup.com/events/phosphates/*
- 12-16 Sept 2016 Rostock, Germany, **8th International Phosphorus Workshop (IPW8),** Phosphorus 2020 – Challenge for synthesis agriculture & ecosystems *http://www.wissenschaftscampus-rostock.de/*
- 7-10 Mar. 2016, Berlin, **European Workshop on Phosphorus Chemistry** and 2nd **International Conference on Sustainable Phosphorus Chemistry** (**SUSPHOS**) *www.susphos.eu*