

Public polilcy

EU policy document Phosphorus and the Circular Economy

The EU Commission "Circular Economy Package" addresses phosphorus losses, waste and recycling.

Ryerson Canada

Phosphorus recovery and reuse workshop

Ontario P-recycling workshop shows actions underway in Canada and enthusiasm for moving P sustainability forwards.

Switzerland

Consultation on P-recycling obligation

Swiss consultation on obligatory recycling for sewage and animal bone meal phosphorus open to 30/11/2014

Technology assessments

P-recovery routes

Database of technology reports

WETSUS Netherlands has compiled for ESPP an inventory of reports assessing phosphorus recycling technologies and routes

Critical review

Nutrient recovery technologies

Review of nutrient recovery routes and technologies, considering the phases of accumulation, release and extraction by biological, chemical and physical/thermal processes.

Comparative assessment

P-recycling technologies from wastewater

Technical, environmental and economic assessment of 18 P-recycling technologies from wastewater, sludge or sludge incineration ash.

Phosphorus recycling technologies

Zero-valent iron

P-recovery via iron adsorption

Nanoscale zero-valent iron (NZVI) shows high potential for P-recovery in a plant available form

Electrochemical P-recovery

Recycling P, S and Fe from ferric phosphate

Experimental recovery of iron, sulfide and phosphate from iron-dosed sewage sludges.

Meat and bone meal ash FLUID-PHOS recovered P fertiliser

SARIA producing a recycled calcium phosphate fertiliser by high temperature treatment of animal by-products.

New calls for projects

Agenda

New European Sustainable Phosphorus Platform member:



Highlands and Islands Enterprise Iomairt na Gàidhealtachd 's nan Eilean

The partners of the European Sustainable Phosphorus Platform



European Sustainable Phosphorus Platform SCOPE Newsletter newsletter @phosphorusplatform.org | www.phosphorusplatform.eu @phosphorusfacts c/o European Partners for the Environment, av. Tervuren 216, B-1150 Brussels, Belgium

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EU policy document Phosphorus and the Circular Economy

The European Commission's "**Communication Towards a Circular Economy: a zero waste programme for Europe**", COM(2014)398, 2nd July 2014, part of the EU "Circular Economy Package" aims to implement resource productivity and circular economy systems, as part of the EU's resource efficiency agenda (Europe 2020 strategy).

Phosphorus is one of five materials and wastes specifically targeted for action, with construction/demolition waste, food waste (which also contains phosphorus), plastic waste and plastic bags, and alongside four more general categories: marine litter, hazardous wastes, illegal waste shipments and EU listed critical raw materials (which includes phosphate rock).

Policies proposed to develop the circular economy include:

- enabling policy framework (including simplification and implementation of waste legislation)
- design and innovation
- investment strategies and public procurement
- business chains with companies and consumers
- defining waste and recycling targets
- resource efficiency targets (including land, water and raw materials consumption).



Phosphorus recycling

On phosphorus, the EU Commission Communication states:

"Recycling of phosphorus: Phosphorus is a vital resource for food production, but it has significant security-of-supply risks and its current use involves waste and losses at every stage of its lifecycle. Following the Consultative Communication on the sustainable use of phosphorus, the Commission is developing a framework for further action ...

The Commission is considering developing a policy framework on phosphorus to enhance its recycling, foster innovation, improve market conditions and mainstream its sustainable use in EU legislation on fertilisers, food, water and waste."

Phosphorus will also be addressed through the Commission's proposal

"that Member States develop **national food-waste prevention strategies** and endeavour to ensure that food waste in the manufacturing, retail/distribution, food service/hospitality sectors

and households is reduced by at least 30 % by 2025".

See SCOPE Newsletter for estimates of phosphorus lost in food waste.

Phosphate rock was designated as one of the EU's 20 Critical Raw Materials in May 2014 (see SCOPE Newsletter n°104) so phosphorus will also be directly addressed as such:

"Recycling of critical raw materials: While all raw materials are important, critical raw materials deserve particular attention as their production worldwide is concentrated in few countries, while many of them have low substitutability and low recycling rates. The Commission promotes efficient use and recycling of critical raw materials in the framework of the Raw Materials Initiative and the European Innovation Partnership on Raw Materials. ...

Member States shall include measures regarding collection and recycling of waste containing significant amounts of critical raw materials in their national waste management plans".



Implementing policies for phosphorus

Phosphorus will also be impacted by the European Commission's "Legislative proposal to review recycling and other waste related targets in the EU" through the proposed objective to ban by 2015 landfilling of recyclable wastes, given that phosphorus rich wastes such as sewage sludge incineration ash or meat and bone ash are "recyclable" (the phosphorus content can be recovered and recycled).

The Circular Economy Package opens the following policy options for phosphorus sustainability:

- **Phosphorus "policy framework"** covering recycling and sustainable use
- **Integration of P into legislation**, in particular as regards on fertilisers, food, water and waste
- Take P into account in upgrading of EU waste legislation
- P-recovery or reuse in food waste valorisation
- Actions on P in the EU Raw Materials Initiative and Innovation Partnership on Raw Materials, in particular innovation, investment, public procurement
- Collection and recycling of wastes containing significant amounts of P (critical raw material)
- Include P in indicators and targets for resource efficiency and raw material consumption

Green Week

"Closing the Phosphorus Cycle in the circular economy" was also the theme of a session of the EU Commission Brussels Green Week 2014:



Chris Thornton, European Sustainable Phosphorus Platform, indicated that phosphorus sustainability is a challenge which is here to stay. Phosphate rock is now on the EU Critical Raw Materials list, and is essential both for food production (global food security) and for a variety of strategic industries (fire safety, electric vehicle batteries, electronics ...).



He estimated that **without consumption of rock phosphate resources we could probably only feed around ¹/4 of the world population** (derived from Dawson et al. SCOPE Newsletter n°80), and reminded of Greenpeace's estimate that for livestock production to be environmentally sustainable meat consumption would have to be cut to around 250g meat / person / week (see SCOPE Newsletter n°96). He underlined the opportunities for local job creation and new business models in phosphorus management, reuse and recycling in a circular economy.

Sofie Bouteligier, OVAM (Flanders Public Waste Agency) presented the experience of Flanders in recycling phosphorus into quality products and making waste into a resource. Closing the phosphorus cycle can create non-delocalisable jobs in Europe (see *"Potential economic and employment benefits of phosphorus stewardship"* on ESPP website, under NEWS *http://www.phosphorusplatform.org/images/ESPP_jobs_and_empl oyment_outline_29-5-13.pdf*) as well as improving agricultural practices and resource efficiency.



She particularly emphasised that recycling and the circular economy enable the development of new smart specialisation and innovative skills, technologies, contributing to improving overall economic performance, improving skills and competence and so enabling export of technology and know-how.

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Ruben Sakrabani, Cranfield University UK, explained how **phosphorus resource efficiency can be improved by reuse of organic wastes in agriculture**.



He started by outlining the **importance of soil organic** matter (SOM) in nutrient retention to meet crop demand. Livestock manures not only provide organic matter, but also nutrients, worth in the UK an estimated UK£ 200 million fertiliser value. Sewage sludges also provide valuable organic matter and nutrients, but are often inefficiently used. This can be improved by processing to produce products which can conform to crop needs and are compatible with farmer's spreading equipment (see End-o-Sludg project, SCOPE Newsletter n° 100). He presented field test results showing that such organo-mineral fertilisers achieve crop performance comparable to inorganic fertilisers, but result in higher residual nutrients retained in soil after the harvest and higher soil organic matter.

European Commission "Communication Towards a Circular Economy: a zero waste programme for Europe", COM(2014)398, 2nd July 2014 http://ec.europa.eu/environment/circulareconomy/pdf/circular-economy-communication.pdf

European Commission "Circular Economy Package" http://ec.europa.eu/environment/circular-economy/

EU press release IP/14/763, 3nd July 2014 "Environment: Higher recycling targets to drive transition to a Circular Economy with new jobs and sustainable growth" http://europa.eu/rapid/press-release_IP-14-763_en.htm

EU press release IP/14/765 "Employment: Commission outlines measures to maximise job opportunities in the green economy" http://europa.eu/rapid/press-release_IP-14-765_en.htm

EU Green Week 2014 "Circular economy – closing phosphorus cycle" – see the three presentations online http://webcast.ec.europa.eu/eutv/portal/env/_v_fl_300_en/player/in dex_player.html?id=22901&pId=22880

Ryerson Canada

Phosphorus recovery and reuse workshop

The phosphorus recovery and reuse workshop at Ryerson University, Toronto, Ontario, brought together nearly 100 participants from Ontario and North America, in cooperation with The Netherlands Consulate. Speakers and participants both onsite and worldwide by Webex identified a number of success stories of P-recycling in action, discussed drivers which mean that sustainable phosphorus management will continue to develop over coming years, and confirmed the interest of a strong Canada participation in a North America Nutrient Partnership to foster collaboration and move things forward.

The workshop was opened by: Imogen Coe, Dean of the Faculty of Science at Ryerson University, Anne Van Leeuwen, Consul General of the Kingdom of the Netherlands, Jim Richardson, Director of Environmental Management at the Ontario Ministry of Agriculture Food and Rural Affairs, Ellen Schwartzel, Deputy Commissioner at the Ontario Environmental Commissioner Office and Tom Kaszas, Director of Innovations at the Ontario Ministry of the Environment. These speakers each underlined the importance of phosphorus sustainability to Ontario.



Don Mavinic, University of British Columbia, underlined that phosphorus is a non-renewable resource, with resources which are limited worldwide and concentrated in a small number of countries. Pressure on supply is increasing considerably with increasing population and changing diet, for example in China and India. He indicated that over 3 decades, the average phosphorus content of traded phosphorus rock has decreased by nearly one third (33% to 23% P_2O_5 from 1980 - 2014), implying progressively increasing costs and contaminant issues for fertiliser production.

P-recovery success stories in Europe

Willem Schipper, WS Consulting and Global Phosphate Forum, emphasised that there is considerable potential for recovering and recycling phosphorus from sewage, slaughter waste and manures, wherever these cannot be used locally because of geographical concentration of populations and livestock production. He underlined that the economic benefit will not be principally in the price of the recovered phosphorus, but rather through synergy with wastewater treatment processes or waste disposal cost reduction. P-reuse and recycling solutions are very variable, from agricultural reuse of processed sewage sludge to recovery of technical fertiliser products, and because waste streams, and pointed to already a number of success stories in phosphorus recycling in Europe.

He underlined the need to develop appropriate and accessible technologies, to develop products adapted to farmers' needs, but to **avoid reinventing the wheel** by continuing research but rather to move to implementation and testing. Areas with a remaining significant potential for pure research today appear as P-recovery from manures, recovery of P from diffuse runoff (e.g. from agricultural drains, ditches) and recovery from certain specific industrial waste streams.

Mr Schipper emphasised the value of nutrient platforms to improve visibility of the phosphorus issue, **develop networking to exchange information and mutual trust**, and to find and promote common positions on regulations and other areas necessary to enable the implementation of phosphorus recycling.

Bert Smit, Wageningen University, reminded that mankind currently puts some 15-20 MtP (million tonnes of phosphorus) into the ecosphere in fertilisers, for only around 3.5 MtP finally in food products. This seems at first sight very inefficient, with **important losses to surface waters, caused by erosion, leaching and runoff and accumulation in soil**. Accumulation of P in soil usually occurs in regions where livestock is concentrated but can also sometimes be for valid reasons, e.g. improving the soil fertility

Mr Smit presented **phosphorus flow analysis for the Netherlands**, showing an annual surplus of 42 MkgP/year in 2011, already significantly decreased from 60 MkgP in previous years. This has been achieved by a nearly 50% reduction in fertiliser use, and a significant increase in manure export. The



Netherlands phosphorus export is principally a result of geographically concentrating livestock production, but this same ecological mistake of livestock concentration is increasingly being made in North America or China.

He also underlined success stories, **SNB/HVC** recovering phosphorus from incineration ashes, **Ecoson** are recovering energy from manures, and a number of operators recovering struvite from wastewaters.

Sustainable phosphorus fertiliser use

Tom Bruulsema, International Plant Nutrition Institute, presented the 4R Nutrient Stewardship: applying nutrients using the right source, at the right rate, the right time and in the right place. He emphasised that fertiliser use is linked to increases in food production, which has helped increase world food security, reducing the proportion of the world's population which is undernourished from 18% to 12% over the past two decades. In eastern Canada, recent high crop prices have led to fertiliser use increases since 2009, despite the presence of accumulated phosphorus in a considerable proportion of the soils. In North America, P in sewage biosolids are estimated to be around 8% of P currently removed in crops, compared to a much larger amount in manures. Manure use recycles phosphorus, but inefficiently when manure application rates are defined to optimise nitrogen supply, which results in overdosing of phosphorus. Recovery of phosphorus as struvite poses the question of how to recover the ammonia nitrogen.

In discussion, **the potential interest of phosphorus recovery in bio-energy production was underlined**, for example the opportunity to process digestates from anaerobic digestion installations to recycle nutrients.

Carrie Vollmer-Sanders, Western Lake Erie Basin Agriculture and Water Quality Project, The Nature Conservancy, presented the Nutrient Service Provider and Nutrient Stewardship Council's voluntary 4R Nutrient Stewardship Certification Program for Lake Erie put in place in cooperation between fertiliser suppliers, farmers, researchers, government agencies and stakeholders. The objective is to ensure via a private third-party audit that quality professional advice is given to farmers and there is appropriate application of fertiliser for farmers to reduce nutrient losses to Lake Erie, which can also result in significant savings in fertiliser purchase for farmer, or improve

productivity by improving nutrient supply to correspond to crop needs. We all need to work together to grow more food and less algae

Nutrients in sewage biosolids, manures and other organic residuals

Michael Payne, Black Lake Environmental, estimates that Canada produces some 660 000 tonnes of biosolids per year (dry weight). He noted the value of the organics and nutrients present in these biosolids, but also the questions concerning contaminants and opposition from populations concerned about odour problems. He underlined that a scientific approach is needed to ensure safety of ongoing biosolids reuse in agriculture.

Mike Kopansky, Miller Waste Systems, presented development of green-bin Source Separated Organics (SSO) food waste collection in Ontario. Strong political drive, population education and close collaboration between contractors and municipalities have enabled considerable development of green bin schemes in Ontario, without regulatory obligation and despite significant additional costs for diversion, collection and treatment. Phosphorus recovery is not yet integrated into these systems, but could provide a positive benefit if high quality end-products can be developed.

Christine Brown, Ontario Ministry of Agriculture and Food, emphasised the advantages of manure recycling, through organic input to soils, which improves soil resiliency, microbial diversity and nutrient cycling (including phosphorus), nutrient and water retention, infiltration and weed and pest control. She emphasised that many Ontario soils continue to need phosphorus input to maintain crop productivity. Green bin organics recycling to agriculture through composting, as well as avoiding landfill, enabled fertilisation of 28 000 acres of cropland (maize), providing 55 000 tonnes of organic matter (dry weight) and economising Ca\$ 5.25 million dollars in fertilisers.

She underlined that **transport costs are a key issue in reusing organic amendments**, as well as application costs and agronomic value. Different organic amendments require different management strategies (for example composts vs digestate). These costs can be reduced by better organisation of storage, transport and application equipment sharing and by combining organic amendments for value added and targeted enduse.

Opportunities for recycling

In round-table discussions, participants identified challenges for phosphorus recycling:

- Opportunity offered by the **need to alleviate phosphorus input to surface waters**, deteriorating water quality
- Misbalance of N and P in manure, leading to a lead to extract and recover nitrogen
- Need to **adapt the regulatory framework**, to involve government, and to build trust between the different stakeholders and companies involved in the recycling chain
- Challenge of **distances between regions** with phosphorus surpluses and regions needing phosphorus input to crops, giving value to concentrated recovered nutrient products
- Given that there is **no urgent risk on phosphorus resource supply**, other drivers for phosphorus recycling need to be identified

Melodie Naja, Everglades Foundation, explained that the State of Florida currently faces a 10 - 15 billion US\$ cost for restoring Lake Okeechobee.

US\$ 11 million prize

The Everglades Foundation is working on developing a US\$ 11 million prize (to be launched in February 2015) for a breakthrough **technology to remove phosphorus from eutrophic surface water**. As this is a worldwide problem, The Everglades Foundation is currently looking for serious international partners and collaborations for launching the prize.

Technology implementation successes

Ahren Britton, Ostara, presented the phosphorus recovery process operated by the company for wastewater streams, producing struvite (magnesium ammonium phosphate), which the company markets as fertiliser Crystal Green® fertiliser. Ostara is operating full scale plants in municipal wastewater treatment plant sludge treatment streams, and is also developing application in manure treatment, phosphate industry, biofuels production. He underlined the importance of Ostara's university roots (University of British Columbia), giving innovation and credibility, of financial support from Canada which has been key in getting the company off the ground and still in



developing in other regions of the world, of good financial engineering through venture capital, and finally of producing a quality product adapted to enduser fertiliser requirements. Ostara currently has seven plants in operation worldwide, and expects that number to double in the coming 24 months, leading to a total struvite production capacity of over 10,000 tonnes Crystal Green/year.

Victor Lo, University of British Columbia, presented a process under development **using microwaves and hydrogen hydroxide to make nutrients available** (release 60 – 80% as soluble) in organic wastes (sewage sludge, manures). The process also breaks long organic molecules down to short-chain fatty acids, which can improve anaerobic digester methane production (bypass the acid phase, reducing digester residence times radically) or feed biological phosphorus removal processes. The process can significantly reduce sewage works sludge production, which is important as sludge disposal costs are often >50% of works operating cost. The solubilised nutrients can be recovered, e.g. as struvite. The objective is to move towards 'zero sludge'.

John van Pol, Incas³ Solutions, explained that fertiliser contains low levels of radioactivity. The company has developed the **NaramaiTM detector** capable of detecting such low levels of natural radiation. Because of the direct correlation between the amount of phosphorus and the amount of natural radioactive elements in a specific fertilizer, measuring radiation is indicative of the amount of remaining phosphorus from past fertilizer application to land, thus allowing to identify where new phosphorus application is needed. This can be done continuously in the field, so enabling accurate targeting of fertilizer application.

Brad Bass, Great Lakes Issues & Management **Reporting Section of Environment Canada.** presented a project developed by Robert Cameron at Penn State University. It integrates a biofilter with plants growing on green walls to treat domestic wastewater using the principles of the trickling filter and the nutrient film technique. Tests showed that at high input levels, phosphorus removal was higher than 60%. The system was also effective at removing other pollutants and microbes. These systems are inexpensive, compact, easily transferrable and adaptable, low-energy, easily built, produce food vegetables, and are resilient in areas susceptible to risks. Obstacles include additional construction to



route waste water to the biofilter and building regulations which do not consider such systems.

Leon Korving, Wetsus presented innovation success stories in P-recycling in the Netherlands. Within the Waterschoon project, running since 2007, currently 60 houses in Sneek are equipped with vacuum lavatories, enabling concentrated collection of urine and feees, thus enabling biogas production and struvite production. The Saniphos development, since 2010, can treat up to 5000 m³ from separative toilets and from pregnant women (the urine is used for hormone extraction for medical purposes), with P recovery as struvite. The **Rijnstaat building project** underway will recover phosphorus (as struvite) and nitrogen (ammonia by electrodialysis) from 4000 users. Struvite precipitation installations are operating at 4 sewage works, with a 5th currently being built (using Anphos, Airprex and Ostara technologies, at Amersfoot, Amsterdam, Echten, Land van Cuijk, Oldburgen). Further there are good perspectives for recovery of phosphate from sewage sludge ash in The Netherlands, considering the fact that 50% of all sewage sludge is incinerated in two dedicated sludge incinerators. In all cases, the driver is not the price of the recovered phosphorus, but other values such as reuse of water, savings on sewage discharge fees.

Concluding remarks

In breakout sessions, participants identified areas where further research and data are needed

- Mapping phosphorus sources and flows, to identify possible P-recovery sources, and to better understand phosphorus discharges at the watershed level
- Understanding of policy needs and obstacles
- Agronomic nutrient availability and other benefits of recovered nutrient products
- **Possibility to harvest algae from eutrophied waterbodies** to remove and recover carbon and nutrients

Don Mavinic, University of British Columbia, underlined that struvite recovery is adapted not only to biological nutrient removal wastewater plants, but to any system with "sludge busting", that is sludge reduction. A struvite recovery installation is currently being built at ????? in a full-scale sewage sludge treatment installation by thermophilic sludge reduction (pasteurisation, recovery of volatile fatty acids, release of nutrients to soluble form).

Chris Thornton, European Sustainable Phosphorus Platform, summarised objectives of the Platform, addressing the phosphorus challenge which is a long-term trend and is not going to go away, because of the range of drives for improved phosphorus management. He emphasised that the price of phosphorus is not the key driver for phosphorus recycling, but that the range of other drivers offer business opportunities and will continue to develop.

David Vaccari, Stevens Institute of Technology, presented the project for a "**North America Nutrient Partnership**" (**NAPP**), under gestation with the objective of finding solutions for phosphorus management, moving R&D into implementation, working with stakeholders. Possible actions for the Partnership include developing business models, evaluating technologies, fostering implementation, facilitating the regulatory context and directing funding proposals towards these goals.

Several key areas for action were proposed by participants in round-tables:

- **Manures**, which offer the biggest quantities of phosphorus, and where recovery and recycling of nutrients, energy and water are expected to develop considerably
- The need to move ripe technologies to implementation and demonstration
- Treating wastewaters and manure as a **resource not as a waste**
- Importance of **outreach** to politicians and regulators to bring phosphorus into regional planning
- How to fund manure treatment costs for farmers and how to fund costs of eutrophication prevention actions by farmers, such as production loss by land use for buffer strips ?
- Addressing phosphorus loadings in **urban runoff** and storm waters
- Ensuring the **dialogue and partnership** necessary to ensure that phosphorus recycling processes produce products adapted to farmers needs and equipment



Final discussion emphasised the **important role of soil** health, including fostering soil organic content and limiting soil erosion which can contribute to phosphorus runoff. The geographical concentration of populations and livestock production and distances between phosphorus surpluses and regions of crop production means challenges, and business opportunities, for both biosolids organics and nutrient processing to enable transport.

In closing comments, **Tom Bruulsema** paraphrased a quote from a recent message from Andrew Sharpley: *let's take the 4 R's to the phosphorus challenge: refresh, rejuvenate, rejoice, reality!*



Phosphorus recovery and reuse workshop: Sustainable Solutions for Infrastructure, Food Security and the Environment, Ryerson University, Toronto, Ontario, Canada, 19th June 2014. Organised by Ryerson University, Ryerson Urban Water and the Consulate General of the Kingdom of the Netherlands in Toronto with the support of the Ontario Ministry of Agriculture and Food and the Ministry of Rural Affairs and Environment Canada are

Workshop slides and presentations contact: **Barbara.Anderson@ontario.ca**



Switzerland Consultation on P-recycling obligation

Switzerland has published a public consultation to overhaul the national Waste Treatment Ordinance, open **until 30/11/2014**. Proposals include obligatory phosphorus recovery from all municipal sewage and animal bone meal.



Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra

Principales nouveautés dans l'ordonnance sur le traitement des déchets

L'ordonnance sur le traitement des déchets (OTD) est soumise à une révision totale. Voici en résumé les principales modifications :

- Des exigences sont formulées pour la valorisation de certains déchets, laquelle n'était pas encore réglementée dans le droit fédéral. Il s'agit notamment des biodéchets (y compris règlementation relative aux possibles installations de traitement) et des déchets riches en phosphore.
- Un plan d'élimination des déchets est exigé pour tout projet de construction. Le maître d'ouvrage est tenu de déterminer les déchets dangereux pour la santé et pour l'anvirgnement des prises déchets de chartier contracture principal.

Art. 15 of the proposed Ordinance text specifies that phosphorus in municipal wastewater and in animal flours and bone meal must be recovered and recycled as follows:

Art; 15: wastes rich in phosphorus

1 – phosphorus contained in municipal waste waters, sewage sludge from central treatment plants or ashes resulting from thermal treatment of such sludges, must be recovered according to state of the art technology and be valorised

2 - The phosphorus contained in animal flours andbone meal must be valorised according to state ofthe art technology

3 – If the residues containing phosphorus are intended for use as fertilisers, the pollutants therein must be eliminated in the P-recovery process in order to satisfy the requirements of Annex 2.6 ch. 2.2 of the Ordinance of 18/5/2006 concerning chemical products.



In the accompanying report it is indicated that these dispositions will reduce dependency on imported phosphorus resources and save precious landfill capacity, stating:

After numerous discussions, the principle of phosphorus recovery is uncontested by concerned stakeholders. It will be necessary to define details, such as the efficiency of P-recovery processes, plant availability, agreements between the cantons and the concerned industry sectors.

In the next update of the 10/1/2001 Ordinance on Fertilisers (RS 916.171) will be examined the possibility to introduce a new category of recycled mineral fertilisers. This should take into consideration levels of pollutants such as uranium, cadmium, zinc and copper, as well as the fertiliser value of the product.

The suggested phosphorus recycling obligations are proposed to enter into force five years after implementation of the Waste Treatment Ordinance.

This article concerning phosphorus is a part of a complete proposed overhaul and modernisation of the Swiss waste treatment legislation (Ordinance) aiming to make material use more sustainable, reduce pollution and eliminate waste with reduced environmental emissions, reduce consumption of raw materials, improve life cycles and remove pollutants, ensure safety.

The proposal **effectively bans landfilling** for most wastes by stating the municipal solid wastes and similar, sewage sludges and all combustible wastes must be treated thermally if they are not recycled as materials. Biowastes must be recycled as fertilisers if possible (nutrient value, pollutant content) or if not then used as an energy source. The Ordinance also defines conditions for recycling of demolition wastes and updates conditions for use of wastes in cement factories and operating conditions for waste disposal and treatment sites, including **composting and methanisation** installations.

Implementation of the Ordinance is the responsibility of the Swiss cantons.

Swiss Confederation 10th July 2014: Draft ordinance available in French and German (Ordonnance sur le traitement des déchets (OTD) 814.600) https://www.news.admin.ch/message/index.html?lang=fr&msgid=53741

Technology assessments

P-recovery routes Database of technology reports

WETSUS Netherlands, with input from ESPP and for the SCOPE Newsletter, has compiled a **database of recent studies and reports assessing different phosphorus recovery and recycling technologies and routes**.

33 studies are identified to date, and categorised according to the level and type of assessment they provide, and a short one-paragraph summaries of their content relevant to P-recovery technology assessment is provided.

The 33 studies listed are recent (2010 or later) technology or feasibility assessments covering phosphorus recovery processes, in some cases 2-3 comparable processes, in other cases a wider range of different routes and technology options.

The database classifies the studies into five categories:

- R-Pol = Overview assessment of P-recovery options for policy / business decision makers
- R-Sci = Scientific analysis of several different P-recovery routes or technologies
- T-Sci = Scientific analysis of one P-recovery route or technology
- LCA = Quantitative comparison between different technologies, using LCA or similar assessment

Inventory of inventories discussing P-recycling strategies

• Other = websites, regulatory information, other sources of relevant information

This identifies **11 recent, overall review of phosphorus recovery options and technologies,** adapted for either decision makers or more technical use, suggesting that R&D projects or industrial projects need not re-do such reviews or literature searches, but should start by accessing and referring to the information already available and collated.

The database, available also specifies the **types of P-recovery technology** covered in each study and indicates the source (author, publication, references, link), date, price or access conditions.

The objective is to extend and update this database, to provide a permanent, up-to-date list of P-recovery technology assessments, as a **tool for decision makers and researchers**, and to avoid future duplication of existing work.

Send us other information!

If you are aware of existing P-recovery technology reviews which are not included in this database, please communicate these to *info@phosphorusplatform.eu* so that they can be added into the data set.

"Inventory of inventories discussing P-recycling strategies", June 2014, PDF/Excel, 8 pages, compiled by WETSUS (Centre of Excellence for Water Technology, the Netherlands) for the European Sustainable Phosphorus Platform (ESPP). On the ESPP website www.phosphorusplatform.org under "Downloads" or http://www.phosphorusplatform.org/images/download/WETSUS% 20P-recovery%20inventories%202014-06-25.pdf

Compiled by Wetus, centre of excellence for water technology and the European Sustainable Phosphorus Platform (ESPP) Focus on studies inventories since 2010. Important studies before 2010 may also be included. Version: 25 June 2014								Categories R-Sci T-Sci LCA Other	R-hol Review of P-recovery strategies oriented at policy and business level decision makers. Review published in a scientific journal giving a critical review of different recovery strategies Review published in a scientific journal with review locasition one technology or strategy Review giving a quantitative comparison between different technologies, preferably on a LCA-basis websites, regularizy information, orkers sources of releant information		
title	authors	journal, publisher	Year	# pages	Type	web link / public access? / price(€)	types of technology covered	Streams treated	P-recycling only?	Abstract	Category
Production of slow release crystal fertilizer from wastewaters through struvite crystallization – A review	Md. Mukhlesur Rahman, Mohamad Amran Mohd. Salleh, Umer Rashid, Amimul Ahsan, Mohammad Mujaffar Hossain, Chang Six Ra	Arabian Journal of Chemistry (2014) 7, 139–155	2014	17	Peer reviewed article	Open access	Struvite crystallization technologies and use of struvite in agriculture	Sewage water, manure waste water and other nutrient rich waste waters		The article reviews available literature on struvite crystallization technologies for recovery of nitrogen and phosphate from waste water. A first section focusses on the physical and chemical nature of different types of struvites. A second section discusses the influences that have been reported on struvite nucleation as wells as the different conditions that have been used in various literature sources for struvite precipitation (like molar MgP raits, pH, aeration rate). The article concludes with an overview of literature describing the agrinomic benefits of struvite use a a fertilizer.	T-Sci
Technologies to Recover Nutrients from Waats Streams: A Critical Review	C.M. Mehtaa, W.O. Khunjarb, V. Nguyenb, S. Taita & D.J. Batstonea	Critical Reviews in Environmental Science and Technology	2014	42	Peer reviewed article	34€	plant and micro-organism processes, digesion and bioleaching, membranes, precipitation, sorption, magnetic binding, liquid/gas stripping, electodialysis and thermal treatment.	Wastewater, sludge, biomass	No, also focus on N and K	The full range of nutrient recovery routes are reviewed, on a multi-criteria basis, considering recovery as a three phase process: nutrient accumulation (or concentration), nutrient release and nutrient extraction to a final nutrient product. The paper categorizes all technologies using operating parameters and technology is analyzed according to implementation and uptake criteria. Most work on nutrient accumulation has addressed application in municipal waste water treatment. For nutrient extraction, struvite recovery is recognised as readily adoptate and already applied full scale. Electrolalitysia and grabably essential in the future for Nan K recovery. The authors recommend both to harness the value of biolistic products (or value but low production cost) and fertilises). The appropriate and economically isolably lesabible technology will depend on context. <i>Recess requiring future</i> READ are identified.	R-Sci
Phosphorus recovery from municipal	Kalmykova, Y. and	Waste	2013	8	Peer reviewed	Open	- Acid dissolution–alkali precipitation	Municipal solid	No, but it is intended to recover	The scientific article describes the potential to recover phosphate from municipal waste ash. The authors test two potential methods for recovery (already applied to other solid waste). Due to high calcium (Ca) content only acid dissolution-akili precipitation recovered P successfully (70 %). The recovered product (contains 3 wt. % phosphorus) is high in trace metals, limiting	T-Sci

European Sustainable Phosphorus Platform SCOPE Newsletter newsletter @phosphorusplatform.org | www.phosphorusplatform.eu @phosphorusfacts c/o European Partners for the Environment, av. Tervuren 216, B-1150 Brussels, Belgium

Critical review Nutrient recovery technologies

The full range of nutrient recovery routes are reviewed, on a multi-criteria basis, considering recovery as a three phase process: nutrient accumulation (or concentration), nutrient release and finally nutrient extraction to a final nutrient product.

Technologies assessed for different phases include:

- plant and micro-organism processes,
- digestion and bioleaching,
- membranes, precipitation,
- sorption,
- magnetic binding,
- liquid/gas stripping,
- electrodialysis
- and thermal treatment.

The authors consider that **nutrient recovery technologies will continue to develop** because of increasing agricultural demand, driven by population increases, will lead to fertiliser nutrient price increases and because recycling is necessary to reduce the environmental impact of nutrients in municipal wastewater, agricultural manures and industrial waste streams: eutrophication, methane and nitrous oxide greenhouse impact.

Framework for nutrient recovery

Because nutrients occur in waste streams at relatively low concentrations (1 - 200 mg/l), compared to concentrations in synthetic fertilisers, recovery generally requires **three phases**:

- nutrient accumulation,
- nutrient release,
- and **nutrient extraction** (to produce a relatively concentrated nutrient product).
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Assessment of nutrient recovery technologies using this three-step framework enables multi-criteria analysis to be independent of application, and independent optimisation of each phase. The different processes below are detailed and assessed in the published paper.



Nutrient accumulation technologies

These aim to concentrate nutrients from waste streams with low nutrient concentrations (e.g. 2 - 20 mg/l) and also to achieve effluent discharge consents of e.g. 0.1 - 3 mg/l. Biological, physical and chemical processes can be applied including:

• **Prokaryotic nutrient accumulation**. Polyphosphate accumulating organisms (PAO) are widely used for phosphorus removal in municipal sewage works and other waste waters (EBPR = enhanced biological phosphorus removal). An important constraint is the need to supply readily

available carbon, such as volatile fatty acids (VFAs). Also, purple non-sulphur bacteria and cyanobacteria can accumulate polyphosphates and be used in such systems.

- Algal nutrient accumulation: algae can be grown • either suspended in the waste liquor or immobilised on a substrate, which can also in some cases accumulate nutrients (e.g. resins). Algal farming in wastewaters is developing as a nutrient removal/accumulation process. In coastal regions, the salinity difference between seawater and wastewater can drive osmosis, and so facilitate nutrient accumulation. Challenges include improving nutrient uptake efficiency to reduce residence time and space required (footprint), and harvesting the algae (because of their small size). Once harvested, the algae can be processed for nutrient release by e.g. anaerobic digestion or thermo-chemical technologies (see below), or can be used directly as a fertiliser or animal feed.
- Plant nutrient accumulation, in wetlands or using free floating plants (e.g. water hyacinth Eichhornia crassipes or duckweeds Lemna minor, Landoltia punctate, Spirodela polyrrhiza). As for algae, above, harvesting and processing or direct use on land are necessary, and a challenge is reducing footprint.
- Chemical accumulation by precipitation. Aluminium and iron salts are widely used for phosphorus removal from wastewaters. They are extremely efficient, but the phosphate sludge produced is agronomically less useful due to low phosphorus bioavailability, so that a subsequent release step is essential. Metal ions can also be delivered by sacrificial anode electrolysis (electrocoagulation). Other nutrient precipitating coagulants potentially include calcium, natural and synthetic polymers.

- Adsorption / ion-exchange. Different substrates can accumulate P, N or K, more or less selectively. These processes tend to work better in wastewaters with low solids concentrations. The nutrients can then be released for recovery by substrate regeneration, or the nutrient-enriched substrate can be used directly as a fertiliser/soil amendment (see e.g. SCOPE Newsletters ??? where snail or shellfish shells are used as phosphorusaccumulating substrate)
- Liquid-liquid extraction, using an organic phase (solvent, possibly with nutrient extractant) which is recycled in the process (see schema in published paper). The process will offer better economics in wastewaters with high nutrient and low solids contents. The recovered nutrient stream can in some cases be used directly as a fertiliser.
- Membrane filtration, including microfiltration, ultrafiltration, nanofiltration and reverse osmosis. These allow concentration of nutrients by 4-6x, giving a stream which can be used for nutrient recovery or directly as a fertiliser, depending on contaminant concentration. Disadvantages are cost, energy consumption and pre-treatment necessary for wastewaters to prevent membrane fouling.
- Magnetic separation. Nutrients are adsorbed to a magnetic carrier material (e.g. magnetite, zirconium ferrate, carbonyl iron, iron oxide), this is then separated using HGMS (High Gradient Magnetic Separation), and finally the nutrients are released by regeneration of the carrier material. The authors consider that further R&D is needed in this area.

Nutrient release technologies

Once accumulated, nutrients must be released or directly extracted into a recovered product (unless the nutrients are accumulated into a substrate which can be directly used as a fertiliser or animal feed, such as algal or plant biomass). This can be achieved, depending on the form in which the nutrients have been accumulated by:

- **Biological processes** such as anaerobic digestion
- **Thermo-chemical processes**: thermal hydrolysis, wet oxidation, incineration, gasification, pyrolysis, chemical extraction (acid, alkali) and combinations of these.
- **Bioleaching**: directly by metabolism by leaching microorganisms, or indirectly by the products of



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Nutrient extraction and recovery technologies

- Chemical precipitation / crystallisation. Struvite precipitation has been widely studied and implemented full scale. Other precipitation products potentially include calcium phosphate, magnesium potassium phosphate (K-struvite) or iron phosphate.
- Gas permeable membrane and adsorption: for ammonia recovery from liquid waste streams. Challenges include low absorption rate per surface area and high capital and operating costs.
- Liquid-gas stripping: a range of different processes have been developed and tested, variously including temperature, pH increase, carbonate removal, vacuum. The stripped ammonia can be recovered by condensation, absorption or oxidation to produce fertiliser products such as ammonium sulphide, other ammonium salts or concentrated ammonium solution. Challenges include operating costs and the fate of the resulting reduced-ammonium waste stream.
- Electrodialysis, whereby anions and cations are separated across an ion exchange membrane driven by an electrical current. Challenges include energy consumption, membrane fouling and chemicals required for membrane regeneration. Research has also suggested that combination of a microbial fuel cell with electrodialysis could potentially harness energy resulting from bacterial degradation of organic matter in the wastes stream to reduce the electrodialysis energy requirement (see SCOPE Newsletters 89, 95)

Multi-criteria assessment

The paper includes a table specifying operating parameters and appropriate waste stream characteristics, and **identifying commercially available processes**, for each technology indicated above.

A second table shows the **extent of published literature for each technology**, as applied to different waste streams.

A further table analyses each technology according to implementation and uptake criteria:

- **Costs** (capital and operating)
- Feasibility, maturity, reliability
- Available information and data
- **Safety** profile
- Environmental impacts and benefits

Feasibility analysis

The authors note that most work on nutrient accumulation has to date addressed application in municipal waste water treatment. **They expect biological processes to** *"ultimately outcompete"* **chemical processes**, because of better costeffectiveness, bioavailability of recovered nutrients and side-impact advantages (e.g. COD and BOD removal).

For nutrient extraction, **struvite recovery** is recognised as readily adoptable and already applied full scale. **Electrodialysis** and **gas membrane ammonium recovery** are considered to be currently embryonic, but probably essential in the future for N and K recovery.

The authors recommend both continuing to harness the value of biosolids products (relatively low value but low production cost) and developing production of high-quality products targeting end-user requirements (e.g. comparable to mineral fertilisers).

For biosolids products, **reducing water content** is essential to reduce transport costs.

Digestates offer significant potential as good fertiliser products if processes to solid forms.

The technology and the processing pathways which are economically feasible and appropriate will vary depending on context: complex nutrient recovery technologies may be adopted by industrial waste producers or large localised municipal or agricultural sources, whereas simple, low-cost systems producing low-value products may remain adapted to rural areas.

Areas requiring further R&D are identified, in particular research into N and K recovery technologies, demonstration and testing of existing nutrient recovery processes and investigation of agricultural application methods for recovered nutrient products.



"Technologies to recover nutrients from waste streams: a critical review", Critical Reviews in Environmental Science and Technology, in print, 2014

http://www.tandfonline.com/doi/abs/10.1080/10643389.2013.866621

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Comparative assessment P-recycling technologies from wastewater

18 different technologies for P-recovery from sewage, sewage sludge and sewage sludge ash are compared. Material Flow Analysis (using STAN subSTance flow ANalysis) is used to estimate potential % recovery rate of sewage works inflow phosphorus and fate of contaminants. Environmental factors including greenhouse direct and indirect emissions are considered, as well as fertiliser quality of recovered materials and works implementation sewage constraints. Economics are evaluated, taking into account potential costs and savings both for the Precycling process and in the whole sewage works process.

The technologies evaluated are:

Recovery of phosphate from liquid streams (sewage sludge dewatering liquor, or sludge digestate):

- precipitation: Ostara®, DHV Crystalactor®, P-RoC, PRISA, AirPrex®
- ion-exchange from liquid streams: REM-NUT®

Treatment of sewage sludge:

AquaReci®, PHOXNAN; MEPHREC®, Seaborne®, Stuttgarter Verfahren

Treatment of sewage sludge incineration ash:

- *direct land application* (considered for comparison only)
- *wet-chemical leaching and extraction or thermo-chemical*: LEACHPHOS®, PASCH, SESAL-Phos, RecoPhos® (phosphoric acid process, not the thermal RecoPhos process presented in SCOPË Newsletter 104), Ash Dec® (now Outotec)
- *fertiliser factory process* (general case, not company specific)
- *thermal*: Thermphos®

A **theoretical reference sewage works** is considered (100 000 person equivalent = 65.7 tonnes P/year = 1.8gP/person/day). Facilities treating 30 000 tonnes/year of sewage sludge incineration ash are considered. The study only considers processes producing products similar to mineral fertilisers, and not nutrient recovery routes producing organic fertilisers (e.g. digestates), or nutrient-rich soil amendments (e.g. phosphorus adsorption onto materials such as shellfish or mollusc shells).

Phosphorus recovery rate

The authors note that precipitation and ion-exchange technologies operating in sewage sludge filtrate liquors can achieve high P-removal from these liquors (>90%) but this represents only a low proportion of the total phosphorus entering the sewage works (15 - 40%). Such processes are today implemented principally because of operating advantages they bring to the biological nutrient removal in sewage works operation: incrustation avoidance, improved biological phosphorus removal. They can produce high quality fertiliser products, with good phosphorus plant availability and handling characteristics. Heavy metal and organic pollutant contamination of such recovered fertiliser products are considered by the authors to be not significant. The authors note that these processes are today applicable mainly to sewage works operation biological nutrient removal (EBPR = enhanced biological phosphorus removal), which effectively excludes most sewage treatment in Austria where chemical P-removal is used.

P-recovery from sewage sludge requires more chemicals and is less economical, but can potentially achieve a higher P-recycling rate of up to 70% and P-recovery from sewage sludge incineration ash can potentially achieve up to 90% P-recycling, on condition that the sludge is incinerated separately (mono-incineration) and not with other lowphosphorus wastes (e.g. domestic refuse). With coincineration of other P-rich sources as meat and bone meal the ash can be "doped" to increase phosphorus content and simultaneously reduce heavy metal levels. Recovery from sewage sludge ash can be economical even though significant amounts of energy and chemicals are required.

For processes operating on either sewage sludge or sludge incineration ash, **higher levels of contaminant removal imply increased levels of chemical use and consequently higher costs**, although this may be less



the case where sewage sludge incineration ash is taken into an existing industrial process (e.g. electrochemical phosphorus furnace, as in Thermphos – now closed; fertilizer industry). P-recycling costs for some processes can be very high, but are in some cases significantly mitigated by converting sewage sludge to an inert waste with low disposal costs or by energy recovery (e.g. wet-oxidation processes treating sewage sludge such as Aqua-Reci® or PHOXNAN).

The authors note that reliable cost assessment is difficult for many processes because of the absence of full-scale operating plant data. Overall costbenefits regarding the whole sewage works process are estimated to range from $-3 \notin kgP$ recovered (net benefit) to $12 \notin kgP$, compared to the estimated price of commercial inorganic fertilisers of c. $2.5 \notin kgP$.

CO₂ emissions are higher for nearly all recycled phosphate products than for a reference situation without P-recovery, but this does not take into account emissions in producing an equivalent amount of mineral fertiliser. At the same time, the additional CO₂-emissions because of P-recovery are negligible (e.g. Ostara: 0,02 %; Ash Dec®: 0,04 %) in comparison to the total annual CO₂-emissions of one inhabitant. The net emissions calculated for use of sewage sludge incineration ash in fertiliser production are however strongly negative (-49% because of use of sulphuric acid in the process, which has a CO₂ credit for heat recovery). The full scale operating precipitation processes (Ostara®, AirPrex®) show CO₂ emissions marginally higher than the reference (see remark above) whereas the processes treating sewage sludge incineration ash or sewage sludge (currently based on pilot scale results only) all show much higher +305%. emissions (+29%)to except for LEACHPHOS® -8% and for Aqua-Reci® and PHOXNAN, both of which have proved difficult to control and have been abandoned).

"(Comparative) Technical, environmental and economic assessment of Phosphorus recycling technologies from waste water", ReWater Braunschweig, 2013, part of "P-Recycling from wastewater" project, Vienna University for Technology (Institute for water quality, resources and waste management) http://iwr.tuwien.ac.at/wasser/forschung/arbeits-undforschungsschwerpunkte/klaerschlamm-und-biogas/p-reycling.html

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Phosphorus recycling technologies

Zero-valent iron P-recovery via iron adsorption

Nanoscale zero-valent iron (NZVI) particles have shown to achieve high phosphorus removal and the resulting product, phosphorus-sorbed iron, can offer phosphorus and iron availability for plants. The authors' first paper presents experiments showing very high P-removal by NVZI from pure chemical phosphate solutions, at different phosphate concentrations and in the presence of other ions and organic acids. Their second paper shows that such NVZI loaded with adsorbed phosphate is an effective fertiliser, with high bioavailability of both P and Fe to spinach and algae.

Nanoscale zero-valent iron (NZVI) particles were synthesised by reacting iron chloride with sodium boron hydroxide, to produce Fe^0 precipitate which was separated from the solution. The NZVI particles were mostly spherical with size distribution 10 – 30 nm (average c. 16 nm). X-ray diffraction analysis (XRD) suggested that NZVI contained traces of iron oxide (because reaction with air) and iron chloride (remaining initial reactant).

Lab-scale batch P-removal experiments were carried out using pure chemical solutions (50 ml) of monopotassium phosphate (at 0.4 - 10 mg PO₄^{3—}P/l) in the presence of other ions (nitrate, sulphate, calcium), salinity, natural organic matter and humic acid (at varying concentrations).

Effective P-adsorption

Very rapid phosphate adsorption was achieved using NVZI, with 88 – 95% P-removal in 10 minutes with 400 mg NVZI/1 in pure phosphate solutions. NVZI P-adsorption was, however, significantly less effective in the presence of sulphate ions, humic acid or organic matter, with removal rates falling to 75 – 80% in 10 minutes.

The observed removal of phosphate are sufficiently rapid and high to suggest that the process **could feasibly be adapted for full scale wastewater treatment** and eutrophic lake remediation with additional testing in real samples before scaling-up.

Plant availability

Bioavailability of the NVZI-adsorbed phosphorus ("spent NVZI") and of the iron present in NZVI were tested using spinach (*Spinacia oleracea*) and freshwater algae (*Selenastrum capricornatum*).

Spent NVZI was prepared by adsorbing P from pure phosphate solution onto NVZI as described in the authors' first paper. Spinach seedlings were grown in hydroponic culture for 28 days using three different (triplicated) feeds: all nutrients, all nutrients with P replaced by spent NVZI (same P dosage), all nutrients except P and Fe. The algae were cultivated in 500 ml bottles for 28 days with five treatments: distilled water, Bristol medium (all nutrients), medium with virgin NVZI, medium without phosphate, medium without phosphate but with spent NVZI.

Results showed algae growth nearly 7x higher with spent NVZI than with standard nutrient medium, and for spinach 2-4x higher growth was achieved with spent NVZI than with standard nutrient supply. Spinach also showed 7-21x higher iron content when treated with spent NVZI compared to the controls.

The authors conclude that the phosphate adsorbed onto NVZI is highly bioavailable to plants, as is the iron in the spent NVZI.

"Nanoparticle-sorbed phosphate: iron and phosphate bioavailability studies with Spinacia oleracea and Selenastrum capricornutum", ACS (American Chemical Society) Sustainable Chemistry Engineering http://pubs.acs.org/doi/pdf/10.1021/sc500109v

"Aqueous phosphate removal using nanoscale zero-valent iron", J. Nanoparticle Research, June 2012, 14:900, http://link.springer.com/article/10.1007%2Fs11051-012-0900y#page-1

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Electrochemical P-recovery Recycling P, S and Fe from ferric phosphate

 cm^3 lab-scale 200 two-component Α electrochemical cell, using carbon electrodes separated by a monovalent cation exchange membrane, was tested for recovery of iron (as iron FeII/FeIII solution) and phosphate (as orthophosphate solution), as well as regeneration of the sulfide $(S^{2-} + polysulfides)$ used in the process.

In a first stage, sulfide solution is added to ferric phosphate solution, resulting in the release of the phosphate (as orthophosphate) in solution and the generation of a colloidal iron sulfide (FeS) suspension.

The iron sulfide was then separated by adjusting to **pH 4**, by dosing hydrochloric acid. This caused the precipitation of the FeS, leaving an orthophosphate rich solution.

The **FeS precipitate is then fed to the anode of the electrochemical cell, where it is oxidised to soluble iron and sulfur** which precipitates on the anode. Periodical reversal of the polarity then allows to reduce the sulfur back to (soluble) sulfide, which can then be recovered and reused. Sodium chloride was dosed to the anode to ensure selective migration of Na⁺ cations to the cathode, to ensure electroneutrality of the cell and to reduce internal electrical resistance. The experimental cell was tested with 4-cycle (polarity reversal) runs, using different carbon electrode types, and using pure chemical solutions and real sewage sludge containing iron phosphate (c. 9 g Fe/L), diluted and real strength.

60% experimental recovery rate

Around 60% of iron was transferred from the inflow stream (where present as ferric phosphate) to the recovery stream. Phosphorus recovery rate was not measured, but can be estimated to be comparable. However, only around 45% of dosed sulfide was successfully recycled, so that the process would require considerable ongoing sulfide dosing. Other operating problems noted included accumulation of suspended solids in the electrochemical cell and binding of FeS to the graphite electrodes. In the case of scale-up to application in wastewater treatment, the



The authors note that this work successfully demonstrates at the lab scale a **possible integrated process for recovery of iron and phosphate from ferric phosphate containing sewage sludges** (resulting from using iron chloride for chemical P-removal in sewage works) but that a number of operating problems would need to be addressed before the process could be operational in large scale.

"A novel electrochemical process for the recovery and recycling of ferric chloride from precipitation sludge", Water Research, 51, pages 96-103, 2014

E. Mejia Likosova, J. Keller, S. Freguia, The University of Queensland, Advanced Water Management Centre (AWMC), St Lucia, QLD 4072, Australia. Y. Poussade, Veolia Water Australia, Level 15, 127 Creek Street, Brisbane, QLD, Australia. e.mejialikosova@uq.edu.au

"Understanding colloidal FeSx formation from iron phosphate precipitation sludge for optimal phosphorus recovery", E. Mejia Likosova, J. Keller, R. Rozendal, Y. Poussade, S. Freguia, J. Colloid Interface Sci. 403 (0), pages 16-21, 2013

Meat and bone meal ash FLUID-PHOS recovered P fertiliser

SARIA producing a recycled calcium phosphate fertiliser by high temperature treatment of animal by-products.

The SARIA group is offering a proven route for phosphorus recycling directly into the fertiliser market by burning meat and bone meal (MBM) to produce a phosphate-based ash product, termed **FLUID-PHOS**.

FLUID-PHOS is produced by Saria UK (formerly PDM Group) at their renewable energy CHP plant at Widnes, Cheshire, England. MBM is the solid product from rendering (cooking and separation) of animal byproducts such as carcasses and parts of animals that are not used for human consumption. It contains phosphorus in the form of bone, and also protein. Whilst MBM can be used as a fertiliser, **Animal By-Product (ABP) legislation** strictly controls the category or source of the MBM which can be used for this application. The high concentration of protein in MBM also makes it unsuitable as a nitrogen-free fertiliser.



Burning MBM to produce an inert ash overcomes these animal byproducts restrictions:

- 1. The CHP plant uses fluidised bed technology and conforms to Waste Incineration Directive requirements. This means that ABP legislation does not apply to the use of the FLUID-PHOS ash product in fertiliser applications. The principal advantage of this is that Category 1 MBM (derived from higher-risk material) and non-derived animal by-products can be used as feedstocks for the plant without affecting the FLUID-PHOS market.
- 2. Selection of the fluidised bed process for the plant means that the uniform combustion temperatures, high level of mixing and closely-controlled feed particle size ensure **complete protein destruction**. This is of major importance in reassuring regulators and potential customers that FLUID-PHOS ash can be safely used as a fertiliser for both arable and grazing land. It also means that the FLUID-PHOS ash product can be used as a P or P-K fertiliser with zero nitrogen.

Production Process

Solid feedstocks are ground and screened, and then mixed with aqueous liquids to achieve a closely controlled final moisture content of typically 50%. The mixed slurry is then pumped to the fluidised bed combustors. The flue gases pass through waste heat boilers, economisers and bag filters before exhausting to atmosphere. Steam from the waste heat boilers is used in turbines and in the on-site rendering plant. The fluidised bed material is comprised solely from the bone particles in the MBM.



MBM combustion plant for production of FLUID-PHOS

Product



Two ashes are produced as a result of incineration: bed ash and fly ash. Bed ash is coarser with particles sized 0.5 - 4mm and Fly ash is a finer ash with particles less than 0.5mm in size. The FLUID-PHOS product is a mixture of these, and currently comprises typically 80% fly ash and 20% bed ash.

The ash contains typically 22% phosphorus as P2O5 (in the form of calcium phosphate), with smaller amounts of magnesium, potassium, sulphur and trace elements. Solubility in water is low, however this increases significantly in acidic soils and in citrate solubility tests. The product is therefore particularly suitable for providing a slow release of phosphorus.



Bulk Storage of FLUID-PHOS

FLUID-PHOS has been spread on land since 2011 and represents a **proven route for recycling of phosphorus** and conservation of this valuable natural resource.

Current annual production is 12,000 tonnes. Market feedback from large scale spreading of MBMA over the last 3 years has been favourable, development work is underway to produce a granular form suitable for small farm-scale spreaders

The product is **authorised for spreading on land as a fertiliser** without waste permitting requirements under the UK Environment Agency "End of Waste" protocol. Work is continuing with the EA to extend the range of liquid feedstocks accepted under "End of Waste". REACH registration can follow the culmination of the End of Waste process.

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EU funding opportunities

Two new EU funding project calls open opportunities for nutrient recovery, in particular phosphorus:

The Bio-Based Industry call (Horizon 2020 R&D BBI.VC4.R10 defines as its funding) scope "Development of dedicated recovery processes for nutrients from biowaste streams and bioresidues rich in plant nutrients (especially phosphorous and potassium *compounds*) through extraction, solubilisation, precipitation, chemical reaction and other emerging chemical or biological processes. Upgrading of recovered nutrients to new sustainable fertilisers by a cost-effective combination of specific organic and mineral components."

The **LIFE Environment and Resource Efficiency** call (DG Environment funding) can fund pilot and demonstration projects, particularly relating to the EU Roadmap to a Resource Efficient Europe

NEW: EU Bio-Based Industry PPP deadline 15/10/2014, Nutrient recovery from biobased waste streams and residues BBI.VC4.R10

http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/6057-bbi.vc4.r10.html

See also: BBI.VC4.R9 http://ec.europa.eu/research/participants/portal/desktop/en/opportu nities/h2020/topics/6057-bbi.vc4.r10.html

NEW: LIFE Environment and Resource Efficiency deadline

16/10/2014, Pilot and demonstration projects for policy or management approaches, best practices, technologies http://ec.europa.eu/environment/life/funding/life2014/#capacity

SPIRE-07-2015 – deadline = 19/12/2014 http://ec.europa.eu/research/participants/portal/desktop/en/opportu nities/h2020/topics/2166-spire-07-2015.html "Recovery technologies for metals and other minerals"

WASTE 7-2015 - deadline = 16/10/2014 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2 015/main/h2020-wp1415-climate_en.pdf "Ensuring sustainable use of agricultural waste, coproducts and byproducts", includes "nutrient, energy and biochemical recovery

WASTE-4d-2015 - deadline = 10/3/2015 http://ec.europa.eu/research/participants/portal/desktop/en/opportu nities/h2020/topics/2113-waste-4d-2015.html "Raw materials partnerships"

from manure and other effluents"

SC5-11(b)-2014 - deadline = 10/3/2015 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2 015/main/h2020-wp1415-climate_en.pdf "New solutions for sustainable production of raw materials" (b) 2014 "Flexible processing technologies"

SC5-13(f)-2015 - deadline = 10/3/2015

http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2 015/main/h2020-wp1415-climate_en.pdf

"Coordinating and supporting raw materials research and innovation"

"Strategic international dialogues and cooperation with raw materials producing countries and industry"

KIC Raw Materials – deadline = 10/9/2014

http://eit.europa.eu/newsroom-and-media/article/innovate-join-theeit-and-spur-innovation-and-entrepreneurship-across-europe/ *To address: raw materials – sustainable exploration, extraction processing, recycling and substitution.*

Please note that the list above may not be complete. It is ESPP's analysis to date. The presentation made by ESPP of call content may not be accurate, and you are recommended to verify directly with the published call texts and obtain competent advice where useful.

Agenda

- 21 August, Berge, Germany: P-REX Regional Workshop www.p-rex.eu
- 26-29 August 2014, Montpellier, France:
 5th Phosphorus in Soils and Plants symposium http://psp5-2014.cirad.fr/
- 1 3 Sept., Montpellier, France, 4th world Sustainable Phosphorus Summit http://SPS2014.cirad.fr
- * 10-12 September, Basel, Switzerland, P-REX summer school (students, researchers, young professionals): Implementation of P-Recovery from Wastewater - Why and How? www.p-rex.eu
- 11 September 2014, Leeds, England Resource Recovery in the Water Industry www.aquaenviro.co.uk
- 17 September, Kobyli na Morave, Czech Republic P-REX Regional Workshop www.p-rex.eu
- 23-24 September, Warsaw, Poland Greener agriculture for a bluer Baltic Sea http://www.balticcompass.org/_blog/gabbs/post/a-greener-agriculturefor-a-bluer-baltic-sea-stakeholder-conference-2014
- 27 Sept. 1 Oct., New Orleans, WEFTEC2014 (Water Environment Federation) www.weftec.org
- 30 Sept 2 Oct, Alkmaar region, Netherlands European Biogas Association Conference http://www.biogasconference.eu/
- 7-8 Oct., Manchester, UK, 8th European Waste Water Conference. Including: wastewater as a resource, nutrient factory. www.ewwmconference.com
- 20-24 Oct., Rio de Janiero CIEC World Fertiliser Congress www.16wfc.com
- 26-30 Oct, Kathmandu, Nepal, IWA: Sustainable Wastewater Treatment and Resource Recovery http://iwa2014nepal.org
- 4 Nov 2014, Brussels ACR+ Circular Economy for cities and regions working group *info@acrplus.org*
- * 3-5 Nov 2014, Long Beach, California ASA, CSSA, SSSA (US & Canada soil and agronomy) meetings, Water Food, Energy, Innovation for a Sustainable World www.acsmeetings.org

- * 17-19th Nov., Manchester UK, 19th European Biosolids & Organic Resources Conference. Session on energy and resource recovery www.european-biosolids.com
- 4-5 December, Florence, Italy: 1st International Conference on Sustainable P Chemistry www.susphos.eu/ICSPC
- 6-8 December 2014, Lisbon, Portugal Nutriplanta2014 www.congressos.abreu.pt/Nutriplanta2014
- * 11-12 December, Cambridge, England., IFS International Fertiliser Society Conference 2014 http://fertiliser-society.org
- ✤ 5-6 March 2015, Berlin: 2nd European Sustainable Phosphorus Conference www.phosphorusplatform.org
- 23-25 Mar 2015, Tampa, Florida: Phosphates 2015 (CRU) www.phosphatesconference.com
- 29 March 3 April 2015, Australia. Beneficiation of phosphates VII http://www.engconf.org/conferences/environmentaltechnology/beneficiation-of-phosphates-vii/
- ♦ 4-8 May 2015, Morocco: SYMPHOS (dates to be confirmed) www.symphos.com
- 1 May 31 Oct. Expo2015 Feeding the planet, energy for life, Milano http://en.expo2015.org/
- *

Nutrient Platforms

Europe: www.phosphorusplatform.org

Netherlands: www.nutrientplatform.org

Flanders (Belgium): http://www.vlakwa.be/nutrientenplatform/

Germany: www.deutsche-phosphor-plattform.de

North America Partnership on Phosphorus Sustainability NAPPS *j.elser@asu.edu*

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