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SCOPE NEWSLETTER

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Issues around phosphorus use, chemistry and applications

Review

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Phytate in diets can reduce mineral uptake but may have beneficial health effects

New !

Sustainable P Initiative blog

Exchange, learn, discuss, participate ...

<http://sustainablep.wordpress.com/>

European Platform meeting



Brussels 2nd December 2014:
www.phosphorusplatform.eu

Define and adopt the Platform's statutes
(establish the Platform as a legal entity)
Fix the 2015 action plan and priorities

Discuss P-rock/P on the EU Critical Raw Materials list

To participate: info@phosphorusplatform.eu

The partners of the European Sustainable Phosphorus Platform





ESCo MAFOR France

Farm use of organic by-products

France has published a collective expertise (ESCo) on the use of fertilising residual materials (MAFOR) in agriculture and forestry, produced jointly by INRA, CNRS and IRSTEA. Also, the French fertiliser industries have launched an observatory of fertiliser element use.

The collective expertise report assesses the quantities of organic fertilising materials (manures, sewage biosolids, industrial by-products, digestates, composts, biochars and biomass ashes, dredging sediments), composition, agronomic impacts, environmental issues.

An 8-page summary is available in English.

Expertise in 7 parts:

- 1 = **overview and objectives.**
- 2 = **physical and chemical characteristics of organic residuals (by-products):** composition, physico-chemical and biologic characteristics, contaminants (metals, organics) in different types of organic by-products
- 3 = **agronomic impacts of application of organic by-products:** fertiliser value, soil amendment value, impacts on soil properties, impacts on dissolved organic carbon substances, impacts on soil organisms, impacts on crop health and on weed development, application decision support tools, economic assessment of application value
- 4 = **environmental consequences of organic by-product application:** biological contaminants (parasites, virus, bacteria), organic contaminants, inorganic contaminants, risk of contaminant transfer to livestock, health risks for livestock, ecotoxicity of organic by-products, atmospheric emissions, decision support tools for limiting environmental risks
- 5 = specific agronomic and environmental aspects residual application in **forestry**
- 6 = **multi-criteria and environmental assessment** (not yet finalised)
- 7 = **legal, social and economic aspects**

Fertilising potential

France produces an estimated **374 million tonnes/year (Mt/y, raw weight) of manures, crop waste and other agricultural by-products**, which are principally directly re-used on the farm. In particular, around 50% of the 274 Mt/y manure is emitted straight onto the field.

Quantities of fertilising by-products from other sources are much smaller, including 0.7 Mt/y dry matter sewage biosolids, 2.2 Mt/y wet weight compost and digestates from municipal wastes and 1.8 Mt/y dry matter industrial organic wastes.

In total, in 2011, **some 6.6 million hectares of cropland and grassland in France received application of organic by-products**, that is around 25% of cropland and 30% of grassland. 94% of these applied organic by-products were manures or manure-derived.

The report underlines the challenge posed by the **geographical imbalance of organic by-product production** (between French regions) and the questions of economic feasibility of either treatment (in the regions with excess) to enable transport (to other regions) or of redistributing livestock production more evenly over the national territory.

Agronomic value

The report notes that **phosphorus (P) and potassium (K) in organic by-products has the same fertiliser value** as in inorganic fertilisers (except P in ashes which is not plant-available). The phosphorus in organic by-products in France could potentially cover all the P removed annually in crops.

Nitrogen (N) in organic by-products, on the other hand, **behaves very differently from N in inorganic fertilisers**, and interacts with the organic carbon present in the by-products. Both the N content and the fertiliser value (plant availability) of the N are modified by drying, composting and anaerobic digestion.

Agronomic use of organic by-products could be improved by **adjusting the N:P:K ratio** in these products (to better match crop requirements), by improving understanding of long-term N availability and agricultural methods for precision application of organic by-product nutrients.



Environmental challenges

The report identifies the following issues related to organic **by-product recycling through agricultural application**:

- **Methane emissions**, if organic carbon decomposes
- Possible **odour emissions**
- Production of **dissolved organic matter**, which can facilitate release and runoff of chemical contaminants from soils
- **Loss of phosphorus to surface waters** or P accumulation in soils, if P in organic by-products is not correctly taken into account
- **Accumulation of metals or organic contaminants** in soils
- Possible **emerging contaminants**, including organic contaminant breakdown products, nanoparticles
- Possible transmission (in manures) of **parasites or illnesses** from one livestock holding to others
- Spreading of **bacterial antibiotic resistance** to man or to livestock, e.g. via soil bacteria

The report notes that the latter two risks have not been proven and can be reduced by treatments such as composting, anaerobic digestion or liming. Further research is needed to better assess and to control these risks.

Upstream quality, economic value

The importance of **improving the upstream quality of organic by-products** is emphasised, for example: changes in animal diet have reduced zinc and copper levels in pig manures, improvement of source separation and sorting of municipal organic wastes can improve compost quality and lower contaminant levels.

The **absence of recent economic studies** is underlined, for the value to agriculture of organic by-product application, market studies for transfers of organic by-products between different French regions, or evaluation of the savings in mineral fertiliser purchase. Such economic studies would enable assessment of the interest of different routes for treating, transporting and placing on the market of organic by-products.

Fertiliser nutrients observatory

In a separate initiative, the French fertiliser industries have established a **national Observatory of Mineral and Organic Fertilisation**, to publish annual agricultural nutrient data. This initiative is developed by ANPEA, a federation of 160 companies producing mineral and organic fertilisers and soil amendments in France, and will draw on data from Unifa, CAS and AFCOME.

The nutrients Observatory will cover the different organic by-product types indicated above and provide data for each category and in total, for **N, P, K, Mg, S, organic carbon and soil neutralising capacity**. This will extend and update the Unifa report on nutrient use in French agriculture, see SCOPE Newsletter n° 107.

“Expertise collective Prospective & études – MAFOR – Valorisation des matières fertilisantes d’origine résiduaire sur les sols à usages agricoles ou forestier” (collective expert report on valorisation in farming or forestry of fertilising materials from by-products), INRA, CNRS, IRSTEA, 2014
<http://www6.paris.inra.fr/depe/Projets/Mafor> or
<http://institut.inra.fr/Missions/Eclairer-les-decisions/Expertises/Toutes-les-actualites/Expertise-Mafor-effluents-boues-et-dechets-organiques>

Summary of expertise in English:

<http://institut.inra.fr/en/Missions/Inform-public-decision-making/Scientific-Expert-Reports/All-the-news/Use-of-fertilizing-residual-materials-in-agriculture-and-forestry> and <https://inra-dam-front-resources-cdn.brainsonic.com/ressources/afile/261380-eeab2-resource-mafor-8-page-synopsis.html>

ANPEA press release, 18/9/2014 “Création d’un observatoire pour la fertilisation minérale et organique” <http://www.afcome.org/wp-content/uploads/2014/10/Création-Observatoire-national-de-la-fertilisation-minérale-et-organique.pdf>

**COMMUNIQUÉ
DE PRESSE**

Puteaux,
le 18 septembre 2014

**Création d’un observatoire pour la
fertilisation minérale et organique**

Porté par les organisations professionnelles membres de l’ANPEA¹, projet a pour objectif de réunir les statistiques de l’UNIFA², de la CAS³ de l’AFCOME⁴ sur les engrais et amendements organiques et minéraux destinés à l’agriculture. En 2013, 18,1 millions de tonnes de produits ont été commercialisés en France dont 12,4M de t. d’origine minérale et 5,7M de t. d’origine organique. Cet observatoire fournit une réponse aux pouvoirs publics, aux organisations agricoles et à société sur la répartition entre origines organique et minérale de fertilisation et sur leurs apports en éléments nutritifs, en valeur neutralisante et en matière organique.

Les fertilisants sont regroupés en sept grandes catégories de produit : amendements minéraux basiques, engrais minéraux et engrais organiques minéraux pour la fertilisation minérale ; engrais et amendements organiques bruts et élaborés pour la fertilisation organique. Pour chaque catégorie de produit, l’observatoire de la fertilisation donne un tonnage brut et un contenu, connu ou estimé, en éléments nutritifs N, P, K, Mg, en matière organique et en valeur neutralisante.

Les données de l’observatoire de la fertilisation sont complétées par le calcul des éléments apportés par les effluents d’élevage non commercialisés et épandus localement. Les autres apports organiques sous statut de déchet épandus en agriculture (boues d’épuration, effluents résiduaires, digestats de méthanisation...) restent à estimer à partir de données publiques des plans d’épandage.

A propos de l’ANPEA
L’ANPEA fédère six organisations professionnelles de la filière fertilisation. Ensemble, ces associations

Phosphate recovery

Update scientific publications overview

Prepared by Prashanth Kumar, Philipp Wilfert and Leon Korving of Wetsus, centre of excellence for sustainable water technology www.wetsus.nl.

As a contribution to the SCOPE newsletter Wetsus has inventoried articles on phosphate recovery technologies that have been published in the scientific literature in the first 9 months of 2014.

The objective of this inventory is to improve access to relevant developments and to identify trends. **The inventory is accessible via the Mendely website** so all interested persons can access the titles and abstracts of these articles. It is the intention to update this inventory periodically, typically every half year.

A group has been created in Mendely with the title “SCOPE inventory of articles on P-recovery technologies”. This group is accessible via: <http://www.mendeley.com/groups/4497601/scope-inventory-of-articles-on-p-recovery-technologies/papers/>

Inventory of articles 2014

| Category | Tags |
|-----------------------------------|--|
| Type of Recovery Product | Struvite, Calcium Phosphate, Iron Phosphate, Adsorbed phosphate, Fertilizers, Magnesium Phosphate |
| Recovery from which stream | Incineration Ash, Sludge (digestate, digester), Manure, Source separated (urine, blackwater, grey water), Food waste, Industrial wastewater, Pure water (distilled water, tap water) |
| Scale (when related to a process) | Laboratory Scale, Pilot Scale, Industrial Scale |
| Technology | Chemical degradation (Wet-Chemical, Thermo-Chemical), Adsorption (Ion exchange), Biological (biomineralization, digestion), Precipitation (Iron phosphate, Coagulation), Crystallization (Calcium phosphate, Struvite), Electrochemical (Bioelectrochemical, electrochemical), Membrane (Reverse osmosis, Filtration), Others (Saponification) |
| Other | Modelling, Process engineering, Review, Life cycle assessment. |

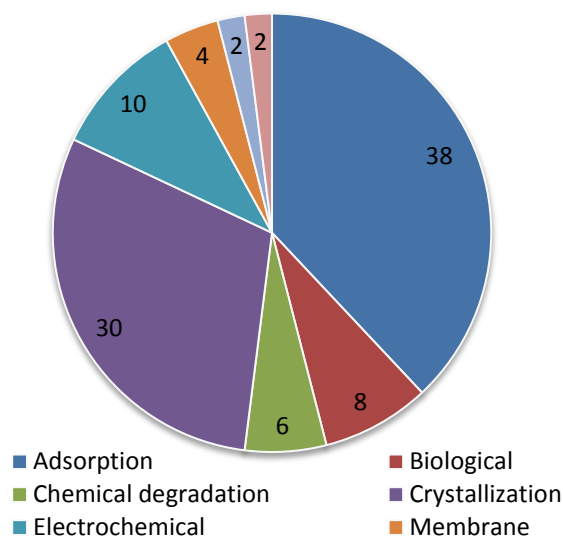
The current inventory consists of 55 articles starting from 1/1/2014 to 30/9/2014. Google Scholar, Scopus and Web of Science were used for finding the relevant articles using the keywords ‘Phosphorus / Phosphate

and Recovery / Removal’. In addition the articles that were found in this way were manually filtered to exclude off-topic articles. Most of the articles were original research articles (50), along with a few review articles (3), a process modelling article (1), and an added-value assessment article (1). Thesis’s, grey literature or reports are not included in the inventory.

To improve access to the articles they were labeled with various tags covering different categories. The table below summarizes the tags that have been used for this labeling.

P-recovery technologies

The pie chart shows the percentage distribution among the 54 articles for the different technologies used for phosphate recovery. It can be seen that the majority of the articles reported on using adsorption and crystallization. The other technologies involved biological, electrochemical, chemical degradation, precipitation and membrane techniques.



Distribution of different technologies (in percentage) used for recovering phosphorus in the inventoried articles.

It is important to mention the difference between the articles reporting on **crystallization and precipitation**. While defining the tags, we included recovery as struvite or calcium phosphate in the crystallization category, whereas recovery as iron phosphate or other more amorphous forms was included in the precipitation category.

It is also noteworthy to mention that in articles that reported on using **multiple technologies**, we tag it according to the primary technology reported. For

example: there are number of articles which primarily remove phosphate using adsorption but later recover the desorbed phosphate as struvite or calcium phosphate. So in such cases we tag the articles with adsorption and not with crystallization.

Useable final product?

Another noteworthy fact is that not all articles report on recovering the phosphate as a specific final product. The definition of recovery also seems to vary in articles. For example, in some adsorption articles, the phosphate is removed from a water stream and then desorbed from the **adsorbent**. The recovery is then defined as desorbing the adsorbed phosphate. In other articles, recovery implies a final product that is recovered as struvite or calcium phosphate. The majority of articles in this list recover phosphate as struvite.

Struvite

The struvite related publications were mostly technological orientated. They often focussed on **investigating parameters that effect struvite formation** and thus to further optimize struvite precipitation (13 out of 23 articles). Five articles concentrated on another technique and have struvite as an end or intermediate product (digestate processing using microbial electrolysis cells, food waste co-digestion, forward osmosis–membrane distillation on digestate, alkaline hydrolysis of sludge and urine softening using ion-exchange).

One article describes a **CO₂ degasification reactor** to recover phosphate from manure. Of the remaining articles one **models phosphorus removal and recovery from anaerobic digester supernatant** using struvite, one describes added-values by **establishing nutrient cycles via struvite** and one **reviews the production of struvite fertilizer from wastewater**.

Adsorption

The articles on phosphate adsorption featured a **wide range of adsorbents** including pure adsorbent particles (eg: Nanoscale zero-valent iron), inorganic composites (eg: Iron oxide impregnated strong base anion exchange), composites containing organic supports (eg: feather protein based polymer networks hydrogel) and biosorbents (eg: Red seaweed (*Kappaphycus alvarezii*)). Although all the studies focus on phosphate removal through adsorption, only 8 out of the 19 articles focus on phosphate recovery by

showing the regeneration and reuse of the adsorbent. However, **where biobased adsorbents are used, these may be useable directly as a fertiliser / soil amendment**, so valorizing both the adsorbed phosphorus and the organic carbon content, subject to their suitability and to bulk transport / storage stability issues.

Selected articles

Two articles were selected for a more extended summary for the SCOPE newsletter. One article concerns struvite precipitation and it was selected as it describes a very **different approach to struvite precipitation** compared to other struvite related publications. The other article focuses on adsorption of phosphate was selected on the combination of the criteria that the **adsorbent was synthesized using a waste residue**, it had a good adsorption capacity and showed the potential to be reused after desorbing and recovering the phosphate.

Microbial mineralization of struvite

“Microbial mineralization of struvite: A promising process to overcome phosphate sequestering crisis”, Water Research, Volume 54, 1 May 2014, Pages 33–43

<http://www.sciencedirect.com/science/article/pii/S0043135414000773#> Arvind Sinha, Amit Singh, Sumit Kumar, Sunil Kumar Khare, Arunachalam Ramanan, Department of Chemistry, Indian Institute of Technology Delhi, New Delhi 110016, India

Sinha and co-authors suggest the application of microorganisms that can withstand elevated heavy metal concentration (“metallophiles”) for harvesting phosphorus from the environment. Such organisms have special strategies to transform metals. It has already been described that metallophiles can form struvite ($MgNH_4PO_4 \cdot xH_2O$) if they are provided with a magnesium, nitrogen and phosphorus sources. The described microbes required high phosphate concentrations.

In laboratory batch experiments the authors investigated the potential and mechanisms of the metallophilic bacterium *Enterobacter* sp. EMB 19 to form struvite in growth medium containing magnesium and low phosphate concentrations (50 mg P-PO₄/L). The bacterium induced the formation of pure struvite crystals (96 mg/L after 7 days, containing about 12 mg

P). At higher phosphate concentrations (about 360 mg P-PO₄/L), struvite formation increased to about 150 mg/L after 7 days. Struvite formation (91 mg/L) was also found in cell free supernatants of the growth media when magnesium was present.

The authors hypothesize that **several factors are responsible for the microbial induced struvite formation**. The microbial formation and release of ammonia (NH₃) causes a pH increase in the media (from pH 7 to 8.4) and provides ammonia (from 0 to 72 mg N-NH₃/L) as building block for struvite within 3 days. The authors further hypothesize that the cells excrete molecules during growth, most likely proteins, which act as crystallization nuclei for struvite. Thereby the formation of struvite in filtered, cell free media can be explained.

Various methods were applied to characterize the air-dried struvite crystals (XRD, FTIR, SEM, EDAX and thermal analyses). The formed struvite was homogenous, single phased and morphologically uniform. This led the authors to the idea that the formation was biologically controlled. It is not stated, however, how struvite formation could have positive effects for the cells.

The described research is in an early state. Experiments were performed in batch experiments with pure cultures of *Enterobacter* sp. EMB 19 cultivated in defined nutrient media. The authors do not directly suggest a technological application for their observation.

See also other work underway using bacteria to enhance precipitation of calcium phosphate (Spérandio et al., SCOPE Newsletter 101) or struvite (Soares et al., SCOPE Newsletter 97)

Hybrid zeolite/lanthanum hydroxide sorbent

“Green synthesis of a novel hybrid sorbent of zeolite/lanthanum hydroxide and its application in the removal and recovery of phosphate from water”, *J. Colloid and Interface Science*, 423 (2014), 13–19

<http://www.sciencedirect.com/science/article/pii/S0021979714000964> Jie Xie, Zhe Wang, Da Fang, Chunjie Li, Deyi Wu; School of Environmental Science and Engineering, Shanghai Jiao Tong University, China

This article describes the removal and recovery of phosphate from water using adsorption. It reports a novel hybrid adsorbent that is synthesized with the help of a waste byproduct. Coal fly ash (CFA) is a solid waste generated in large quantities

globally. The synthesis of Zeolites (ZFA) from CFA has been used as a means of recycling. The traditional process for ZFA synthesis however produces large amounts of waste alkaline solution as by-product.

This study reports the addition of soluble lanthanum chloride to the mixture of the ZFA and the waste alkaline solution. This leads to formation of **Lanthanum hydroxide on the ZFA (La-ZFA)** due to neutralization of the alkaline solutions according to the following reaction: $\text{NaOH} + \text{LaCl}_3 \rightarrow \text{La(OH)}_3 + \text{NaCl}$.

The La-ZFA produced this way shows a **higher specific surface area** of 55.69 m²/g as compared to the CFA and ZFA, which have specific surface areas of 1.10 m²/g, and 28.74 m²/g, respectively. Floccules of lanthanum hydroxide were observed on the ZFA surface using Scanning Electron Microscopy (SEM). The adsorption isotherms were fit according to Langmuir model and showed that the La-ZFA has a superior maximum adsorption capacity of 71.94 mg P/g (P denotes phosphorus associated with phosphate) as compared to the ZFA which had a maximum capacity of 6.05 mg P/g. The adsorption capacity of CFA was too trivial to fit the Langmuir model.

The studies determining the influence of pH on phosphate adsorption found that at initial concentrations of 5 mg P/L and 100 mg P/L, the adsorption performance of La-ZFA was not affected between pH 2.5 and 10.5, with removal always exceeding 95 %. At an initial concentration of 500 mg P/L, the adsorption performance of La-ZFA decreased significantly with increasing pH. This was attributed to the competition for phosphate adsorption sites from OH⁻ ions. The phosphate adsorption mechanism was suggested to be an inner-sphere complex /ligand exchange reaction. Increase in pH was observed after phosphate adsorption onto the La-ZFA, indicating that **phosphate interaction with La-ZFA resulted in release of OH⁻ ions**, thereby inferring the adsorption mechanism to be ligand exchange.

X-Ray Diffraction (XRD) studies found that the synthesis of ZFA from CFA led to new peak formation on the XRD patterns, indicating the presence of zeolite. However, the synthesis of La-ZFA from ZFA didn't lead to formation of any new peaks; instead the peak intensities of the crystalline phases of the ZFA were decreased to some extent. This indicated the formation of amorphous lanthanum hydroxide floccules on the ZFA surface, as observed by the SEM images. Examination of La-ZFA consisting of



adsorbed phosphate showed newly emerging peaks that indicated the presence of monoclinic LaPO_4 . The detection of LaPO_4 suggested that the major surface species formed by phosphate adsorption was monodentate species as per the following reaction: $\text{LaOH} + \text{PO}_4^{3-} \rightarrow \text{LaPO}_4 + \text{OH}^-$.

The recovery of phosphate adsorbed on the LA-ZFA was studied using hydrothermal NaOH treatments. More than 95% of the phosphate from phosphate-saturated La-ZFA could be recovered using 3 M NaOH at a temperature of 250 °C. To examine the reusability of the regenerated La-ZFA, the sorption and desorption experiments were performed for 5 cycles and it was shown that the adsorbents could be reused with high adsorption efficiency. The La-ZFA was thus found to have potential for removing phosphate from water, showing a superior phosphate adsorption capacity, and allowing for the adsorbed phosphate to be recovered by regenerating the adsorbent.

The studies done in this research are **so far on lab scale**. All the experiments were done in a batch mode where equilibrium conditions are established. Moreover solutions of Lanthanum in distilled water were used for the sorption isotherms.

The above article summaries were prepared by Prashanth Kumar, Philipp Wilfert and Leon Korving of Wetsus, centre of excellence for sustainable water technology www.wetsus.nl.

Netherlands – Fosfaat Retour

Phosphate chains implemented

The Provincial Development Agencies of the three southern provinces in The Netherlands (BOM, LIOF and Impuls-Zeeland, in cooperation with REWIN) have launched the Fosfaat Retour project to implement local phosphorus recycling value chains with phosphorus waste/resource managers, technology suppliers and recovered product users.

Much has been published on sustainable use of phosphate, and keeping it in cycles. Many routes to valorise and re-use phosphate from manure, sewage sludge and slaughter waste have been identified. Some initiatives have been implemented at market scale, but **there is a large potential for more**.

The Fosfaat Retour project will connect technology providers, raw materials suppliers, customers for phosphates and other relevant stakeholders in such a way that new valorisation chains are formed for

phosphate. The South of The Netherlands is the area of primary focus: there is a large supply potential here and a need for smart solutions. The project will provide a practical, local implementation of the objectives of the **Netherlands Nutrient Platform** www.nutrientplatform.org

Moving to action

Potential technologies include, but are not limited to, **incineration, gasification/pyrolysis, wet chemical methods, as well as thermal and wet-chemical treatment of ashes and other residues**. The objective is to convert phosphorus in what are at present waste streams, especially animal manures and champost (used mushroom growing substrate) into useful products such as fertilizers.

Separating P from streams such as manure will also **facilitate balanced local application in agriculture**, because the P content is currently often limiting, resulting in an obligation to transport and export manure.

Likewise, creating outlets for ashes may help biomass-based heat or power generation materialize. Creating multiple benefits along the chain will help in making these cases succeed.

Geographical nutrient concentration

Since the South of The Netherlands is a concentration area for **pig farms and mushroom growers**, pig slurry and champost are focal points for the project. Millions of tons of pig slurry need to be treated yearly, as well as 100 000 tonnes of champost.

Feasible business cases will be identified, including energy benefits, avoidance of costs, phosphate profits and sustainability. Even though such cases are not expected to be common, smart combinations of technologies and partners may yield promising models for the near future.

Twan Goossens of ODBN and Willem Schipper, phosphate consultant, are in charge of implementation. They are using their knowledge of the field and the markets to connect the right stakeholders and support the formation of valorisation chains.

More information (in Dutch) can be found at www.fosfaat.jouwweb.nl

NV Brabantse OntwikkelingsMaatschappij – www.bom.nl

NV Industriebank LIOF – www.liof.nl

NV Economische Impuls Zeeland – www.impulszeeland.nl

NV REWIN West-Brabant – www.rewin.nl



Germany

P in sewage sludge

Sewage sludge incineration ash from 24 of Germany's 26 mono-incineration plants (plants incinerating municipal or industrial sewage sludge only, not mixed with urban refuse or other wastes) was analysed for phosphorus content, and the potential phosphorus available for recovery and recycling via this route was estimated.

Germany produces **c. 2 million tonnes/year (dry weight) of sewage sludge**, of which around 45 % is recycled to land (spread as a soil amendment), some is co-incinerated in power plants or cement mills, and 800 000 t/y is incinerated in mono-incineration plants, resulting in 300 000 t/y of mono-incineration ash.

Loss of phosphorus

The sewage sludge incineration ashes currently go to landfill or are used in road construction, with only around 5 % being spread on land, so that nearly all the phosphorus in them is lost.

The **24 mono-incineration plants** for which ash was analysed in this project (out of 26 mono-incineration plants operating in Germany) represent >97 % of mono-incineration ash production by weight. In these plants, around 40 % (by tonnage) is ash from incineration of municipal sewage sludge only, 8 % from industrial sludge only and just over 50 % from mixed municipal and industrial sewage sludges.

The ashes from German sludge mono-incineration plants contain **around 19 000 tonnes P/year**, which is around 13 % of annual phosphorus consumption in mineral fertilisers in Germany.

Contaminants in ashes

The ashes from each plant were dissolved using a mix of perchlorid, nitric and hydrofluoric acid and then analysed for Aluminium, Calcium, Iron, Potassium, Magnesium, Sodium, Phosphorus, Sulphur, Silicon and for **a range of metals and heavy metals** : Ti, Sc, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Sr, Y, Zr, Nb, Mo, Ag, Cd, Sn, Sb, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Au, Hg, Pb, Th.

The analysis shows that, in particular, **arsenic, chromium, lead and mercury pose issues** regarding

land spreading because levels of these contaminants are limited under German fertiliser regulations (although the regulatory limits are defined with aqua regia extraction, not directly comparable to the more complete digestion used in this report).

The study estimates that approximately 12 ktP/year, of the 19 ktP/y potentially available for recovery in the mono-incineration sludge ash, **cannot be used on land** because of these heavy metal contaminants, unless these are extracted in a purification process.

The **phosphorus in the sludge incineration ash showed to be ca. 30 % soluble** in neutral ammonium citrate (often considered as an indicator of plant availability – fertiliser value). This implies that a treatment of sewage sludge ash prior to fertilizer use is necessary, because fertiliser ought to have a phosphorus solubility of 100 %.

Properties of the ashes **varied depending on incineration technologies**. Carbon content of ash was around 1% for fluidised bed incinerators, and 5 – 8 % for grate firing or gasification. Fluidised bed and grate firing resulted in higher cadmium and mercury levels in filter ash.

"Monitoring von Klärschlammmonoverbrennungsaschen hinsichtlich ihrer Zusammensetzung zur Ermittlung ihrer Rohstoffrückgewinnungspotentiale und zur Erstellung von Referenzmaterial für die Überwachungsanalytik" (Monitoring of sewage sludge mono-incinerators to assess nutrient recycling potential and develop reference analysis methods), 160 pages in German with English summary, German federal environment agency (UBA Umwelt Bundesamt) Texte 49/2014, ISSN 1862-4804 <http://www.umweltbundesamt.de/publikationen/monitoring-von-klärschlammmonoverbrennungsaschen>

"Complete survey of German sewage sludge ash", Krüger, O., Grabner, A., Adam, C., 2014.. *Environ. Sci. Technol.* 48, 11811-11818.

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Multiform Harvest Inc., USA

Phosphorous recovery as struvite from organic waste streams

Multiform Harvest Inc., Seattle, USA, provides a struvite recovery system suitable for application in any wastewaters rich in orthophosphate phosphorus, including municipal, agricultural, industrial, food processing, and other industries (see SCOPE Newsletters n°s 77, 68 and 55).

The company today has **two full-scale plants operating in municipal wastewater plants works and one at a large dairy farm** with total capacity over 4.5 million litres per day net reactor flow-through, producing over 2,600 tons struvite per year, containing > 10% phosphorus. New projects are under development or in production in North America.

Caustic or ammonia for pH adjustment

Multiform's cone-shaped struvite harvesting reactors, using magnesium chloride to supply magnesium and caustic or ammonia dosing to adjust pH, can be installed both upstream and downstream of anaerobic digesters (MultiWAS™ configurations). Multiform's system is presented as a **“quick”, once-through system with no recycle and no on-site fertilizer drying**, screening, and packaging equipment. The “flash-crystallized” product is of a quality appropriate for utilization in fertilizers.

Multiform carries out **downstream processing off-site, producing patented Multiform fertilizers** formulated to the required size, shape, hardness, and nutrient profile needs of the specialty fertilizer markets using methods developed and tested with support from the USDA.

Pellet fertiliser product

Multiform's pelletized material is composed of round, smooth spheres, which is thus very flowable, which is **important for handling by fertilizer equipment** and for “bounce and roll” to achieve good distribution when spread onto the ground. Different pellet size ranges can be supplied through processing, and hardness on crush tests measures 4 to 8 pounds-force, ideal for pelletized fertilizers for resisting break-down during handling. Multiform also can produce tablets, spikes, plugs, and other formed products to cater to each client's requirements.

The full-scale Multiform struvite recovery systems already in place today include:

- **Yakima Municipal Wastewater Plant in Yakima, Washington, USA**, commissioned 2012, operating downstream of the sludge anaerobic digesters, after centrifuges. There are two reactors, with 900 litres per minute net flow-through capacity and 35 – 45 kg struvite per hour production.
- **Boise Municipal Wastewater Plant in Boise, Idaho**, commissioned 2012. This is a five-reactor system with each reactor of 490 litres per minute net flow-through capacity and around 50 kg struvite production capacity per hour.
- **Jones Dairy, Maryland**, commissioned 2013, 2500 head of cows, 20 tonnes struvite per year.

Multiform also provides North American and international wastewater operators with **portable struvite recovery pilot plants**, which can operate on specific waste streams. Pilot plants can optimize plant layout and design factors as well as provide hands-on experience with the ease of operation. Pilots have been operated for municipal, food processing, swine production, and dairy waste streams.

Multiform Harvest www.multiformharvest.com

“Scientists testing sustainable P reclaimed from waste”, April 2013 <http://www.agprofessional.com/news/Scientists-testing-sustainable-P-reclaimed-from-waste-194832611.html>

By Steve Werblow

Separation anxiety

Livestock producers await newest struvite crystallization system

Livestock producers anxious to find efficient ways to deal with phosphorus in manure may soon benefit from a new crystallization process that can remove 50% or more of the phosphorus from dairy manure and 80% from swine effluent. Balancing nitrogen and phosphorus can be a challenge when applying manure to crops. Phosphorus (P) is also getting the attention of an increasing number of regulators concerned about its effects on water quality. That means managing it may continue to be an issue for livestock producers. “(Limiting phosphorus is) not mandatory in our nutrient-management plans today, but they're going to be watching it,” predicts dairyman Andy Werkhoven, who milks 900 cows and farms 700 acres with his brother, Jim, near Monroe, Wash.

P balance. Craig Westerbeek of Smithfield Foods hog subsidiary Murphy-Brown in Warsaw, N.C., who hosted a crystallizer pilot project, points out that many producers may someday hit an upper limit for phosphorus application. They'd then be forced to spread their applications out over more acres, add commercial nitrogen



about this tack is it has the possibility of allowing the producer to dial in a nitrogen/phosphorus ratio without having to buy additional nitrogen.”

► Above: Keith Bowers of Multiform Harvest in Seattle, Wash., is fine-tuning the process of crystallizing phosphorus in manure as struvite.



Thermal chloride treatment

Heavy metal extraction from sludge ash

Two papers present results of experiments in pilot scale rotary kilns where pelletised sewage sludge incineration ash was heated to 900 – 100 °C with a chlorine donor chemical to remove (by evaporation of metal chlorides) heavy metal contaminants from the ash.

The flue gas was treated by a cyclone and a wet scrubber. Effectiveness of heavy metal removal required the higher temperatures. **Relative effectiveness for copper or zinc removal depends on the chlorine donor chemical used.** All phosphorus is retained in the ash (but some is lost as ash is lost in flue gases), whereas much of the potassium (K) is lost.

In the 2008 paper, **two different rotary kilns** were tested, a 1.25 m long x 0.35 m diameter directly heated kiln (methane and oxygen injected into the kiln) and a 1.07 m long (of which, heated zone 0.6m) x 0.08m diameter indirectly heated kiln (electrical heating round the kiln body). In this paper, two different chlorine donor chemicals (KCl, MgCl₂) were tested.

In the 2010 paper, **two different ashes were tested** (from a cyclone and from a fluidised bed sludge furnace), plus a mixture of these two ashes, in two different pellet forms (briquettes, rolled pellets), at different temperatures (900°C, 1000°C, 1100°C).

Residence time in the kilns was c. 30 minutes, with flue gas flow rates of 120-180 Nm³/h.

Pelletised ash

Previous studies (eg. Adam 2004, Kley et al. 2004, 2005, SUSAN 2006) have tested **heavy metal removal from sewage sludge incineration ash using MgCl₂, KCl, liquid hydrochloric acid HCl and gaseous chlorine Cl₂.** These studies used fine ash, as produced by sludge incinerators, whereas the two studies presented here pelletised the ash with the chlorine donor chemical by adding water, then passing through pelletising equipment.

The pellets then had to be dried, in the case of rolled pellets, but not in the case of pressure-compacted briquettes. Pellets were around 1-3 cm³ with density of 1.4 g/cm³ (rolled) or 1.9 g/cm³ (briquettes).

Most of the chlorine added to the ash pellets (c. 85% at

1000°C) is volatilised in the kilns. Some 5 – 35% of the ash is lost in the flue gas, and recovered in the cyclone flue gas treatment. Phosphorus loss is correlated to ash loss.

Heavy metal removal

Three groups of heavy metals are distinguished: non-volatile (Cr, Ni), partly volatile (Cu, Zn) and highly volatile (Cd, Pb). Removal of the non-volatile metals from the ash is low (zero removal - 35%), whereas removal rates for Cd and Pb range from 65% to nearly 100%.

The 2008 paper indicates that **copper removal** was better with KCl used as chlorine donor, whereas zinc removal was better with MgCl₂.

KCl caused particle abrasion from pellets in the kiln, and also at lower temperatures released liquid KCl which acted as a barrier to heavy metal evaporation.

The 2010 paper does not specify what chemical was used as a chlorine donor. In this paper, **temperature was again a key variable for obtaining effective heavy metal removal.** Ash type was important, as higher silicon content of the ash from the fluidised bed sewage sludge incinerator (more complete burning) reduces the availability of chlorine for heavy metal volatilisation. Pellet form (and density) seemed to make only marginal differences. 15-19% of the added chlorine remained in the treated ash pellets (at 1000°C).

The authors conclude that such **high temperature, chlorine addition treatment can provide an effective route for removing heavy metals from sewage sludge incineration ash** to generate a product which can be used for inorganic phosphate fertiliser production. They note that specific operating conditions will define to what extent copper and zinc are removed.

However a number of questions remain.

- What is the **economic feasibility and overall ecological impact** of this process, given the high temperature process and the chemical inputs required?
- Does the **residual chlorine** left in the treated ash pose a problem?
- **How much of the phosphorus is effectively lost** in the flue gases (as particles, recovered in the polluted cyclone waste)?



- What are the **gaseous emissions** of this process (NO_x, chlorine compounds, heavy metals) and can these be fully removed by flue gas treatment?
- What about **heavy metals (Cr, Ni)** which are not or scarcely removed by the process?

Current status update

These two 2008 and 2010 papers reflect the state of the technology when they were written, some time before their publication date. The **ASH DEC technology** is very similar to the **SUSAN** process (see SCOPE Newsletter n° 78) www.susan.bam.de). It has now been taken over by **Outotec, Finland**, but has not yet implemented at large scale.

Outotec currently estimate **the cost of the recovered phosphate product is c. 1.8 Euros/kgP** (phosphorus). The overall ecological impact has been positively assessed by various authors (e.g. Lederer and Rechberger 2010 (see SCOPE Newsletter n° 89).

Losses of particulates from the furnace have been reduced to c. 2% of recovered phosphate product. The high losses during the tests were due to the small kiln that was heated by a large gas burner blowing into the kiln and causing high gas velocities in the kiln. Because this is the only loss of phosphorus in the process, 98% of phosphorus is thus recovered.

Control of gaseous emissions is achieved using a semi-dry air pollution control system. Chlorine is internally recycled in the process by dry adsorption. Nickel and chromium are not removed from the treated sludge incineration ash, and remain in the recovered phosphorus product, but this is usually not a problem because of low concentrations of these contaminants in sewage.

Plant fertiliser value

The fertiliser value of the recovered phosphate product has been assessed in **pot trials using rye grass *Lolium multiflorum***.

See Nanzer et al. "The plant availability of phosphorus from thermo-chemically treated sewage sludge ashes as studied by 33P labelling techniques", *Plant Soil* 2014 <http://link.springer.com/article/10.1007%2F978-94-007-1110-4-013-1968-6>).

The plant uptake (mgP/pot) and the plant availability (% P uptake from the fertiliser) were assessed for 2 different recovered phosphate products (produced by this thermal + chlorine donor process) and compared to a water-soluble phosphate fertiliser.

See also Nanzer et al., 2010 in SCOPE Newsletter n° 102 (PHOSKRAFT project).

The recovered phosphates showed similar plant availability to phosphate fertiliser **in non-alkaline soils (pH 4.5 or 6.2)** when magnesium chloride was used as the chlorine donor in the process. In soil pH 7.8, the plant uptake from the recovered phosphate was significantly lower than from the phosphate fertiliser. **Plant availability from the recovered phosphate was lower when calcium chloride was used as a chlorine donor.**

Since publication, **an alternative treatment has been developed which overcomes the low solubility on alkaline soils** but with a less effective heavy metal removal.

"Sewage sludge ash to phosphorus fertiliser: Variables influencing heavy metal removal during thermochemical treatment", *Waste Management* 28 (2008), pages 2709–2722, www.elsevier.com/locate/wasman

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"Sewage sludge ash to phosphorus fertiliser (II): Influences of ash and granulate type on heavy metal removal", *Waste Management* 30 (2010), pages 1622–1633

Authors as above plus M. Jöller (a), P. Herk (b), L. Hermann (a,c)

The phosphorus challenge

Blog

Role of researchers in decreasing P inequality

From September 1st to September 3rd, scientists from around the world met in Montpellier to discuss how to better manage an essential element for all of us at the Sustainable Phosphorus Summit 2014.

This article is a personal contribution by Genevieve Metson and does not represent ESPP. For reactions to this article and other contributions see the Sustainable Phosphorus Blog at <http://www.phosphorusplatform.eu/blog.html>

Phosphorus is an essential fertilizer in agricultural production, but mineral deposits are not equally spread around the world, and access to and need for such

fertilizers is also unequal. As such, **phosphorus matters for food security**.

In addition to this scarcity problem, when we lose phosphorus from agricultural landscapes or from cities to our waterways, **detrimental algal blooms can occur in our lakes and oceans** (for a recent example look at Lake Erie summer 2014).

Scientists, policy makers and industry are working on ways for society to **use phosphorus more efficiently and recycle wasted phosphorus along the food chain back into agricultural production**, but we still have a way to go.

Over the Sustainable Phosphorus Summit, we heard some of the cutting edge research on both problems and solutions associated with phosphorus management, from soil-plant interactions to regional changes in human diets and wastewater treatment processes.

Phosphorus inequality

One of the big problems, which many at the conference thought deserved more attention, is **inequality of access to phosphorus**.

In a workshop session on the last day of the conference, 25 of us decided to think about what role we, as researchers, can play in decreasing inequitable access to this non-substitutable fertilizer. We decided to do so by contextualizing the role of researchers within the priorities of phosphorous producers and phosphorus consumers in the development of more equitable phosphorus management.

Setting the stage: What is the phosphorus inequality problem?

Although the vast majority of mined phosphorus reserves are in Africa (mostly in Morocco), farmers on **in Africa** often have the highest need for P fertilizer and the least access. There are high phosphorus requirements for agriculture because most of the soils are old and high in other elements, like iron or aluminium, that make it difficult for plants to access the phosphorus that is applied. In addition, as fertilizer applications have been low for many years, there aren't even reserves in the soil that could be utilized by plants that have developed advantageous adaptations to these soil conditions.

Access to fertilizers is difficult for farmers in Africa because costs are high (due to transportation

difficulties and limited amounts on the market) and because often farmers have a very limited income, making fertilizer purchases unaffordable for them.

On the other hand, **many areas of the world with more money have been applying excess phosphorus for years**. Sustainable phosphorus management not only entails limiting pollution, it also means ensuring that all farmers have access to enough phosphorus to ensure local and global food security.

Currently poorer nations, especially in Africa, are far from having access to the phosphorus they need, creating a situation of inequality.

The workshop: how can researchers help the situation?

There is no pressure or driver for phosphorus producing countries and companies **to change processes or business models** as long as they have access to the resource and are selling phosphorus at a good price. Requiring a firm target for use of recycled products in fertilizer production and encouraging enterprise for local and small-scale production could be a way forward. This entails changing the market, but also changing what it means to be a "producer of phosphorus". This new definition could include phosphorus reuse sources and small exploitation. Such a shift could allow for the local redistribution of power with regards to phosphorus availability and take advantage of co-benefits between phosphorus management, sanitation, and food security (to name a few), and as such address multiple local priorities at once.

The primary **concerns of phosphorus consumers** (including phosphorus importing countries and individual farmers) moving forward are related to understanding the diversity of the phosphorus resources and the security of supply. Access to phosphorus resources should be tailored to each specific region, country, and context so that the consumers have fair access to the forms of phosphorus they can afford either financially and/or practically.

Research needs

Research needs to **support recycling** in order to achieve an equitable redistribution of resources ensuring fair rights to phosphorus.

We need to develop easy and **low cost soil tests** and tools that make it possible to assess phosphorus needs



and resources at many scales. Such tests would allow more equitable access to information.

We, as researchers, should also support more comparative (or partnered research) between nations, farms, and cities across the spectrum of phosphorus accessibility to ensure research findings are accessible and applicable to many contexts. Specifically **partnering research projects** to include currently phosphorus-rich areas of the world to phosphorus-poor areas would be an important step forward.

Whilst it was agreed that large-scale policy changes emanating from governments and international organizations are essential to create a more equitable phosphorus system, researchers can help to drive this transition by **communicating and translating the needs of farmers and communities into practical research** that presents tangible, multi-scale solutions. Improving technologies for phosphorus recycling through industry- and NGO-partnered research will also help to drive policy change by improving the socioeconomic acceptability of phosphorus exploitation from alternate resources.

The role of **economic incentive** as a driver of change cannot be over-emphasized. As such, it must be a central consideration for research development to deliver the impact required to effect the systemic change necessary for future food security.

This article is a personal contribution by Genevieve Metson, McGill University Montreal Canada genevieve.metson@mail.mcgill.ca With thanks to: Tina Shmid Neset, Jessica Sheperd, Zenah, and Rosanna Kleeman for helping run the workshop. Sustainable Phosphorus Blog at <http://www.phosphorusplatform.eu/blog.html>

ECIP vision for sustainable phosphorus management

Improving phosphorus use efficiency on EU dairy farms



Increasing global demand for dairy products presents a significant opportunity for expansion within the dairy sector. The EU dairy sector

recognises that its drive to sustainable intensification requires more efficient P management and identifies a vision where farmers, their consultants and supporting

industries will: (1) engage with the P sustainability agenda, (2) target P inputs to optimise utilization, (3) embrace emerging cost-effective recovery and recycling technologies, and (4) minimize adverse effects on the environment and human health.

Farmer awareness and engagement

Development of **gold standard metrics and user-friendly tools** will be required to build confidence and encourage proactive engagement by the farming industry in P use efficiency. This can be aided through **EU wide initiatives to share information, exploit emerging technologies for more sustainable P use**, and co-ordinate EU dairy research and knowledge exchange to optimise P efficiency, minimise environmental damage and improve profitability.

Vision: a progressive sector that is proactive in creating and encouraging uptake of tools, metrics and emerging technologies to meet farmer needs towards more sustainable P use.

Targeted P inputs

The sector recognises the **need to realign P inputs to match requirements more precisely** through improved understanding of the P requirements of both forages and livestock. Development and uptake of rapid forage and soil testing techniques, supported by innovative IT solutions for data recording and decision support, should be encouraged to facilitate precision management of P at farm, field and animal scales. Technologies should also be developed to improve the digestibility and utilization of feedstuff P and the placement of fertiliser P. These developments should be underpinned by increased understanding of the role of animal and plant genetics in improving P efficiency.

Vision: A sector that better understands P requirements of crops and animals and embraces existing and new measurement techniques to better target P inputs.

Closing the P cycle

Advancing technological developments in low cost options for manure processing and storage present an opportunity to **improve the recycling of P in dairy manures**. However, further work will be required to reliably quantify the availability of P in recovered and recycled products. There is scope for technologies such

as manure separation to facilitate improved distribution of P to land and manure processing to increase N:P ratios so that manures can be applied without breaching any future restrictions on organic P loading to land.

Vision: Recovered and recycled 'fertilizer-grade' products which substitutes imported rock-phosphate derived fertilizers and feed supplements.

4. Minimize environmental impacts

Dairy sector participation in **river basin and catchment management planning** is required to help develop landscape-based solutions to sustainable P management. Sustainable intensification requires an integrated approach which takes account of landscape connectivity, soil and local climatic factors to balance environmental and productivity objectives. There is also scope for greater awareness and adherence to the 4R stewardship of input management to reduce P losses in surface runoff.

4R's of nutrient stewardship incorporates the Right fertiliser source at the Right rate, Right time and the Right place.

Vision: A sector that is actively involved in strategies to minimise environmental impact of the dairy sector while recognising the requirements of profitable production.

ECIP: The European Cattle Innovation Partnership (ECIP) is a collaboration of farmer funded levy bodies, which aims to work more closely in the co-ordination of applied research, development and knowledge exchange in the European cattle industry. The partnership was formed under a Memorandum of Understanding, signed in June 2012 by dairy levy boards from Denmark, Netherlands, France, GB, Northern Ireland, Sweden, Republic of Ireland and Israel. The Memorandum sets out an overarching deliverable to improve the efficiency of resource utilisation, aiming to increase the economic, social and environmental sustainability of dairy farming. ECIP represents around 10m dairy cows, and thousands of SME's, which make up the dairy sector in key milk producing regions of the EU. Focussing on farmer requirements, the objective is to ensure better value for money for levy funded research and development, by sharing knowledge, avoiding duplication, and ensuring better translation of research results into practice.

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Challenges

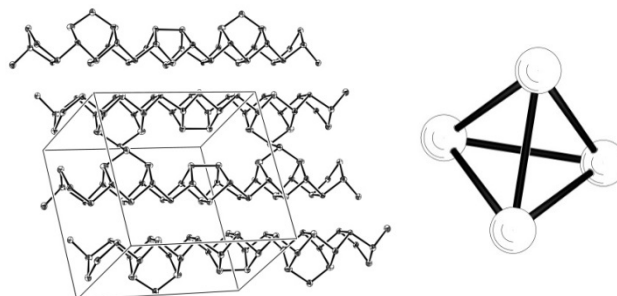
Phosphorus chemistry

C. Cummins (MIT) summarises the qualitative challenge of phosphorus management (why P is scarce in the cosmos, so making it critical for life on Earth and for environmental quality) and identifies some specific chemistry challenges to make industrial P-use more sustainable.

The element phosphorus P never occurs naturally as a phosphorus, and in particular not as a double atom molecule (P₂), despite its similarity to nitrogen N, which occurs naturally as very stable and inert N₂ (with a triple bond linking the two N atoms), the gas which is 80% of Earth's atmosphere. Phosphorus only occurs in nature in oxidised forms (phosphates, PO₄ and derivatives).

Elemental phosphorus can be synthesised as P₄ (white phosphorus, see below) which is highly reactive. White P can be converted to the more stable red phosphorus with cages of P atoms connected into linear tubes and cross-linked to form a polymeric network, see below.

Structures of red (right) and white (left) phosphorus:



In industry, **white phosphorus, P₄**, is used to produce a wide range of valuable organic and inorganic products, by first combining with chlorine to produce PCl₅ (so bringing the phosphorus to oxidation state +5) before exchanging the chlorine with other molecules.

Chlorine-free P chemistry challenge

Developing a route to use white phosphorus in the chemical industry without chlorine as an intermediary would offer environmental advantages (avoid pollution and waste issues related to chlorine production and chemistry). The author suggests that organic radicals could provide an alternative intermediary, but initial experimental work needs developing and taking to industrial application.

Another route could be to synthesise P₂ from white phosphorus and then to react this with organic molecules.

Cosmic scarcity

The author explains that **phosphorus is a nuclear improbability**. Nuclei with odd atomic numbers are generally unstable, yet ³¹P is the only atomically stable form of phosphorus. ³¹P is produced by a highly improbable sequence of nuclear reactions (terminating by ³¹Si → ³¹P) which occur only in an explosive neon burn phase in the core of massive, hot stars. **This is why phosphorus is present in the cosmos, and on Earth, at levels which are orders of magnitude lower than the other biogenic elements** (carbon, hydrogen, nitrogen, oxygen, sulphur). It is for this reason that phosphorus is the “limiting element” in many ecosystems.

Mankind’s massive consumption of phosphorus, mined from phosphate rock, which consists mainly of biological deposits from the sea mineralised over millions of years, is thus not only posing long-term questions of how long these reserves will last, but also causing **massive ecosystem disruption through eutrophication** of inland and coastal waters.

“Phosphorus: from the stars to land & sea”, *Daedalus*, *J Am Chem Soc*, 143 (4), 2014 online at <http://www.mitpressjournals.org/toc/daed/143/4>

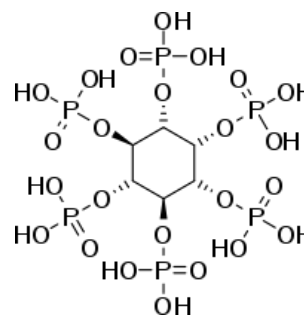
C. Cummins, *Massachusetts Institute of Technology*
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4-5 December, Florence, Italy: 1st International Conference on Sustainable P Chemistry
www.susphos.eu/ICSPC

Review

Phytate and health

Phytate (myo-inositol hexakis phosphate) is widely present in other plant-derived foods (see SCOPE Newsletter n°78), comprising 0.5 – 5% weight of seeds and grains. It is poorly digested by non-ruminant animals (including man). Phytate is known to reduce availability of a number of minerals in food (calcium, several metal micronutrients) and may possibly also reduce nutritional value of protein. However, there is also evidence that phytate in diet may have positive health effects, including reducing risk of kidney stones or of certain forms of cancer.



Phytate (above) is particularly high in vegetarian diets and in diets rich in non-processed seeds and grains, and is significantly lower in processed foods (such as white bread). **Phytate intake is estimated at 2 - 2.6 g/day for vegetarian diets, compared to 0.15 - 1.4 g/day for mixed diets**. Phytate in vegetables can be reduced by cooking, for example by -20% by boiling.

Non-available phosphorus

Because phytate is not or only poorly broken down in the digestive system of non-ruminant animals (including man), **its phosphorus content is not bioavailable in diets**, and it may also have other significant health impacts.

Phytate and metal ions, proteins, starch

The phosphate groups of phytate act, in a wide pH range, as a highly negatively-charged ion, with a **negative impact on bioavailability of positively-charged metal ions such as calcium, magnesium, zinc, copper, manganese**. This may have negative health implications if mineral levels in the diet are low.

There has also been discussion of **possible negative effects of phytate on protein digestibility**. This may be consequence of formation of insoluble phytate-

protein complexes, or phytate-induced modifications of protein structure. Phytate may thus inhibit certain digestive enzymes. However, other studies have shown no negative impact of phytate on protein nutritional value.

It has also been shown that **phytate can reduce the digestibility of starch** in vitro, so may possibly have a positive effect in Western diets with excessive carbohydrate levels and risks of diabetes, but this also has not been confirmed by studies.

Positive health effects of phytate?

It has been suggested that phytate in diet may help **prevent risk of heart disease**, but this is based on only a few animal and in vitro studies. The mechanism may be related to phytate **preferentially binding zinc rather than copper**, so increasing copper/zinc uptake ratio.

More convincing is evidence that **phytate plays a significant role in reducing risk of kidney stone formation**, probably by preventing the formation of calcium oxalate and calcium phosphate crystals which function as nuclei for stones.

There are also suggestions that **phytate may reduce the risk of certain cancers**. Phytate has been shown in vitro to be a wide-spectrum antineoplastic agent, inhibiting the growth of a range of different human cancer cells, and in vivo to reduce colon cancer in both rats and mice. This may be related to phytate's chelating properties, or possibly by modification of cell signalling mechanisms, binding of metal ions which are related to DNA synthesis or inhibition of starch digestion.

Also, phytate is recognised to have an **anti-oxidant** role, with one known mechanism being its interaction with iron to prevent iron catalysing hydroxyl radical formation.

The author concludes that **very little data is available concerning the health effects of dietary phytate on humans** and that more work would be important because of phytate's significance in plant-based foods.

"Potential health benefits and adverse effects associated with phytate in foods: a review", Global Journal of Medical Research K Interdisciplinary, 14, 3, 10 2014

<http://medicalresearchjournal.org/index.php/GJMR/article/view/709/0>

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Call for papers

Science of the Total Environment: Special Issue "Sustainable Phosphorus"

Taking stock: phosphorus supply from natural and anthropogenic pools in the 21st century.

Submission deadline: December 2014

This issue will target understanding of stocks of phosphorus in the environment and vulnerability to supply security, in particular regions with limited access to phosphorus compared to demand.

- **Reserve and resources assessments** of phosphate rock (at particularly relevant mine sites; also offshore)
- **P availability, access, and processing** (issues of cost, related energy or water use, other minerals)
- **Stock quality and impurities** (e.g. Cd, U, REE; by-product recovery)
- **Anthropogenic stock**: e.g. manure, urine, food (trade/waste), bio waste, processes animal feed, waste, water; urban P mining)
- **Other natural stocks**: e.g. soils
- **Methodological or technological advances** in mining, processing, or recycling (including barriers and opportunities)
- **Conceptual or theoretical papers** on e.g. reserves/resources terminology are also welcome

Guest Editor: *Andrea E. Ulrich, ETH Zurich*
andrea.ulrich@usys.ethz.ch Editor-in-Chief: *James P. Bennett, University of Wisconsin, U.S., jpbennet@wisc.edu*

Authors instructions and further information:
<http://www.journals.elsevier.com/science-of-the-total-environment/call-for-papers/special-issue-on-sustainable-phosphorus/>



Agenda

- ❖ 27 Nov., Strasbourg, 13^o RITTMO professional workshop: **European Harmonisation of fertilisers & growing media**, in French http://www.rittmo.com/IMG/pdf/programme_des_23emes_rencontres_professionnelles_rittmo.pdf
- ❖ 27 Nov., Aachen, **Phosphorus: sustainable management of a critical raw material**, in German <http://www.aka-ac.de/>
- ❖ 28 Nov., Wageningen, Netherlands, **Smart Fertilisation Seminar** precision fertilisers & recycled products www.fertilizerplacement.nl

❖ 2 December, Brussels: **ESPP (European Sustainable Phosphorus Platform) meeting**: legal establishment of the Platform, P as an EU Critical Raw Material www.phosphorusplatform.eu

- ❖ 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>
- ❖ 15-16 Jan 2015, ETH Zurich, Switzerland: **P in Agriculture: where are we going** http://www.plantnutrition.ethz.ch/box_feeder/booklet_2p.pdf
- ❖ 24 Feb 2015, Nottingham, UK, **Phosphorus removal from catchments** (AquaEnviro) <http://www.aquaenviro.co.uk/view-product/Phosphorus-Removal-from-Catchments--Technology-or-Source-Control>

❖ 5-6 March 2015, Berlin: **2nd European Sustainable Phosphorus Conference** www.phosphorusplatform.eu

- ❖ 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/mining-and-metallurgy/beneficiation-of-phosphates-vii/>
- ❖ 31 Mar - 3 Apr, Seattle, International Conference on Livestock and Poultry Environmental Quality – **Waste to Worth** <http://water.okstate.edu/news-events/conferences/waste-to-worth-2015>

- ❖ 3-7 May 2015, Barcelona, SETAC Livestock Environmental Assessment and Performance (LEAP) Partnership session, **challenges for global modelling of N & P in agriculture supply chains** http://barcelona.setac.eu/home/?contentid=767&pr_id=766
- ❖ 1 May – 31 Oct. **Expo2015** Feeding the planet, energy for life, Milano <http://en.expo2015.org/>
- ❖ 18-20 May 2015, Marrakesh, Morocco: **SYMPHOS** www.symphos.com
- ❖ 18-21 May, Gdansk, Poland, **IWA Nutrient Removal and Recovery Conferences** <http://www.iwahq.org/2jw/events/iwa-events/2015/nrr2015.html>
- ❖ 18-22 May 2015, Washington DC, **Phosphorus Research Coordination Network (P-RCN)** <https://sustainablep.asu.edu/>

❖ 19 May, Washington DC **launch of the North America Phosphorus Partnership (NAPPs)** <https://sustainablep.asu.edu/>

- ❖ 2-4 Dec 2015, Ghent, Belgium, **ManuResource II** (manure valorisation) <http://www.manuresource2015.org/>

Calls for papers

20th October 2014: call for papers - **Resources, Conservation and Recycling**: Losses and Efficiencies in P Management <http://www.journals.elsevier.com/resources-conservation-and-recycling/>

15th November 2014: call for presentations, success stories, posters – **2nd European Sustainable Phosphorus Conference** <http://www.phosphorusplatform.eu/conference/espc2015.html>

December 2014: call for papers – **Science of the Total Environment** - Taking stock: Phosphorus supply from natural and anthropogenic pools in the 21st <http://www.journals.elsevier.com/science-of-the-total-environment/call-for-papers/special-issue-on-sustainable-phosphorus/>

Nutrient Platforms

Europe: www.phosphorusplatform.eu

Netherlands: www.nutrientplatform.org

Flanders (Belgium):

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

Germany: www.deutsche-phosphor-plattform.de

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