European Sustainable Phosphorus Platform

SCOPE NEWSLETTER

Sustainable phosphorus policies

European Sustainable Phosphorus Platform

Regulatory challenges to phosphorus recycling

45 stakeholders discussed regulatory issues surrounding the use of recycled phosphates in agriculture. Proposals concerning the EU Fertiliser Regulations, End-of-Waste, REACH, Nitrates Directive and national regulatory implementation were developed and will be taken forward.

Phosphorus policies

Denmark, Baltic States P-recycling policies

Baltic region States (HELCOM) have committed to improved nutrient management, including enhanced phosphorus recycling. Denmark has announced a new waste recycling strategy, including P-recycling from manure, sewage biosolids and food wastes.

Phosphorus on the field

Phosphorus management in the UK

An update on eutrophication challenges in the UK, national phosphorus flow analysis and agricultural management of phosphorus in biosolids was presented at the European Sustainable Phosphorus Platform stakeholder meeting at the Farmers Club in London.

Phosphorus biotechnology

Review of the Phosphorus Challenge

Current Opinion in Biotechnology has published a special edition examining the challenge posed by phosphorus stewardship, reviewing the different areas where progress in biotechnologies is needed to address this challenge.

P-REX Poděbrady

P-recycling technologies and markets

Evaluating and demonstrating P-recycling technologies and stakeholder workshop on markets for recycled phosphate products

Phosphorus supply and fertilisers

Fertilisers Europe

European fertiliser decadmiation workshop

70 stakeholders met to discuss current science on cadmium in agricultural soils, on fertiliser decadmiation process development, on the current and proposed regulatory context and on proposals for action.

Phosphorus supply

P rock resources and reserves critically examined

A detailed examination of various phosphate rock reserve and resource figures and consumption scenarios criticizes the IFDC figures, which quadrupled reserve estimates in 2010, stating that they contain a number of significant errors. The review suggests that considerable confusion abounds in various published figures and that an independent reassessment of global deposits is needed.

Peak phosphorus debate

Predictions of phosphorus resource depletion

Production – demand interaction model and new estimates of rock resources are used to make new predictions for 'Peak Phosphorus'

IFDC

IFDC clarifies and confirms phosphorus rock reserve figures

IFDC (International Fertilizer Development Center), Alabama, has provided clarification of its phosphate rock reserve and resource estimates, widely used internationally, confirming that these figures conform to industry and professional expert opinion

Nutrient management ideas challenge

EU consultation on phosphorus use

http://ec.europa.eu/environment/consultations/phosphorus_en.htm
(until 1st December 2013)

Agenda: dates 2013-2014

The partners of the European Sustainable Phosphorus Platform

ICL Fertilizers Europe · Nutrient Platform NL · Thames Water · Outotec · Fachhochschule Nordwestschweiz · United Utilities · Science Campus Phosphorus Research Rostock · NuReSys · Ecophos · Ostara · Fertilizers Europe

Sustainable phosphorus policy

European Sustainable Phosphorus Platform

London meeting addresses regulatory challenges to phosphorus recycling

45 stakeholders from agriculture, authorities, waste water treatment, the fertiliser industry, the waste sector and recycling operators met on 24th September 2013 at the Farmers' Club, London, to discuss regulatory issues relating to the use of recycled phosphates in agriculture. Organised by the European Sustainable Phosphorus Platform, the meeting was based entirely on questions and field examples submitted by operators and participants beforehand, and aimed to identify key issues and proposals to take forward with regulatory authorities.

This Newsletter provides a summary of the meeting, a more complete record of discussions is available online on the European Sustainable Phosphorus Platform website *www.phosphorusplatform.eu*

From waste to product

Discussion and examples from different countries emphasised the **complexity of regulations concerning phosphorus recovery and biosolids recycling** to farmland, with different specific legislations covering:, animal by-products, waste, end-of-waste and quality protocols, possibly in the future: fertiliser regulations, operating authorisation for processing plants, land application constraints: Nitrates Directive, Water Framework Directive, Sewage Sludge or Soil Directives and their regional implementation

- Proposal: Simplify and harmonise the **regulatory status of bio-waste/biosolids processing products derived from multiple input streams**, to facilitate appropriate and safe nutrient recycling. In all cases, it must be ensured that the processing chain entails no risk for pathogen contamination and that complete information is given to the users e.g. agronomic efficiency, nutrient contents, etc.
- In particular, review the regulation of **Meat and Bone Meal Ash**, because this contains significant phosphorus resources, to facilitate phosphate recycling subject to safety requirements.
- Proposal: "Waste" is perceived as negative. There is a need to **recognise biowastes / biosolids as a resource**. The development of End-of-Waste criteria or comparable certification processes (product characteristics specifications) could contribute to this.
- Proposal: There is a strong **need for support to operators**, to assist in identifying the regulations applicable to a given biosolids treatment and output (depending on the different biosolids input), and to define the appropriate dossiers and regulatory processes needed.

The principle set by the Waste Framework Directive 2008/98/EC is that, to enable recycling, "waste" can be processed to cease to be a waste, according to specific **"End-of-Waste" criteria (EoW)** (defined at either the EU or national level), and so becomes a "product" (no longer subject to waste regulation). The Directive specifies that, for EoW criteria to be defined, "a market or demand" must exist and that the produce must be "commonly used for specific purposes" and must "fulfill the technical requirements for the specific purposes". End-of-Waste also requires that the substance is safe, that is not risk harm to humans and offer "a high level of environmental protection" or "not lead to overall adverse environmental or human health impacts". This can be summarised as 'recovery without harm'.

The EU is currently considering **possible European EoW criteria for composts and digestates**. Stakeholders can submit input and comments at *http://susproc.jrc.ec.europa.eu/activities/waste/* and report at http://susproc.jrc.ec.europa.eu/activities/waste/documents/IPTS%20EoW%20Biodegradable%20waste%20Draft%20Final%20Report.pdf

- Proposal: **End-of-Waste and Quality Protocols** can be valuable tools to ensure the quality of recycled products, and so maintain consumer confidence in recycling routes.
- Proposal: Where End-of-Waste criteria are developed, these should explicitly specify the **interactions with other legalisation**, including product use specifications (eg. fertiliser regulations), manure and animal by-product regulations, Nitrates Directive …
- Proposal: **Nutrient content of biosolids** should be taken into account in defining EoW criteria, should be specified and of course appropriately communicated to farmers.
- Proposal: End-of-Waste criteria should be coherent with the **Fertiliser Regulations update**: the "technical requirements for the specific purpose" for End-of-Waste should be conformity to the Fertiliser Regulations
- Proposal: Research and monitoring nto **contaminants**, with a **risk assessment approach**, should ensure that traces of pharmaceuticals, endocrine disruptors, hormones or other contaminants in biosolids, as used, are not an environmental or human health risk, in order to ensure farmers and the public.
- Proposal: the European Sustainable Phosphorus Platform is planning to organise a future European stakeholder meeting to specifically address the question of how to **increase phosphate recycling whilst ensuring food safety**, consumer confidence, agronomic and economic efficiency of the recycled phosphates.

REACH obligations

Rachel Green (ReFaC) explains that REACH registration is generally obligatory for any company (or organisation) producing a recovered phosphate chemical product, which ceases to be a "waste", subject to various provisos and comments. REACH registration obligations and formalities are explained to participants.

Compost and biogas do not require REACH registration because they are specifically exempted from registration and certain opinions suggest that anaerobic digestates are also exempted from REACH. Biochars, however, can be considered to be comparable to charcoal which does require REACH registration, as do ashes from incineration of biosolids, biomass or wastes and products produced from such ashes.

A question has been raised concerning how **"recovered substances" are exempted from REACH registration** under certain conditions (art. 2(7)d of the REACH regulation). However, it is currently unclear whether this can exempt producers of recovered phosphate products (e.g. struvite), because of differing National Authority interpretations, and because it is only applicable in certain specific situations.

- Proposal: The European Sustainable Phosphorus Forum will work to clarify question concerning interpretation of the **REACH "exemption" for recycled phosphate products**.
- Proposal: It would be helpful to facilitate access for recycled P producers to **appropriate accompanying services for REACH formalities**: identify service providers familiar with the products and issues in question

The REACH dossier for struvite was successfully submitted by Berlin Wasserbetriebe for the 2013 REACH registration deadline (EINECS n° 232-075-2). Organisations and companies producing struvite must purchase a 'Letter of Access' to the struvite joint registration dossier before submitting their REACH registration.

- Proposal: **All companies or utilities producing or planning to produce struvite** should contact as soon as possible Berlin Wasserbetriebe to organise purchase of the Letter of Access to the struvite REACH dossier, obligatory for REACH registration of struvite: *Alexander.Schitkowsky@bwb.de*
- Proposal: It is recommended that **clear definition(s) of struvite (or of different grades of struvite)** are agreed and made public, in order to

avoid confusion between products with negligible organic content and contaminants and products consisting of a mixture of struvite with organics.

- Proposal: Further **science-based information is needed concerning organic chemical contaminants** (hormones, pharmaceuticals, consumer product additives) in struvites as a function of the waste stream from which the struvite is produced and as a function of the product's organic content. Similarly this should be done for other phosphates recovered by different process routes.

Recovered P fertilisers and fertiliser standards

The EU Fertiliser Regulations 2003/2003 are currently undergoing revision, and are likely to be widened to cover organic soil amendments. Participants envisaged that recycled phosphate products be part of this revision, which should hopefully simplify access to the EU market for those products.

The importance of but **difficulty in defining and testing available P and N in composts and organic soil amendments** is underlined. It is very important to inform the users in support of their efforts to reach optimal nutrient use efficiency and sustainable farm productivity. Both immediate availability and long-term nutrient availability are important, but with different implications for the farmer and for the environment. However, requirements must not result in excessive testing costs. The question was raised of plant availability (and so fertiliser value) of phosphates in recycled sewage biosolids-based products where iron or aluminium is used for chemical P removal in municipal wastewater treatment.

- **Proposals for the EU Fertilisers Regulations updating**:
- **Clearly define what can be considered to be a "recycled" product** (or partly recycled product). This should be coherent with the End-of-Waste process, including e.g. specifications concerning % of different nutrient and organic content which are recycled and concerning the % of nutrients which are plant-available (although plant availability may be difficult to define/test)
- Clearly **differentiate in definitions** between organic soil amendments, precipitated recovered phosphates, products recovered from thermal processes/ashes, fertilisers derived from phosphate rock or thermal processes. Wording such as "mineral" should be made explicit as to whether it refers to phosphate rock or to inorganic phosphate chemicals.
- **Contaminant and safety requirements should be clearly defined for the different types of fertilisers**. Based on these requirements, appropriate testing methods and obligations should be identified. Only fertiliser types for which it can be demonstrated that a given contaminant is not expected to occur (because of the raw materials and production process) should be exempted from testing. The variability of organic materials and waste recovered materials should be taken into account. Full testing of substances used for food production is important to guarantee food safety to consumers and public confidence.
- **Specifications for different types of product may depend on defined intended uses**. They should be coherent with End-of-Waste criteria.
- **Farmers should be fully and precisely informed** on the products they use, and thus the nutrient content and release pattern. Nutrient content and plant availability (rapidly available or slow release, probably using pragmatic proxies such as extractability or solubility) should be defined in the Fertiliser Regulations, within reasonable ranges, and communicated in a harmonised manner for all products.
- **Regulations must be flexible to encompass new processes combining different waste flows** to optimise process operation and recycling potential, to take into account different recycling routes and waste stream characteristics in different Member States, and must ensure coherence with other regulations (animal by-products, REACH, End-of-Waste, Nitrates Directive, food safety)
- In particular, **coherence must be ensured** between the updated Fertiliser Regulations and the proposed Sludge or Soil Directive and possible updating of the other legislation.

Policy proposals for phosphorus recycling

Participants consider that existing regulations were not designed with phosphorus recycling as an objective, and that there are opportunities for taking better account of phosphorus management when regulations are updated or modified, as well as in implementation of existing legislation.

- **Proposals for regulatory support to develop phosphorus recycling**:
- Establish **clear, stable over time, political targets** for phosphorus recycling and for sustainable phosphorus management to drive their integration into regulation and policies and market implementation
- **Incentive to include recycled phosphates in fertilisers placed on the market**. There is need to develop a workable proposal and assess its economic impacts, feasibility and other effects.
- **Penalise or phase-out waste and biosolids disposal routes** which result in phosphorus being lost to ash where it is not recycled (mixing of high and low P wastes in incinerators, landfill or non-reversible disposal of ash)
- Promote integration of phosphorus management objectives into **EU Common Agricultural Policy (CAP) and Rural Development Programmes (RDP)** (cross compliance)
- Need to propose **appropriate funding and cost coverage frameworks tools** to facilitate phosphorus recycling from wastewaters, depending on the water industry private / public / local authority organisation and regulation in different countries (are P-recycling investment costs and sales of recovered products accounted to water companies or passed on to consumers ?)
- **Awareness raising** concerning phosphorus stewardship (public, decision makers, industry), with the accent on the positive aspects of moving from 'waste to resource' and on redistribution and better use rather than reduction.

Research and integration

Several participants underline the need for **better circulation of existing information, to avoid "re-inventing the wheel"** and losing time carrying out studies when similar data already exists elsewhere and can be transposed. Phosphorus stewardship requires cooperation between different sectors (agronomy, water treatment, social/political, chemical industry, waste operators …) and existing knowledge from one sector is often not readily accessible to other sectors (up-to-date bibliography, summaries accessible to actors who are not experts in the specific sector).

Cost-benefit analysis of phosphorus management strategies and of P-recycling technologies is important. The on-going P-REX project will assess costs for recovering P from the wastewater stream and environmental impact estimation *www.p-rex.eu*

- Proposal: **Develop a 'research, integration and implementation agenda',** with an open and inclusive methodology, involving representative stakeholders, and starting from a collation and assessment of existing information (for methodology, see 'Research needs' in SCOPE Newsletter 96). It needs to be emphasised that significant knowledge and information already exists, and that further R&D should be done in parallel to implementation and launch of actions.
- Proposal: **Integrate phosphorus stewardship** in scientific and industrial R&D and innovation concerning waste and water treatment, agriculture, food processing …

The European Commission consultation on sustainable phosphorus management is open until 1st December 2013 (see SCOPE Newsletter n° 95) at *http://ec.europa.eu/environment/consultations/phosphorus_en.htm* Francesco Presicce (European Commission) indicates that this consultation is part of the overall effort to improve resource efficiency and responds to stakeholder pressure for Europe to move forward on phosphorus stewardship. The objective is not necessarily to establish new European regulation but to identify actions to facilitate phosphorus recycling and stewardship.

- Proposal: **All stakeholders are invited both to respond individually** to this consultation (1st December 2013 deadline) and to promote and circulate to members and contacts

Further actions in the UK

The European Sustainable Phosphorus Platform meeting put forward proposals for further action in the UK:

- **Establishment of a UK 'group' within the European Sustainable Phosphorus Platform**, to facilitate information exchange, awareness raising, and address specific UK questions (phosphorus flow data, water utility funding)
- combine with the **BioRefine** project meeting: 19-20 November, Manchester see *www.biorefine.org*
- **meetings on "Sludge and phosphorus management in Europe, present and future"**, organised by the End-o-Sludg project (see SCOPE Newsletter 96) in London 3 December 2013 and Brussels 11 December 2013 *www.end-o-sludg.eu*
- **Develop a 'catalogue' of competence and actors in the UK**, active in phosphorus management: technology suppliers, operational phosphorus recycling installations, R&D support, scientific/expertise …

Full record of meeting discussions online at
www.phosphorusplatform.eu

Phosphorus policies

Denmark, Baltic States announce P-recycling policies

The Ministerial Declaration signed by the 9 Baltic region States (HELCOM) on 3rd October 2013 includes revised nutrient reduction targets for the Baltic Sea and a commitment to enhance phosphorus recycling. Denmark has announced a new waste recycling strategy to double household waste recycling by 2022, including recycling 6x more food waste and P-recycling from manure and sewage biosolids.

The Baltic Ministerial Declaration of 3rd October 2013 aims to **improve the environmental quality of the Baltic Sea and to achieve "Good Ecological Status" by 2021** (EU Water Framework Directive criteria). The Ministerial Declaration recognizes that the environmental status of the Baltic Sea remains fragile and impaired, and is already being further impacted by climate change.

Agricultural nutrient management

Agriculture is identified as critical for achieving this and measures agreed include **annual nutrient accounting at the farm level** (nutrient balanced fertilization) by 2018. Mandatory requirements on nutrient bookkeeping are suggested as a tested, positive approach. National guidelines or standards for nutrient content and use of manures will be developed.

Figures for maximum admissible nutrient emissions to the Baltic, for each of the 9 water basin States (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden) were revised following 5 years of scientific studies and negotiation of a fair sharing of efforts.

The Declaration states that achieving eutrophication improvement objectives will bring a **one billion Euros per year economic benefit**. While it may take "a long time" before the HELCOM eutrophication objectives are achieved, significant improvement is expected to take place rapidly after Maximum Allowable Inputs are reached.

Tightening of nitrogen emission targets

Total phosphorus emission targets (Maximum Allowable Inputs) are increased slightly compared to the 2007 HELCOM Baltic Sea Action Plan figures (from 13 400 to 14 400 tonnes P total), but with variation between States (in particular a lower target for Poland). Nitrogen emission targets are on the other hand considerably reduced (from 129 000 to 89 000 tonnes N total), with particularly important target reductions for Denmark, Poland and Sweden.

Baltic phosphorus recycling

The development of "environmentally sound approaches" to nutrient removal is recommended. The **Ministerial Declaration**:

"recognizes the concerns about limited future supplies of nutrients, especially phosphorus … stresses the need for sustainable use of nutrients". The Declaration includes an agreement to "enhance the recycling of phosphorus (especially in agriculture and waste water treatment) and to promote development of appropriate methodology".

The Declaration also adopted specific **HELCOM recommendations** including concerning biodiversity objectives, bird habitats and migration routes, pollution accident response, management of different species of fish and sustainable aquaculture (including limiting nutrient pollution), marine litter, shipping, hazardous substances and pharmaceuticals.

Denmark waste policy

Denmark's Environment Minister has published a strategy on resource use aiming to double household recycling by 2022. Specific objectives include increasing recycling of food waste by 2022 by 6x for households and 4x for restaurant and retail sectors, and targets for paper, cardboard, metal, glass and plastic packaging, and for waste electronic and electrical equipment (WEEE). An annual budget of 6.7 million € will support waste management and a waste reduction plan will be developed.

The strategy officially recognises phosphorus as a critical resource for the Danish government, and states phosphorus recycling as an objective.

Initiatives announced to facilitate phosphorus recycling include

- Grants for development, testing and demonstration of technologies to extract P from sewage sludge.

- Assessment of the integration of phosphorus recycling in sewage sludge treatment systems, and optionally manure treatment, e.g. P-recovery from biosolids incineration ashes.

- Possible establishment of "Phosphorus banks" through separate storage of ash of phosphorus-rich sewage sludge incineration ash

The Government strategy fixes an **objective of 80% recycling of phosphorus in municipal sewage**, either by agricultural use of sewage biosolids (recycling phosphorus as a crop fertiliser) or by phosphorus recovery technologies. Today, around 50-55% of phosphorus in sewage in Denmark is recycled. Where manure is used for energy production (e.g. anaerobic digestion for biogas), the phosphorus should continue to be recovered or reused in agriculture.

Denmark Government resource strategy announcement and link to waste strategy document, 7th October 2013 (in Danish) http://www.mim.dk/Presserum/20131007_ressourcelancering.htm

"HELCOM Copenhagen Ministerial Declaration Taking Further Action to Implement the Baltic Sea Action Plan, Reaching Good Environmental Status for a healthy Baltic Sea", 3rd October 2013 http://helcom.fi/news/Pages/Master-blueprint-ready-for-future-regional-actions-for-a-healthier-Baltic-Sea.aspx

Phosphorus on the field

Phosphorus management in the UK

The European Sustainable Phosphorus Platform stakeholder meeting at the Farmers Club in London included up-to-date information about eutrophication challenges posed to UK surface waters by phosphorus losses from sewage works, agriculture and other sources, a national phosphorus substance flow analysis, and phosphorus management in biosolids recycling to agriculture.

Rachael Dils (Environment Agency England) presented an overview of the impacts of phosphorus pollution for the water environment in England. **Phosphorus levels are the principal reason for failure, among water quality parameters, of UK inland surface waters to achieve Water Framework quality objectives. 45% of river water bodies in England and 7% in Wales exceed their phosphorus standard.** Water Framework Directive (WFD) Reasons For Failure (RFF) investigations have identified that 31.7% of all water bodies failing to achieve WFD Good Ecological Status (GES) are attributed to the 'agriculture and rural land management' sector. Of these waterbodies, 57% are failing because of phosphorus (they may fail for another element as well). 54% of failure sample points exceed phosphorus limits by > 2.5x and 37% of water bodies remain "at risk" or "probably at risk" of failure by 2015. Achieving objectives will therefore be very difficult in many cases, and possibly unachievable in around one quarter of cases.

Eutrophication challenge

The largest contributor to these problems is **phosphorus discharges from municipal wastewater treatment plants (WWTP),** at about 70% of the total phosphorus load to UK waters, whilst agriculture represents about 20% of total phosphorus load.

The water industry in England & Wales had already invested nearly one billion UK£ capital on introducing phosphorus removal at WWTPs by 2010, rising to £1.3bn through measures agreed for introduction by 2015. It has been estimated that a further £ 1.5 billion investment would only reduce Water Framework Directive river phosphorus failures by <6%. **Phosphorus discharge controls for municipal**

sewage works are being significantly tightened. WWTPs of 2 000 person equivalent and more are concerned.

The UK is re-orientating its **rural development programme (RDP)** towards water protection and biodiversity. Soil protection is a further objective.

The UK is therefore trying to reduce other phosphorus sources/inputs: tap water phosphate dosing (to prevent lead dissolving into drinking water from lead pipes), detergents (domestic laundry detergents are already P-free in Europe and domestic dishwasher detergents are expected to be so in 2017), food additives.

Farm phosphorus stewardship

Catchment Sensitive Farming policy work undertaken for DEFRA, has examined economic, supportive/voluntary and regulatory mechanisms for controlling diffuse pollution. **The Defra analysis indicated that agriculture, on average, needs to reduce phosphorus loss by 48%** for there to be a minimum 80% probability of meeting the WFD phosphorus standards for rivers by 2015. Since 2010 the Environment Agency and the NFU (National Farmers Union) have been working in partnership, to identify what water quality improvements can be delivered through a voluntary initiative aimed at addressing diffuse phosphate pollution from farming. A report summarising the evidence is available on the NFU website (Phase 1 Evidence Report - *https://brand.environment-agency.gov.uk/mb/BCR0jt*).

The question of phosphorus losses to surface waters from **septic tanks** was raised. Opinions varied regarding the significance of these losses. A CEH report (to be published soon) suggests that septic tank losses may be small if septic tanks are correctly sited and well maintained, but many older installations may pose a higher risk especially if they are located on high risk soils close to sensitive waterbodies.

Adapting phosphorus application to crop needs

Europe, as a whole, does not have regulation defining phosphorus application limits. Many participants consider that such legislation would not be appropriate because of local variability, and the need to take into account soil type, agricultural system, and the often **significant 'legacy' of accumulated phosphorus in soils**.

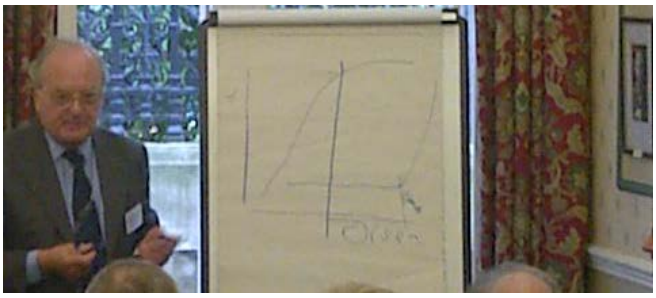
In some cases, application of phosphorus fertiliser even on a high P status soil can increase crop yield, and so increase crop P off-take, thus reducing final soil phosphorus levels. Several participants emphasise that **around twice as much phosphorus goes to farmland in manures in Europe as is applied in mineral fertilisers**.

Francesco Presicce (European Commission) highlights that phosphorus is addressed by EU water legislation. For instance, the **Nitrates Directive requires measures to prevent and reduce water pollution from agricultural activities**, including eutrophication, for which phosphorus is often the limiting factor.

In the framework of the Nitrates Directive, Member States implement good agricultural practices which have the effect of limiting nutrient losses to water bodies. In particular, the Nitrates Directive requires that land application of fertilizers be carried out according to crop needs and this measure has been translated, by some Member States, in phosphate application standards.

Furthermore, **phosphorus is addressed by the Water Framework Directive**, which addresses all surface waters and groundwaters in the EU with a view to achieve water quality status objectives.

In the UK, Defra indicate that sewage sludge use in agriculture regulations specify application according to "nutrient needs", which means both N and P. The regulations also state that "the quality of the soil and of the surface and ground water is not impaired" which link to the Water Framework Directive obligations cited above.



Johnny Johnston explains critical soil phosphorus management

Johnny Johnston (Rothamsted Research) explains the importance of the critical soil P level, below which there is significant increased crop yield response to additional phosphorus, but beyond which there is no significant crop response. This must be assessed from soil P status, not from annual P application rates. This "breakpoint" depends on soil type.

A UK water industry-led nutrient management matrix is also being discussed, which will limit sludge applications based on the P content of the soil. For soils with P-index 1-2, sewage sludge applications are permitted every 12 months, for soils with P-Index 3-4, the return frequency is defined based on soil type, and for soil with P-index 5, no application is permitted.

It is noted that this approach covers risk of P leaching from soils, including runoff from permanent grassland where a similar 'breakpoint' can be identified. However, this approach does not apply to **P losses relating to soil erosion**. The importance of a catchment-based approach is emphasised.

Phosphorus substance flow analysis (SFA)

James Cooper (University of Birmingham) indicates that a phosphorus flow analysis for the UK food production and consumption system has been completed (published in Resources, Conservation and Recycling, Vol. 74, 2013). Regional or local flow studies could be developed using this methodology and basic data. Further work is ongoing to develop this for the water industry by gathering information about the size and treatment methods for all UK wastewater treatment works.

Results suggest that over 80% of the UK population (in population equivalent) are served by WWTPs >25,000 p.e.) and over 60% of the population are served by WWTPs >100,000 p.e., implying that **targeting only the larger works for P-recovery will capture the majority of wastewater P flows**.

An issue raised is that most P-removal occurring in the UK is through **iron dosing**, which could limit P recovery options. Contact: *JXC637@bham.ac.uk*

A number of phosphorus flow analysis studies exist at national, regional or city level from different countries (see eg. SCOPE Newsletter 93 and analysis of 18 such studies in SCOPE Newsletter 95). Conclusions are largely transposable to other countries and areas, so that **extensive research is not needed before actions can be engaged**. Applied local or sectoral phosphorus flow studies can provide further information to define local priorities and to inform local decision makers or water or waste stream operators.

Phosphorus biotechnology

Review of the Phosphorus Challenge

The special edition on 'Phosphorus Biotechnology' presents 11 papers addressing the challenge to humanity posed by non-renewable phosphorus resources, and reviewing the different areas of biotechnology necessary to address this challenge. Reviews cover cellular phosphorus function and biotechnologies, analysis, phosphorus stewardship in agriculture, recovery of phosphorus from waste streams and the societal challenge of phosphorus sustainability.

This journal issue represents an integrated content bringing together specialists from diverse fields in a coordinated manner to not only review the issue but also to assess the possible solutions.

Elser provides an overview of the **phosphorus sustainability challenge**.

Cordell et al. indicate the need for **phosphorus flow analyses** to identify phosphorus losses and potentially important points for actions to reduce these and improve phosphorus management.

Blank reviews **developing biotechnologies** relating to the functions of phosphorus in cells, with applications in for example improving the availability of phosphorus in crop products or the functions of microbes in wastewater treatment, and discusses the issues around relevant genetic engineering.

Majed et al. review progress in **analytical techniques** for both total phosphorus and different forms of phosphorus, underlining the current lack of universally recognised protocols.

Phosphorus in farming

McDowell examines the poor **efficiency of phosphorus use in agriculture** and the accelerating rate of phosphorus loss associated with intensification of farming. He concludes that losses are not evenly distributed, but are linked to critical source areas. Cost-effective strategies should concentrate on identifying and mitigating these points.

Tian et al. review **bioengineering possibilities**, including plant breeding and field management, for improving crop-plant phosphorus efficiency, either by better P mobilisation in soil or increased P uptake by the plant. They emphasise the need for better understanding of how such strategies interact with other agronomic objectives in field implementation.

Kebreab et al. review strategies to reduce P losses in **livestock production**, including optimising animal feeding, use of phytase enzymes to improve P uptake, functional genomics (specific diets for individual animals, based on genetics) and genetic manipulation of livestock breeds.

Phosphorus recovery and recycling

Yuan et al. review the development of EBPR **(enhanced biological phosphorus removal)** for removal of phosphorus from domestic and other wastewaters, highlighting that while this technology is now well developed its extension to full phosphorus recycling is relatively limited.

Pratt et al. discuss a range of **chemical technologies for removing phosphorus from waste streams**. They consider that the currently widely used chemical dosing (iron, aluminium) is expensive and non sustainable, and that currently emerging technologies (reactive filters such as zeolites or slag, nanomaterials, polymers) offer promising alternatives for low concentration phosphorus streams, whereas struvite precipitation offers a feasible route for removing and recovering phosphorus from more concentrated streams (> 10 mgP/l).

Using plants and algae to recover phosphorus

Shilton et al. identify several **obstacles which limit the reuse of phosphorus** from wastewater by direct irrigation onto agricultural land:

- **Quality constraints depending on the use**: fate of pathogens or pollutants in the wastewater
- **Temporal constraints**: crops only require nutrients during the growth season
- **Spatial constraints**: waste streams concentrate nutrients in areas where they exceed local agricultural needs, either around big cities or because of geographical concentration of livestock production
- **Dilution of nutrients** in municipal sewage, making spatial transfer problematic

The authors review the **potential for using plants and algae to recover phosphorus from wastewater**. They show that algal or macrophyte ponds require around 1/10th of the area needed by terrestrial crops to recover phosphorus, that is to take phosphorus up into biomass. This area could potentially be further decreased by a factor of three if **'luxury uptake'** were developed, similar to the biological process used in EPBR (biological nutrient removal) microbes in sewage works. It has to date been shown that algae in wastewater ponds will from time to time be triggered to uptake phosphorus well in excess of what it needed for cell structure and so to store large quantities of polyphosphate granules. Understanding the environmental 'triggers' offers an opportunity to develop this mechanism in a new environmental technology by optimising and maintaining this uptake.

The use of **high-rate algal or plant ponds**, designed to concentrate nutrients into enriched biomass, offers an alternative to simply trying to pump dilute wasters long distances. Indeed ultimately offshore installations that create floating ponds above sea wastewater outfalls could considerably improve economics and avoid land use.

Most algal ponds currently use suspended algae, growing freely in the wastewater, but various other systems are proposed including algae immobilised in beads (using materials such as alginate, carrageenan, chitosan) or grown as a biofilm on a surface (where biomass can be recovered by scraping the surface).

Macrophyte plants also offer significant potential for phosphorus recovery. Systems currently under development include emergent macrophytes floating in rafts with their roots in the wastewater which ensures that all the plant's nutrient needs are taken up from the wastewater (rather than soil); developing luxury P uptake in macrophytes; and improving macrophyte harvest. Research suggests that a high proportion of phosphorus removal by macrophytes may in fact occur in algal biofilm growing on the macrophyte surface, which may offer routes for improving phosphorus uptake.

Algae or plants grown to recover phosphate from wastewater can be **used either as fertilisers, as animal or human foods, as input to human food production via fish growth, or in some cases in added-value products** such as cosmetics or for extraction of certain cell substances, to enable the recycling of the phosphate. However, questions concerning the storage, stability, plant availability and soil amendment value, and presence of contaminants in recovered biomass require further research.

"Plant based phosphorus recovery from wastewater via algae and macrophytes", Current Opinion in Biotechnology, Volume 23, Issue 6, pages 884–889, December 2012, Elsevier
http://dx.doi.org/10.1016/j.copbio.2012.07.002

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Current Opinion in Biotechnology, phosphorus biotechnology special edition, vol. 23, issue n°6, pages 827-984 (Dec 2012)
http://www.sciencedirect.com/science/journal/09581669/23

P-REX Poděbrady

P-recycling technologies and markets

The P-REX project (see SCOPE Newsletters 88 and 94, running 2012 – 2015) aims to evaluate full-scale demonstration plants operating phosphorus recovery and recycling technologies, assess market potential and conditions for recycled phosphate products and define strategies for implementing widespread P-recovery and recycling from municipal wastewater in Europe.

Two meetings in Poděbrady, Czech Republic, 16 and 17 September 2013, organised with the support of ASIO *www.asio.cz*, presented progress of the project to date and made proposals for moving forward, and then brought together some 60 stakeholders from across Europe to discuss issues and make proposals concerning the market for recycled P products.

The P-REX project includes an **analysis of legal and market requirements for recycled phosphate products** and stakeholder discussions in different European regions to propose strategies for achieving high levels of P-recovery (see SCOPE Newsletter 94 summary of Basel workshop).

Demonstration P-recycling from sludge ash

The first day's meeting (P-REX general assembly) presented and discussed status of the project to date. A core element of the P-REX project is the evaluation of full-scale demonstration plants, operating different P-recovery processes from municipal sewage sludge incineration ash (SSA).

The processes proposed for assessment, by the project partners, are:

- P-Recovery from sewage sludge incineration ash (SSA), proposed by **Outotec (ASH DEC process).** The process is based on an updated version of the **Rhenania process** (used for many years to produce fertiliser from phosphate rock), and involves calcination of the SSA at 800-100°C with Na_2CO_3 to produce $CaNaPO_4$ (a citrate-soluble fertiliser). At present lab scale (<1 kg ash) and technical scale (20 – 30 kg/h ash) tests are performed at BAM Federal Institute for Material Research. A pilot plant (300 kg/h ash) was operated 2008-2010. A semi-industrial scale demonstration production is planned within the next half year, either at IbuTec (Weimar, Germany) or another suitable facility.
- **Mephrec (Ingitec)** process. The planned demonstration plant is currently pending a funding decision.
- **Leachphos (BSH Umwelttechnik)**. A demonstration plant trial was successfully performed at the decommissioned municipal sewage waste incinerator in Berne, Switzerland, 2012-2013. Some 45 tonnes of Swiss sewage sludge incineration ash were treated, providing useable data concerning process inputs, costs, etc. Pilot plant trials are currently being performed at FHNW, Basel, Switzerland (10 kg ash/hour)

The evaluation of the processes, at demonstration scale, will include a Life Cycle Analysis and cost analysis, looking at input chemicals and energy, operating and capital costs, and at the quality, characteristics and potential market of the recovered product. **Participants noted the need to update the Life Cycle Analysis data for mineral fertilisers** and proposed to establish an international working group to collate and update data for mining, processing, etc.

The P-REX project will revise the list of processes to be evaluated, given that the Mephrec plant data are not yet available.

Also, **Canton Zurich, Switzerland, is currently evaluating processes for recovery of phosphorus from sludge incineration ash** (SSA) as a public procurement decision: the AshDec = Outotec and Leachphos processes, as well as the Recophos process, in order to select a process for full-scale implementation (see SCOPE Newsletter n° 96). Other processes using SSA also exist, for example the Ecophos process producing DCP (di-calcium phosphate), see www.ecophos.com

P-recycling from sewage sludge liquors

P-REX will evaluate a number of **processes for recovering P from sewage sludge or sludge digester liquors**:

Process	***Recovered P***	***Liquor treated***	***State of development***	***See***
Pearl/Ostara	struvite	Sludge digester liquor after dewatering (centrate)	Several full scale plants operating in North America. Full scale plant built and operating soon in UK (Thames Water, Slough). Others in project.	*SCOPE Newsletter 93, 70*
Phostrip/Véolia	Struvite	Sludge digester liquor after dewatering (centrate)	Pilot operational in Brussels	
Airprex	Struvite	Sludge digester liquor before dewatering	Full scale plant operational, Berliner Wasserbetriebe, Wassmannsdorf plant	*SCOPE Newsletter 97*
DHV Crystallactor	Calcium phosphate	Sludge digester liquor after dewatering (centrate)	Full scale plant at Geestmerambacht, Netherlands, no longer operation	*SCOPE Newsletter 55, 54*
Stuttgart process	Struvite	Sludge is dissolved at pH3, heavy metals are removed using citrate, then struvite is precipitated.	Offenburg (Germany), 12 m^3 batch-operating pilot	*SCOPE Newsletter 89*
Gifhorn process	Struvite plus ammonium sulphate	Sewage sludge is dissolved using sulfuric acid, heavy metals are removed as sulphates, then struvite is precipitated	Full scale plant operational at Gifhorn, Germany	*SCOPE Newsletter 86*
Budenheim process	Calcium phosphate	Sewage sludge	1 m^3 lab-scale semi-pilot	*SCOPE Newsletter 95*

Pot and field trials of recovered phosphate products

Maize pot trials (using soils of pH 5.5 and 6.6) are underway to **compare a number of recycled P products to rock phosphate and to triple superphosphate fertiliser**. The objective is to test whether the recovered phosphates are effective fertilisers. Full scale field trials are planned in several regions of Europe, again using Maize, to provide demonstrations which can be visited by farmers and stakeholders.

Participants suggested that it is important to ensure that the soil in such trials is low in phosphorus (inadequate for crop needs), in order to obtain meaningful results, and that **soil pH in such trials should be near-neutral**.

Green polymers and toxicity testing of biosolids

In another part of the P-REX project, **green polymers (bio-sourced and bio-degradable)** are being tested, in close cooperation with the municipal waste water operator and farmers around Brunswick, Germany, to assess their **potential for replacing petro-chemical based PAM (polyacrylamide) polymers** currently used to enhance sludge dewatering.

Concerns have been raised about biodegradability of PAM and possible accumulation on fields where biosolids are used as soil amendments.

Germany is currently discussing an obligation for >20% biodegradation in 2 years for all sewage sludge additives where used on fields, which would probably exclude the use of PAM.

Chitosan, starch and tannin based bio-polymers have been initially tested, however there are **problems with sheer-force stability, and so physical resistance to the centrifuge dewatering process**.

One family of bio-polymers has been identified as potentially valid, and further testing is proceeding, including full scale use in the municipal waste water treatment works and on fields.

Part of the P-REX project is also working on the development of **toxicity bio-assays** which could potentially be used to test biosolids or recovered phosphate products for toxicity to soil and water organisms. The objective is to develop tests which assess the complete biosolids matrix as a whole (including all contaminants present and their possible combined effects), in order to complement current testing methods which look only at concentrations of a number of specific substances (eg. heavy metals, certain organics). Adaptation of existing testing method norms is considered to try to achieve simpler and faster methods.Initial results show toxicity of biosolids at 1 – 5% in soil or water (earthworm avoidance test, invertebrate immobilisation) and of triple superphosphate at 5% in soils. **The challenge is now to adapt the testing methods to give meaningful results for lower levels of biosolids or fertilisers, more representative of reality in the field**.

Participants noted that ecotoxicity tests of recovered phosphates may in any case be required for the REACH dossiers.

Stakeholder consultations

P-REX includes a number of actions to facilitate the development and market uptake of phosphorus recycling processes. **Several regional stakeholder workshops will be organized in Spring – Autumn 2014**, in order to present and discuss strategies for recovery of 80% of the phosphorus in the regional wastewater stream. Bioavailability and farmers' and fertilizer distributors' needs and specifications for recovered phosphate products will be considered.

A P-REX **P-recycling summer school** will take place in September 2014 to enable training of students and young professionals. Online communications tools will develop a catalogue of P-recycling processes, demonstration plants which can be visited, sites producing recycled phosphates, networking of operators, users of recycled phosphates, stakeholders.

The second day in Podebrady was a one-day stakeholders' workshop, with some 60 participants from the Czech Republic and across Europe. The objective, presented by **Anders Nättorp, (FHNW, University of Applied Sciences and Arts Northwestern Switzerland), Christian Kabbe (Kompentenzzentrum Wasser Berlin, P-REX project coordinator) and meeting host ASIO** *www.asio.cz*, was to present the status of P-recovery and recycling technologies and their implementation in Europe, to discuss with stakeholders **how to bring recovered phosphate products onto the market** (as fertilisers or as raw materials for fertiliser production) and to discuss policy and regulatory tools needed to facilitate P-recycling uptake.

Marek Holba (ASIO *www.asio.cz*) and Ludwig Hermann (Outotec/Proman Management GmbH) presented the project results on **market structure and legal framework for phosphorus recovery** and marketing of inorganic products. In particular, problems are posed by differences in requirements between EU and national fertiliser regulations, and in End-of-Waste criteria concerning contaminant concentrations or raw materials between fertilisers produced from rock phosphate and recycled phosphate products

Pre-normative matrix for recycled P products

P-REX has the objective to develop a pre-normative matrix, defining quality characteristics ranges and specifications for recycled phosphate products, intended for use as fertilisers or as raw materials for fertiliser production, covering for example chemical properties, plant availability and solubility, purity, contaminants, water content, physical form (granulometry, dust, flow properties …).

Participants reminded that **a significant proportion of sewage phosphorus is currently recycled in agricultural use of biosolids, after appropriate treatment** to ensure hygiene and quality.

It was discussed that **vocabulary needs to be clarified**: agricultural spreading of biosolids should only be considered as phosphorus recycling if the phosphorus is adequately plant available (this needs to be defined) and if the biosolids are applied according to a fertilisation plan, ensuring that phosphorus is only applied if needed by crops (according to crop needs) and so as to minimise risk of losses to surface waters.

Hynek Charvat (FOSFA) presented the position of a local fertiliser manufacturer. FOSFA's objectives are to reduce fertiliser wastage (over-application), to improve plant efficiency (farmers want products offering immediate plant availability) and to reduce contaminant levels (heavy metals), all in the context of considerable pressure on fertiliser prices (decreasing market prices over the last two years, Czech farmers' short term vision because of economic and land-ownership issues)

Jiri Wanner (Prague Institute of Chemical Technology) emphasised that little work has been done on phosphorus recycling in Eastern Europe. In the Czech Republic, the short term potential for P-recovery technologies is limited because most sewage works are small or medium sized: a recent thesis by **Eva Sykorova with Véolia** concludes that P-recovery is currently only economically feasible in a few larger sewage works. However, eutrophication is an increasing problem in Eastern Europe, because of still inadequate nutrient removal in sewage works, and increasingly because of agricultural soil phosphorus losses, accentuated by the development of maize cultivation for bio-fuels (loss of soil cover results in increasing P-losses through soil erosion, accentuated by over-fertilisation).

Francesco Presicce (European Commission DG Environment) presented the current EU consultative communication on the sustainable use of phosphorus (see SCOPE Newsletter 95 and *http://ec.europa.eu/environment/consultations/phosphorus_en.htm*, response deadline 1st December 2013).

The background is that **phosphorus is a vital resource** that is currently used inefficiently and such inefficiency results in significant environmental impacts across its life-cycle, including losses to surface waters causing considerable environmental damage (eutrophication).

The European Commission considers that there are considerable opportunities for improving the efficiency of phosphorus use and for reducing losses, recognises the wish of stakeholders to make progress, and hopes to identify through the consultation both current obstacles to P-recycling and opportunities for improving sustainable phosphorus management. All interested parties are invited to respond online to this public consultation (companies, associations, administrations, individuals).

Max Schulmann, Finnish Farmers Association and Jan Neuber, Otto A Müller Recycling GmbH

The P-REX workshop then included 7 interactive tables addressing:

- **Fostering P-recovery innovation** through multi-stakeholder cooperation (moderators: Arnoud Passenier, Netherlands Nutrient Platform, Jana Matysikova, ASIO)
- The **market for recovered phosphate products** and a pre-normative matrix of product specifications (Carl Dewaele, NuReSys, Christian Kabbe, KWB)
- **Market barriers** (Ludwig Hermann, Outotec and Dirk Halet, Flanders Knowledge Center Water/ Flemish Nutrient Platform, Belgium)
- **End-user requirements** : farmers, fertiliser industry (Max Schulmann, Finland Farmers

Association, Jan Neuber, Otto A. Müller Recycling)

- **Waste and product regulatory issues** (Chris Thornton, European Sustainable Phosphorus Platform, Christine VanHoof, VITO)
- **Harmonising the legal framework** for phosphorus recycling (Francesco Presicce, European Commission, Michaela Pokorna, ASIO)
- **Learning from experience** of demonstration plants and business cases (Willem Schipper, consultant, Kirsten Remmen, FHNW)

Arnoud Passenier, European Sustainable Phosphorus Platform, emphasises the importance of exchanging experience

Case by case

Several of the table rapporteurs emphasised that no one solution fits all circumstances. Experience both in Europe and Japan (see SCOPE Newsletter 91) shows the **difficulty of finding a market for recovered phosphates**, because production remains relatively low volume compared to fertiliser industry operations (even in a large sewage works or from centralised sludge incineration). Therefore, **specific local markets need to be found**, for example through a local fertiliser manufacturer or wholesaler, local authority or niche application markets. The general market price of standard fertilisers may not therefore be directly relevant.

A key criteria, however, is always to meet the specifications of farmers, and of their suppliers (wholesalers, cooperatives, fertiliser companies). These criteria will include the nutrient value and availability of the product, but also the physical form (particle size, dusting, flow properties, storage stability compatible with existing fertiliser handling and spreading equipment). It is important that these characteristics are guaranteed by appropriate quality standards and independent validation. Farmers are concerned about possible contaminants in recycled phosphates. Dialogue with farmers and field demonstrations showing the fertiliser performance of recycled phosphates are important.

Because of the relatively small scale **of P-recycling, economic viability will not be driven by the standard market price of industrial phosphate fertilisers**, but by other factors, such as value-added as a "green product", advantages offered to sewage works operators (avoidance of nuisance struvite deposits, reducing sewage sludge ash landfilling costs), lower cadmium levels, regulatory or policy pressures.

Participants considered that a **stable and reliable regulatory and market context** is necessary for widespread development of phosphorus recovery technologies, for example through clearly defined and long-term stable regulatory incentives or obligations.

Also, long-term guarantees of supply of raw materials are necessary for **investments in P-recovery plants** to be made, eg. long-term contracts with local authorities or water companies producing sewage sludge incineration ash.

Willem Schipper, phosphate industry consultant, summarises criteria for success

Shared vocabulary

An issue repeatedly raised is the need to better define a **common vocabulary regarding phosphorus recycling**.

As indicated above, **sludge biosolids use on land should only be termed recycling under certain**

conditions (plant availability of phosphorus, application limited to crop P requirements), and at the same time it should be generally accepted that "sludge spreading" assumes quality criteria (fertilisation plan, treatment of biosolids, control of contaminants) and that uncontrolled disposal to land is nowhere acceptable.

Criteria for success

Some criteria for success of P-recycling projects were identified, including process flexibility (limited risk, reduced complexity), reliable quality of recovered product (important for demonstration and marketing), environment and safety. Projects' profitability often depends on external factors (see above) and not principally on the market value of the recovered phosphate. A stable legal framework for raw materials input, plant operation and recovered phosphate use and market are therefore essential.

The P-REX project is invited to further develop this work on success criteria, including also assessing why certain projects have failed to be realised or plants have been closed in the past.

P-REX Podebrady workshop slides available online: http://p-rex.eu/index.php?id=5

Phosphorus supply and fertilisers

Fertilisers Europe

European fertiliser decadmiation workshop

The Fertilizers Europe workshop on decadmiation, Brussels 3rd October 2013, brought together 70 industry representatives, scientists, technology experts and regulators to discuss recent developments in understanding cadmium in agricultural and food systems, decadmiation technologies, current and proposed regulations in Europe.

Jacob Hansen, Fertilizers Europe, opened the meeting by reminding that phosphate fertilisers are essential for food production and so for life, but inevitably bring some impurities to farmland, and that it is necessary to ensure that cadmium (Cd) in mineral fertilisers is not an issue for human health or for the environment.

Vincent Delvaux (European Commission, DG Enterprise, responsible for revision of the EU Fertiliser Regulation) explained that there is an increasing interest in this question over recent years, and that **the European Commission intends to take cadmium into account in the currently ongoing revision of the EU Fertiliser Regulation 2003/2003**.

Industry wants a harmonised EU market for fertilisers, whereas today the EU Fertiliser Regulation does not include cadmium limits but 3 Member States have derogations in place to apply cadmium limits in fertilisers (Austria, Finland, Sweden). The Commission is currently working on an Impact Assessment of possible cadmium limitations, based on the knowledge available to date.

He presented the regulatory context: cadmium is recognised to be a category 1B carcinogen and category 2 mutagen/reprotoxin. Cadmium is known to impact the kidney and osteoporosis. Cadmium is designated a Substance of Very High Concern (SVHC) under REACH. It also can have negative impacts on biodiversity (aquatic, terrestrial) and is an EU Water Framework Directive priority substance so that Member States are required to prevent emissions to water.

The main route of population exposure to cadmium (Cd) in Europe is food (except for smokers, who face higher exposures in tobacco). The EU food safety committee EFSA Opinion in 2009 (link below) considered that the critical endpoint for cadmium exposure from food is kidney toxicity, and that average population exposure in Europe is 2.3 µg/Cd/kg body weight per week, close to a recommended TWI (Tolerable Weekly Intake) of 2.5. This followed publication of an EU Risk Reduction Strategy, based on a 2008 Risk Assessment (link below).

Possible proposed EU fertiliser cadmium limits

Options currently being considered by the EU Commission include:

- Status quo: no EU cadmium limit, Member States can enact national limits
- 60 mg Cd (per kg P_2O_5) EU limit with the possibility for Member States to enact where justified lower limits at 20 or 40 mg Cd.

These options are based on the European scientific committee CSTEE (now SCHER) 24/9/2002 Opinion (see link below) which concluded that with fertiliser levels > 60 mgCd (per kgP_2O_5) cadmium would on average accumulate in "most" European agricultural soils and that at <20 there would be no accumulation.

Mr Delvaux indicates that such limits are not risk assessment based, and are not defined to achieve food cadmium levels below the EFSA recommended diet limits, but are **based on estimated likelihood of accumulation or not in soils**.

Revisiting cadmium balance estimates

Prof. Erik Smolders (Katholieke Universiteit Leuven, Belgium) explained how understanding has changed over the past decades years concerning cadmium mass balances in agricultural soils, following the first studies published in the 1970s. Rothamsted archives of soil and sample crops from 1843 showed increases in soils, and to a lesser extent in crop products.

The 2008 cadmium Risk Assessments cited above concluded that cadmium was expected to accumulate in European soils by around 6% in 100 years, that is "close to a steady state", assuming continuing use patterns.

However, a more recent study (Smolders 2013) revisits this assessment and concludes a 15% reduction in cadmium in surface soil over 100 years (plough depth 25 cm). This is the consequence of three changes in assumptions of Cd inputs and outputs:

- There has been a **reduction in phosphate fertiliser application rates** in Europe.
- The **estimates of atmospheric deposition of cadmium have decreased significantly** over the past 10-15 years. This is a result both of a reduction in atmospheric emissions (mainly from metal smelters, incinerators) and of better monitoring and measurement equipment. Past monitoring data tended to include re-deposition of dust, which is not in fact 'new' atmospheric deposition, but simply local cycling of soil cadmium already accounted in inputs, whereas more recent monitoring equipment avoids this distortion.
- **Increased estimates of leaching of cadmium from soil**. This is a result of a better estimate of soil pH (5.8, while previously estimated to be 6.5) and a more accurate Cd leaching model. Cadmium is lost more easily from more acidic soil. Prof.

Smolders emphasises that **measurement of changes in surface soil cadmium is very difficult**, in that total average soil cadmium is around 900 g Cd/ha, compared with estimated inputs (in the new study) from mineral fertilisers 0.88 g Cd/ha/year, atmospheric deposition 0.35g Cd and net manure, lime and biosolids inputs 0.15 g Cd. Estimated crop uptake of 0.21 g Cd/ha/year (cereals) and leaching of 1.44 g Cd result in a negative balance (soil cadmium reduction) of -0.27 g Cd/ha/year. This estimate assumes a phosphate fertiliser with a cadmium level of 36 mg Cd/kg P_2O_5 (= European average).

Prof. Smolders also showed figures of **cadmium concentrations in grain grown in Sweden**, with an increase in cadmium concentrations over the period 1920 – 1980 but then a reduction over the period 1980 – 2000. He considers that this reduction is probably the consequence of reduced atmospheric emissions (and so deposition) and of soil recovery following reductions in acid rain.

Because the annual in- and outflows of cadmium are so small compared to the soil cadmium stock, monitoring data has limitations and modeling is important.

Soil monitoring data

The limitations of soil cadmium monitoring were made clear by **Rannveig Anna Guicharnaud (EU Joint Research Centre, soil action)** who presented results to date from the European LUCAS topsoil survey. The objective of this survey is to collect and analyse soil samples from 22 000 points out of the 250 000 CORINE land cover / land use survey points.

To date, heavy metal data from only three Member States is available, and this shows no statistical correlation between cadmium levels and land use or any soil factor (iron, pH, phosphate, organic content …). The data to date does show correlations between zinc and iron, pH, phosphate and organics.

In discussion with conference participants, it was noted that **leaching estimates are very approximate**, because these are based on estimated concentrations of cadmium in soil pore water, for which available measured data are highly scattered. Also, cadmium losses in surface runoff or soil erosion are not accounted. Cadmium leaching from the top 25 cm of soil considered will mostly be to lower soil, so will not necessarily reach surface waters. The question of cadmium losses to waters does need to be considered. Prof. Smolders indicated that the average cadmium concentration in EU surface waters is c. 0.05 ppb (parts per billion), much lower than the quality limit of 25 ppb. Also, soil pH increases with depth in the soil profile, resulting in a lower mobility of Cd in the lower ground layers.

Health risks and imported cadmium

The question of a possible link between cadmium and osteoporosis, and consequent welfare costs, was raised. Prof. Smolders noted that the impact of cadmium on health is through total cumulative input over a lifetime, so that occasional intakes in certain products are not an issue and a European approach is logical to tackle total lifetime exposure.

Several participants underlined that the **health effects of cadmium are not linked only to cadmium intakes**, but are very strongly dependent on intakes of other minerals, in particular iron, and vitamin C.

Frank Swartenbroux (European Commission, DG SANCO consumers and health) confirms that the current proposal for a food cadmium level regulation is based on the EFSA 2009 Opinion cited above, and that the Commission considers that there is a need to further reduce cadmium levels in the European diet. The complexity of cadmium reduction, as indicated above, is recognised. However, **a tightening of food cadmium limits would result in a greater fraction of the crops of eg. potatoes, cereals being non-compliant** unless sufficiently long transitional measures are applied. However, there is strong farmer opposition to changes which could reduce cadmium levels in crops (eg. changing varieties of crops cultivated, or changing which crops are grown in which areas in some countries).

There is discussion of the **contribution of different types of food to human cadmium intake**. Some participants suggest that fish or certain specific meat products make important contributions, and that fertiliser cadmium limits are not appropriate to address these sources. The European Commission (SANCO) reminds that EFSA identified the main diet sources of cadmium as cereals, vegetables. This is largely because of the large proportion of these in the diet, in particular for populations particularly at risk of cadmium toxicity because of low iron intake.

The question of cadmium present in human foods and animal feeds or fodder imported into Europe was raised. This cadmium will mostly enter the human diet and principally end up on farmland (e.g. through recycling of sludge biosolids, manures, food waste digestates …). Mr Smolders replied that this is why manure and biosolids give a net input of 0.15 mgCd/ha/year in the new study. It is noted that this raises the question of a level playing field for European farmers and industry if the EU introduces cadmium limits in fertilisers, which will imply increased costs, in that imported foods and animal fodders may be produced in systems without fertiliser cadmium limits and so without these costs.

Imported foods are subject to the same cadmium limits as those produced in Europe. Verifications must be carried out by Member States to ensure enforcement, in order not to unfairly disadvantage the European food industry and European farmers.

Decadmiation technologies

Antoine Hoxha (Fertilisers Europe) introduced the session on fertiliser decadmiation technologies, indicating key criteria for assessing the interest of such processes

- **Applicability** to the different fertiliser production routes : sulphuric acid routes directly to simple super phosphate or via merchant-grade phosphoric acid, nitric acid route to nitrophosphates
- **Feasibility at large scale**: the European phosphate fertiliser market is appromixately 3 million tonnes P_2O_5/year
- **Level of cadmium abatement** (what % of Cd is removed)
- What **waste product** is produced (where does the cadmium go) ?
- **Costs**

Carsten Gellermann (Fraunhofer Institute Germany IKWS Materials Recycling and Resource Strategies), Marc Collin (Prayon Technologies), Ole Bjorn Jenssen (Yara, phosphate innovation platform) and Ludwig Hermann (Outotec, Ash Dec) presented industrial knowledge of decadmiation processes.

A range of different processes have been tested at the laboratory or pilot scale for removing cadmium from phosphoric acid:

- co-crystallisation (or co-precipitation) in anhydride $CaSO_4$,
- co-precipitation using sulphur compounds (sulphur esters, H_2S, Na_2S, NaSH),
- solvent extraction,
- ion exchange,
- membranes.

Solvent extraction is widely used to purify phosphoric acid for industrial, animal feed and food purposes, but costs are considerably too high for application for fertilisers. Ion exchange and membranes are expensive and unproven beyond laboratory scale or in real operating conditions. Also, where cadmium is removed from such technical phosphates, it is often transferred into the unpurified phosphoric acid stream, so marginally increasing the cadmium content of the fertilisers produced.

The **co-crystallisation** processes offer the most promising routes, and also remove certain other problem metals from the phosphoric acid. The main disadvantage is the low Cd concentration in the precipitate (< 1 % Cd), which limits potential for cadmium recovery for reuse. The sulphur precipitation processes produce lower quantities of waste (precipitate with up to 18% cadmium) but are significantly more expensive (chemicals used twice as expensive).

Prayon Technologies has worked to develop a process to concentrate this, in order to reduce waste disposal costs. 1990's estimates suggest for the co-crystallisation route investment costs of 4 million US$ (for a 500 tonnes P_2O_5/day plant) plus operating costs of 10 US$ per tonne P_2O_5, but this does not include waste disposal costs. These costs should probably be multiplied by 2x – 4x to cover increases since then in energy and other costs. **Prayon Technologies consider that the co-crystallisation technology is today relatively well known and understood, and that a full scale plant could be contracted not too far from now, although further optimisation would then be necessary**, in particular regarding the solid cadmium waste treatment. However the best approach would be to set up a demonstration plant in order to fine tune the technology and to adapt it to the specific origin of the acid treated.

Yara explained that the company has been researching decadmiation technologies for 30 years, has tested several processes at the laboratory scale, but to date has no decadmiation installed at a production scale. The company's fertiliser production is via the nitrophosphate rout, which has the advantage of not generating gypsum waste (calcium nitrate is produced, a fertiliser product), so that phosphoric acid decadmiation processes are not applicable. Access to Finnish Kola rock (igneous, low cadmium) enables the company to achieve cadmium limits set in Scandinavian countries (only) by blending this rock with other sources which do contain higher levels of cadmium.

This would not be possible if low cadmium limits were applicable across the European Union because supplies of low-cadmium rock would insufficient to provide EU with enough P. Yara also note recent instability of access to phosphate rock imports from Russia, as national legislation there now requires priority to be given to supplying the domestic market. Yara is addressing these issues with two major new phosphate rock mining projects in Finland and Canada, both in deposits with low cadmium levels.

Outotec is developing a thermal (calcination) decadmiation process for phosphate rock, based on known and tested technology already used for alumina production. The rock is heated to 900°C at which temperature cadmium comes off as a gas. 80% or higher cadmium removal can be achieved, or higher by adding reducing chemicals. Technical innovation is needed to recover the cadmium as a solid when in condenses in offgases whilst maintaining the energy recycling which ensure the energy efficiency and low carbon footprint of the process: this has to date been tested at laboratory scale. Disadvantages are that 2-3% of phosphorus is lost with the removed cadmium, and that the treated rock is less reactive, leading to a loss of efficiency in downstream fertiliser production. The process is adapted to phosphate rock sources which contain organics, because these are burnt, reducing the system energy consumption. Total costs are estimated at 40 – 80 € / tonne P_2O_5. **Outotec consider that around one year of further process testing would be necessary before contracting a full scale plant**.

Discussions amongst participants suggest that **the co-crystallisation/co-precipitation decadmiation route is recognised to be technology mature and feasible**, but with a need for better cost estimates, and for time for R&D to improve operation and develop processes to concentrate the cadmium containing waste, in order to avoid prohibitive landfill tonnages.

Possibilities for cadmium recycling

Christian Canoo (European Cadmium Association) and Carsten Gellermann (Fraunhöfer institute) indicated that the main use of cadmium today is in nickel cadmium batteries = 85% worldwide. 10 – 15% of use is in pigments. (Editor's note: cadmium is effectively banned in batteries in Europe [limit of <0.002% by weight] except in certain emergency and medical equipment and powertools). Cadmium in pigments are not classified substances because they are highly stable, so that the cadmium is not bioavailable. Smaller applications are in thin photovoltaic technologies, fire safety (temperature sensitive sprinkler release solders). The EU market for cadmium is stable at around 2000 tonnes Cd/year. For comparison, the total cadmium in fertilisers sold in the EU is only around 200 tonnes.

Other participants consider that the market for cadmium use could reduce considerably in the future if other battery technologies replace nickel-cadmium in industrial applications. There is general agreement that even if the cadmium could be recovered from decadmiation processes in an appropriate form (stable, concentrated) the **cadmium has effectively zero value for recycling** and at best could result in some cases in avoiding classified landfill costs.

Discussion of decadmiation obligations

Francesco Presicce (EU Commission, DG Environment) indicates that the public consultation currently underway (open until 1st December 2013 (see SCOPE Newsletter n° 95) at *http://ec.europa.eu/environment/consultations/phosphorus_en.htm*) includes a question on the risk of soil contamination linked to phosphorus use in the EU. Cadmium is the contaminant of most concern in phosphate fertilizers and views from all stakeholders in response to the consultation would be welcome on this issue. However**, cadmium contamination is only one of the impacts in the phosphorus supply chain, and sustainable phosphorus management offers opportunities to improve phosphorus use efficiency in many other areas**. The result of the consultation will help shape the further work of the Commission regarding the contribution that the EU can make to the sustainable use of phosphorus.

Defra UK indicates a preference for a **risk assessment and science based approach to fixing fertiliser cadmium limits**, in order to ensure proportionate measures, considering cost implications for the fertiliser industry, and so for European farmers and consumers. The Fertiliser Regulations update focuses on fertiliser safety, but other implications must also be assessed, for example impact on water quality or environmental costs of decadmiation processes (chemicals and energy used, waste). Defra emphasise that regional differences in soil and climate are very important for cadmium (bioavailability and so crop uptake, soil accumulation or leaching) so that subsidiarity is justified and Member States should be allowed to define fertiliser cadmium limits nationally or locally where necessary, rather than fixing a lowest common denominator level across Europe. Another possibility would be for the EU legislation to fix different limits for different regions of Europe, as is done in the implementation process for the plant protection directive (see *http://www.eppo.int/PPPRODUCTS/ppp_standards/comparable_climates.htm*)

Participants point out that certain non-EU countries have already set different levels of cadmium limitation in fertilisers, based on risk assessments. These vary widely: 400 mg Cd (per kg P_2O_5) in California, 148 in Japan, 131 in Australia, 122 in New Zealand, 33 in Norway, 21 in Switzerland, 20 in Canada. The science behind these different limits should be taken into account.

Participants emphasise that Member State derogations should be science-based and justified, not only political.

The European Commission confirms that the new Smolders study (see above) will be taken into account, once it has been peer-reviewed, and that consequently an updated Opinion will be requested of the European scientific committee SCHER.

The European Investment Bank indicates that loans have already been made to fund development of decadmiation technology in Tunisia, but that no return of information is available. If EU policy or regulation were to fix fertiliser cadmium limits, then the Bank would de facto have a mandate to make loans for other decadmiation investments.

Antoine Hoxha (Fertilizers Europe), Vincent Delvaux (European Commission), Murray Hart (EU Government Defra), Carsten Gellermann (Fraunhofer), Christian Canoo (International Cadmium Association), Franceso Presicce (European Commission)

Impacts on industry

Mr Delvaux (European Commission, DG Enterprise) indicates that the current average cadmium level of fertilisers sold in Europe is 45 mg Cd (per kgP_2O_5). A proposed 60 mg Cd cadmium limit would exclude 21% of fertilisers, whereas EU limits of 40 or 20 mg would cause very considerable disruption to the fertiliser market.

Co-crystallisation technology seems today to be the most feasible decadmiation route subject to developing a process to deal with the cadmium containing waste. It is a known technology similar to existing industry processes, estimated to have lower cost than other routes, does not require high temperatures. Industry participants stress however that this is **only applicable to phosphoric acid, and so only to around 2/3 of fertiliser production** (not to the single super phosphate or nitrophosphate routes).

Cadmium limits could thus have very different impacts on different sectors of the fertiliser market and on different companies, depending on their process route. Supply and prices of low-cadmium rock would come under increased pressure. Some fertiliser producers in Europe could be forced to close, others with access to low-cadmium rock, using the phosphoric acid route or with local options or cadmium-waste recycling or disposal, would be advantaged. Economies of scale and waste disposal issues could further push fertiliser production upstream to rock-mining countries.

Several participants note that European decisions on cadmium levels in fertilisers or on cadmium in imported food and animal feeds will have impacts worldwide, e.g. through impacts on supply and price of low-cadmium rock.

It should be ensured that EU cadmium limits do not result in cadmium being "transferred" to farmers outside Europe, if cadmium extracted in producing low-cadmium phosphoric acid is transferred to other phosphoric acid streams.

Eric Liégois (European Commission, DG Enterprise) notes that industry recognises that cadmium is a human health issue which needs to be addressed and recommends industry to prepare economic data on decadmiation costs and impacts for the political discussion of the Fertiliser Regulation revision.

Workshop conclusions

Sonja van Renssen (environmental journalist and session moderator) summed up as follows:

- **Most participants consider reasonable the proposal of an EU 60 mg Cd (per kgP_2O_5) limit on cadmium in fertilisers**, with a subsidiarity possibility for Member States to fix lower national or local limits where justified. However, derogations should be science-based.
- This is likely to be the European Commission's proposal, but can be expected to come under considerable **political debate** in the European Parliament and Council (Member States)
- **The current European Commission consultation on sustainable phosphorus management** will provide input to this debate

- It is necessary to **submit the new study on cadmium soil accumulation (Smolders, see above)** to peer-review and then to the European scientific committee SCHER
- There is discussion as to whether cadmium limits should be defined on **Risk Assessment basis** or by modeling of calcium soil balances (avoid soil accumulation)
- Participants generally agree that **feasible decadmiation technologies are available for the phosphoric acid route of fertiliser production (2/3 of fertilisers),** but with considerable cost implications which would impact European industry, farmers and consumers, and necessitating some time for implementation to scale up, optimise and to find solutions to treat the generated cadmium waste.
- **Further data is needed regarding decadmiation technologies** in order to adequately assess the impacts of fixing cadmium limits: energy consumption and other inputs (life cycle analysis), updating of estimates of costs, demonstration scale testing
- **There is no economic market for recovering cadmium**
- **Decadmiation technology has not progressed significantly over the last 20 – 30 years.** Cadmium limit legislation would drive forward technology and implementation, and also facilitate project funding.

Fertilisers Europe concluded the workshop by emphasising that the new Smolders study considerably changes the frame of the fertiliser cadmium discussion, and should be fully taken into account and considered by the EU scientific committee SCHER. The risk assessments justifying cadmium limits set by different countries outside the EU should also be considered.

Fertilisers Europe considers that **a priority is development of cocrystallisation/coprecipitation decadmiation technology** (for merchant grade phosphoric acid): update of cost estimates, R&D into waste processing. An industrial scale demonstration plant is needed to deliver reliable data.

Finally, it is reminded that **fertilisers are vital and positive**, for farmers, food production and the quality of life in Europe and worldwide.

Smolders 2013: "Revisiting and updating the effect of phosphorus fertilisers on cadmium accumulation in European agricultural soils", IFS (International Fertiliser Society) Proceedings 724 www.fertiliser-society.org

European Commission (DG Enterprise) Fertiliser Regulations page: http://ec.europa.eu/enterprise/sectors/chemicals/documents/specific-chemicals/fertilisers/

EU Commission (DG Environment) public consultation on sustainable phosphorus management, until 1st December 2013 (see SCOPE Newsletter n° 95) http://ec.europa.eu/environment/consultations/phosphorus_en.htm

Cadmium EU risk assessment report 2008 http://esis.jrc.ec.europa.eu/doc/risk_assessment/SUMMARY/cdmetal_cdoxidesum303.pdf

Cadmium risk reduction measures, European Commission communication , OJ C 149, 14/6/2008, page 6 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2008:149:0006:0013:EN:PDF

EFSA (European food safety committee) Opinion on cadmium 2009 (n° 980) http://www.efsa.europa.eu/fr/efsajournal/pub/980.htm

SCHER (then CSTEE) Opinoin on the risk to health and the environment from cadmium in fertilisers, 24th September 2002 http://ec.europa.eu/enterprise/sectors/chemicals/files/cadmium/scte e_en.pdf

Phosphorus supply

Phosphate rock resources and reserves critically examined

This new review of phosphate rock reserve and resource figures offers a detailed critical assessment of recent publications estimating these reserves (IFDC 2010, USGS 2011-2013) and of the older publications on which these are based.

The authors conclude that the IFDC figures published in 2010, which multiplied previous reserve estimates by a factor of four, contain a number of significant errors and use an inappropriate, new simplified method of classifying different types of reserves/resources which is not compatible with leading resource classifications, including the increasingly adopted United Nations Framework Classification (UNFC) for mineral reserves.

The authors identify **broad confusion across the literature** between 'concentrate' (that is extracted and upgraded phosphate rock) and raw phosphate rock (c.

1--6x difference or more, depending on the ore in question), between tonnes and m^3 (c. 2x difference), and between reserves and resources.

The authors also point to **unrealistic predictions of world phosphorus use** in the IFDC 2010 revision of the "Peak P" discussion: the IFDC estimate of how long phosphate reserves could last is based on an estimated annual consumption rate of 160 million tonnes phosphate rock per year (MtPR/y), whereas world consumption in 2011 was already 198 MtPR/y and expected by many authors to increase with population growth, development, diet change, biofuels production and other factors, even though others underline that this increase may be mitigated by the P reserves effectively stockpiled in farmland in some regions of the world (see eg. Sattari et al. in SCOPE Newsletter n° 93).

IFDC figures and Morocco's deposits

The authors criticize the IFDC's figures for world phosphate rock reserves and resources, published in 2010 and taken into USGS figures also in 2011 - 2013 (see SCOPE Newsletter n° 77 and 91) which **increased estimates of global phosphate rock reserves from 16 000 MtPR to 65 000 MtPR (67 000 MtPR in 2013).**

As already pointed out by Cooper et al. (SCOPE Newsletter 81) and GPRI (SCOPE Newsletter 77), this increase corresponds to an **increase in estimates of Moroccan phosphate rock reserves** from 5 700 MtPR to 57 000 MtPR, based apparently only on Gharbi, 1998. The authors argue, on the basis of other publications by both Gharbi (Gharbi and Mchichi, 1996) and the Moroccan producer OCP, that Gharbi and IFDC have confused "reserves" and "resources", so that this apparent increase in reserves appears to represent an error in classification rather than a real re-estimate of deposits or their accessibility.

The authors' criticisms are of four types:

- **Methodology of classification**
  The authors indicate that the methodology introduced in the IFDC 2010 report and used to generate these figures is not conform to the principles of the USGS classification or the United Nations Framework Classification mineral reserves classification principles, as increasingly accepted globally (UN ESOTOC resolution 2004/233, alignment with CRIRCSO petroleum industry methods in 2009). Beyond the 'expert' debate about methodologies, the authors suggest that the simplification in the 'new' IFDC system results in decreased reliability of estimates and in confusion between realistically exploitable, unexploitable and hypothetical or speculative deposits. The authors also argue that, according to available information, the spacing between drillholes in Morroco means that the term "reserves" is inappropriate for the Moroccan deposits identified in Gharbi (1998) and used in the IFDC 2010 report, and that these deposits should be qualified as "resources" as they are in other publications by Gharbi and OCP (see above). For example, standard methodology recommends <1km distance between sampling points to confirm deposits as "reserves", in order to limit uncertainty concerning extrapolation between drillholes.
  SCOPE Newsletter editor's comment: these issues may or may not reflect unreliability of the PR deposit estimates, they certainly contribute to the lack of transparency, understanding and consensus about these estimates.
- **Confusion between PR reserves and resources**
  Reserves can be loosely defined as deposits which are considered exploitable under current price and foreseeable technology conditions. Resources are deposits which might become exploitable under different price and technology conditions. Sub-resource deposits, or occurrences, are deposits which are not deemed recoverable in the foreseeable future. The authors point to confusion between these categories in many publications concerning phosphates.
- **Errors in accounting PR reserves and resources**
  The authors point to a number of significant errors in accounting both PR-reserves and PR-resources: confusion between m^3 and tonnes of phosphate rock (factor x2), confusion between figures for PR 'concentrate' (phosphate extracted from rock after mining and beneficiation losses) and in-the-ground phosphate rock (factor 1-6x or more). In particular, it is unclear whether certain key figures published by USGS in certain recent individual country updates are in fact expressed as concentrate or as phosphate rock.
  SCOPE Newsletter editor's comment: the above two points principally point to a possible significant error in classification of resource s as reserves in the increased figures published since 2010, based on an error in the use of Garbi's data (resources not reserves). Although

this might be considered to not critically modify the debate about "how long the world's phosphate rock deposits will last", it would considerably modify expectations of developments in phosphate (and so fertiliser and food) prices and availability as 'reserves' are consumed and exploitation of 'resources' requires new technologies and implies considerably higher costs.

The authors note that a number of authors have expressed belief that there are likely to be few to-date truly **unidentified regions of phosphate deposits in the world (speculative resources),** because of the specific biogeophysical conditions necessary for phosphate rock deposit formation and because such deposits could be expected to have been already identified during prospection for oil.

The authors remind that **phosphorus cannot be substituted and is essential for and closely linked to food production**, so that is essential that adequate phosphorus reserves are preserved for future generations. They conclude that the range of inappropriate methods, errors, confusion and ambiguities in reporting and analysis of phosphate rock reserve and resource figures show the need for an independent review of phosphate rock deposit estimates, using recognized classification methodology, as well as scenarios for demand and use and models for evolution of price and availability over time.

"Recent revisions of phosphate rock reserves and resources: reassuring or misleading? An in-depth literature review of global estimates of phosphate rock reserves and resources", Earth Syst. Dynam. Discuss., 4, 1005–1034, 2013, www.earth-syst-dynam-discuss.net/4/1005/2013/

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Peak phosphorus debate

Predictions of phosphorus resource depletion

Recently published phosphorus rock resource data, with both static and dynamic demand – production models, are used to estimate resource depletion and so derive cumulative "Peak P" predictions (dates when world phosphorus production would peak before declining) as 2029, 2031 and 2087 for low, best estimate and high ultimately recoverable resource figures. The dynamic models, where production increases in response to market demand, does not significantly modify these Peak P horizons, but suggests that production would initially decline more slowly in each case after the Peak.

SCOPE Newsletter Editor's note: Such 'Peak P' scenarios are questioned by some actors in industry, who believe that if demand remains high and prices increase, new resources will be identified and be extracted, that is resources which are not currently considered as 'recoverable' because of accessibility and cost issues. This is in effect what has happened for oil and gas, as unconventional resources such as tar sands and shale gas are exploited, resulting in anticipated horizons for peaks not occurring when announced but sliding forward into the future.

The predictions are based on estimates of **URR (Ultimately Recoverable Resource)** of phosphate rock derived by different methods:

- **Low estimate: derived by Hubbert Linearisation**, fitting a Hubbert trend to production data plotted versus cumulative production. The authors recognize that this method works well in a situation where peak production was some time in the past, but not where production is increasing where it will give a "lowest" estimate.
- **Best estimate: based on the authors' believed most accurate estimates for each country** from literature and various estimation techniques.
- **High: based on the IFDC 2010** (see SCOPE Newsletter n° 77) **and USGS 2012** (see SCOPE Newsletter n° 91). These data included a significantly higher reserves estimate for Morocco.

Static and dynamic models

The phosphate production models used are based on a model of mine production (over time), where mine production does not interact with demand (static model) or where it does (dynamic model).

The models suggest that actual annual production is quite variable, sometimes above or below demand. Once production reaches a level near to the "Peak P" production it will plateau and remain at this level for some time, before a rapid decrease as resources become exhausted.

The authors also model cumulative production and cumulative demand for the low, best and high resource estimates and for static and dynamic models. This takes into account the stockpiling of extracted phosphate in years when production exceeds demand. The point when cumulative demand exceeds cumulative production is the critical point for 'Peak Phosphorus', that is when demand can no longer be satisfied. This occurs ~2030, ~2090 and >2200 for the low, best and high resource estimates using the dynamic model (2090 for high resource estimate, static model).

World peak phosphorus production is estimated at 28, 50 and 55 million tonnes P/year for the low, best and high scenarios.

The authors also model the impact of production disruption in Morocco/Western Sahara over a decade (2040 – 2050), in order to **assess the significance of the very high proportion of resources identified as being in this area in the high URR estimate** (70% of total resources). The number of operating mines in the area is reduced to 1 from 2040 to 2050, instead of 8 in 2040 and 14 in 2050 in the model without disruption. The model assumes that the disruption ends in 2050. The modeled disruption reduces world production by 6 -11 MtP/year, that is a very significant proportion of world production, both during the disruption period and considerably beyond that.

The authors recognise that such 'Peak P' modeling is very simplistic, but note that there is a real possibility that the world beyond 2030 will be heavily dependent on the Morocco/Western Sahara area for phosphorus supply and so vulnerable to any disruption in production or transfer of phosphate materials from this area.

"Projections of Future Phosphorus Production", philica.com, article n° 380, 2013
http://www.philica.com/display_article.php?article_id=380 *and summary at:* http://www.resilience.org/stories/2013-08-29/new-projection-of-peak-phosphorus

S. Mohr, Institute for Sustainable Futures, University of Technology Sydney), and G. Evans, School of Engineering, University of Newcastle, UK Steve.Mohr@uts.edu.au

IFDC

IFDC clarifies and confirms phosphate rock reserve figures

The articles by Edixhoven et al. and Mohr & Evans summarized below reference IFDC estimates of phosphate rock reserves and resources. The first questions the methodology and accuracy of the estimates. The second constructs a production-demand model using new estimates of phosphate rock resources. This note is to clarify the approach used by IFDC in establishing its estimates and address some of the inappropriate assertions of the authors.

IFDC's use of a "static" consumption rate in stating enough phosphate reserves exist to produce fertilizer for the next 300 to 400 years is criticized. The static scenario is commonly used by economic geologists and by public companies to report on mine life. It is a **straightforward and unbiased way to look at the reserves**. It is not a depletion analysis.

Static or dynamic models

Efforts to perform depletion analyses far into the future are fraught with challenges, evidenced by the broad range of outcomes that can be found in the literature. The depletion article acknowledges that "peak P" modeling is very simplistic. Moreover, **such studies seldom recognize that the resource base is dynamic**. This model used an arbitrary adjustment in establishing the "best" URR estimate, with a guess regarding Morocco more than accounting for the difference compared to the high case.

The phosphate rock reserve and resource article criticizes IFDC for proposing a drastic oversimplification of terms for reserves and resources. **IFDC made no such proposal, but rather employed classical definitions to consolidate information reported under varying classification systems across the world**.

Most of the resources in the IFDC report were derived long before the UN or other classification systems were devised. While the authors contend that the UN classification system is increasingly accepted globally, they offer no examples of any phosphate rock producers who use it; IFDC is not aware of any producers who use the system.

IFDC's only proposal regarding terminology was it be as simple as possible and that a common system be devised for any future phosphate inventory. Furthermore, any system must recognize the varying data requirements across deposits and the costs associated with developing the information for resources that will be consumed centuries in future.

Reserves and resources

The term "reserves" clearly refers to the portion of deposits that are technically and economically producible. **The "resource" definition, as given by IFDC, does not rely on data that may not exist and eliminates prognosticating on what phosphate rock may be too deep or might be mined too far into the future.** Using a broad resource definition eliminates complicated systems and subjective judgments.

The methodology of the USGS/USBM system was questioned, not criticized by IFDC, with respect to the uses of terminology. Authors may use USGS terminology without any adherence to USGS definitions. Furthermore, IFDC did not propose discarding the USGS reserve base estimates. They were dropped because USGS did not have the resources to continue this effort.

While the authors of the phosphate rock reserve and resource article may be confused by using concentrate as the basis for reserves, **it is common practice in many industries to report in terms of saleable product**. Raw Moroccan ore figures, stated in terms of cubic meters, were confirmed by OCP along with the conversion factors used. The IFDC report clearly stated that all reserves were on a common basis as concentrate. Concentrate is what matters to users and investors and eliminates confusion for those familiar with the industry.

The article implies that, since the USGS criteria are not used when estimating and reporting Moroccan reserves and resources, they are incorrect. No reserves and resources need to be based on USGS or any other particular criteria unless they are appropriate for the deposit. The continuity and consistency of beds determines appropriate distance between bore holes, which is determined by experience with a deposit.

The authors imply that the IFDC report did not classify the Moroccan Meskala deposit as reserves in a ploy to argue its report is conservative. Not classifying that deposit as a reserve was based on no development in this region despite extensive exploration and the announcement at the time of publication of four new mines in other deposits. This may be considered conservative, but the reasoning is clearly communicated in the report.

Best practice and confirmed estimates

IFDC estimates conform to best practice and informed opinion

Prior to release, an informal survey of IFA members generated a similar total world phosphate rock reserve figure. Several former consultants for the World Bank reviewed the draft report and indicated it was a good current evaluation of world phosphate reserves and resources. World Bank officials also confirmed that the final figures in the draft report were similar to the ones they use.

The IFDC report does not depart from evolving best practice. The methodology in the report was a way of making a world estimate using varying practices of diverse groups involved in phosphate mining worldwide. **The IFDC report provides a consistent, reliable assessment of the global phosphate rock situation until further work can be done**.

Text provided by IFDC (International Fertilizer Development Center), S. J. Van Kauwenbergh, Principal Scientist and Leader, Phosphate Research and Resource Initiative, IFDC, P.O. Box 2040, Muscle Shoals, Alabama 35662, U.S.A. www.idfc.org

Nutrient management ideas challenge

Innocentive challenging nutrients

Transformative Strategies for Reducing Excess Nutrients in Waterways

Challenge for ideas for reducing nutrients in waterways at any stage of cycle. US$15000 award. Deadline 1 Dec.2013

Solvers are invited to submit a description of an innovative approach to reduce nutrients in waterways, in particular applicable to the Mississippi River Basin and Gulf of Mexico, including a description of technical feasibility (general approach, technical advances), impact, novelty and distinction from other ideas, user adoption strategy.

https://www.innocentive.com/ar/challenge/9933112 …

*The **SCOPE Newsletter** is now published by the **European Sustainable Phosphorus Platform**.*
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*The SCOPE Newsletter summarises news and publications concerning sustainable phosphorus management, with the aim of furthering debate and knowledge, and **does not represent an official position** of the European Sustainable Phosphorus Platform nor of its members.* ***To SUBSCRIBE*** **www.phosphorusplatform.eu** .
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Europe: ***www.phosphorusplatform.org***

Netherlands: ***www.nutrientplatform.org***

Flanders (Belgium): ***dh@vlakwa.be***

Germany: *launch 15th November 2013*

Agenda 2013 - 2014

- 27-31 October, Berlin
  Global Soil Week "Losing Ground?"
  www.globalsoilweek.org
- 3-8 November, Tampa, Florida
  ASA/CSSA/SSSA + Canada SA + SERA17
  Water, food, energy and innovation for a sustainable world
  www.acsmeetings.org and *http://www.sera17.ext.vt.edu/*
- 6 November, Amsterdam, The Netherlands
  Resource recovery from the water cycle
  part of International Water Week
  http://www.internationalwaterweek.com/events/programme-iww-conference/resource-recovery-from-the-water-cycle/
- 6-7 November, Braunschweig , Germany
  Re-Water *www.re-water-braunschweig.de*
- 6-7 November, Dortmund , Germany
  VDI Klärschlammbehandlung (Sewage sludge management) *http://www.vdi-wissensforum.de/en/nc/events/detailseite/event/06KO006013/*
- 6 November, Slough sewage works, UK.
  Thames Water unveiling Ostara struvite P-recycling plant
- 15 November, Berlin , Germany, 15h00
  Launch of German Phosphorus Platform
- 18-20 November, Manchester
  18th European **Biosolids & Organic** Resources Conference & **Biorefine**
  http://www.biorefine.org/ & *www.aquaenviro.co.uk*
- 3 December 2013, London: **End-o-Sludg : Sludge and phosphorus management in Europe, present and future (UK)**
  eoslondon@gyronllp.co.uk
- 5-6 December 2013, Bruges:
  ManuResource 2013
  (manure management and valorisation)
  http://www.manuresource2013.org/registration
- 10 December, Brussels, **European Sustainable Phosphorus Platform steering committee** *info@phosphorusplatform.eu*
- 11 December 2013, Brussels: **End-o-Sludg : Sludge and phosphorus management in Europe, present and future (EU)**
  http://www.end-o-sludg.eu/es/wp-content/uploads/2013/09/EOS_Brussels.pdf
- 12-13 December, Cambridge, UK
  International Fertiliser Society conference: soil structure, manure, fertiliser P use
  www.fertiliser-society.org
- 6-10 January 2014, Phoenix Arizona
  2nd **Sustainable Phosphorus RCN** (US Research Coordination Network) meeting.
  http://sustainability.asu.edu/research/project.php?id=704
- 23 January, Rennes, France
  Phosph-OR 2014 (P-recycling meeting, see SCOPE Newsletter n°83)
  http://phosph-or2014.irstea.fr/
- 23-25 March 2014, Paris: **Phosphates 2014** (CRU) *www.phosphatesconference.com*
- 26-29 August 2014, Montpellier, France:
  5th Phosphorus in Soils and Plants symposium *http://psp5-2014.cirad.fr/*
- 1 - 3 Sept. 2014, Montpellier, France
  4th world **Sustainable Phosphorus Summit**
  http://SPS2014.cirad.fr
- 3rd-4th March 2015, Berlin: **2nd European Sustainable Phosphorus Conference**
- 23-25 March 2015, Florida:
  Phosphates 2015 (CRU)
- May 2015, Morocco: **SYMPHOS**
  www.symphos.com