SCOPE NEWSLETTER

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Phosphorus and sustainable food

European Commission

Public consultation on sustainable food

The EU has opened a public consultation on resource efficiency in a sustainable food system.

Research needs

Identifying priority knowledge needs for sustainable food production

A collaborative methodology, involving 46 experts and practitioners, enabled identification of 26 questions where more knowledge is needed to support development of environmentally sustainable agricultural production for the UK.

Greenpeace

Propositions for ecological livestock

Greenpeace summarise ecological impacts of livestock and propose positions for sustainable meat and dairy production and consumption

The Phosphorus Challenge

Global TraPs and Global Partnership on Nutrient Management

Phosphorus stewardship stakeholders meet in China

A number of stakeholders, including Global TraPs project partners, researchers and students met in Beijing to discuss project progress, work on several case studies underway, and to present the challenges of nutrient management to interested parties.

Sustainable phosphorus research agenda

US Research Coordination Network RCN

Consultation on priorities for phosphorus research questions

The US P- Sustainability Research Coordination Network (RCN) has opened an internet stakeholder consultation to identify priorities within 35 questions/projects for integrative research into phosphorus sustainability.

Phosphorus recovery and recycling

End-o-Sludg

Developing sustainable sewage sludge processes

The European project End-o-Sludg is looking to reduce sewage sludge generation, increase energy recovery and produce safe, farmer-friendly products to recycle nutrients.

HAIX-Fe resin

P-recovery using hybrid anion exchange

Hybrid anion exchange resin containing hydrous ferric oxide (HAIX-Fe) was tested for P-removal and recovery by sorption/regeneration in different waste streams including urine and sewage works liquors.

Japan

Pharmaceutical and hormones in struvite

Struvite precipitated in synthetic and real urine containing 11 pharmaceuticals and hormones showed presence of 3 of the pharmaceuticals

ESPP technical – training meeting

Regulatory issues around recycled phosphates

The European Sustainable Phosphorus Platform is organizing a technical meeting to look at regulatory issues involved in recovering phosphates and using recycled phosphate-containing products in agriculture, open to Platform members and experts.

Agenda: dates 2013-2014

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European Sustainable Phosphorus Platform

European Commission

Public consultation on sustainable food

The European Union has opened a public consultation (to 1st **October 2013**) on how to move towards a sustainable, resource efficient food system. Phosphorus depletion is one of the underlined impacts of food production and consumption, alongside greenhouse gases, land and water use, pollution and chemicals.

The European Commission's web page presenting the consultation objectives indicates a number of key issues which make today's food production system unsustainable:

- Environmental impacts, including nitrogen exceeding planetary boundaries by a factor of 4 and phosphorus at planetary boundary levels
- One fourth of world greenhouse gas emissions
- Principal cause of biodiversity loss
- Price volatility, accentuated by climate change and loss of agricultural diversity, to the detriment of food security
- High intakes of meat, fat and sugar make the average Western diet a health risk

Europe 2020 resource strategy

The consultation refers to the Europe 2020 strategy 'Resource efficient Europe' and the 'Roadmap to a Resource Efficient Europe' and the EU Parliament report (2011) on food wastage, emphasising that sustainable a food system requires both a lower environmental impact of food production and less waste throughout the food supply chain.

The European Commission estimates that **around 89 millions tonnes of food is wasted in Europe** annually, likely to rise to 126 million tonnes if no action is taken.

Editor's note: this probably corresponds to 180 000 tonnes of phosphorus lost, rising to 250 000 tonnes (see calculation in SCOPE Newsletter n° 95)

Public consultation on sustainable food:
http://ec.europa.eu/environment/consultations/food_en.htm

European Commission web page:
http://ec.europa.eu/environment/eussd/food.htm

Research needs

Identifying priority knowledge needs for sustainable food production

Using a structured methodology, a representative selection of 29 practitioners and 17 environmental scientists was convened to propose areas where more knowledge is needed to support improvement of the environmental sustainability of agricultural food production in the UK or for import into the UK, but excluding issues relating to consumption of food, health and nutrition. The outcomes will guide knowledge exchange work, science funding and policy.

An **initial list of 264 knowledge need areas was collaboratively developed**, then selected down to 26 priority areas by a three stage process of voting, discussion and scoring.

Knowledge integration

Many of the identified priorities involve integration of knowledge from different disciplines **to inform policy and practice**.

Sustainable food production is an increasing focus of the food industry, policy makers and R&D, driven by **consumer sustainability concerns, global environmental change issues, pressure from increasing world population and changing diet and corresponding concerns about food security**. Environmental sustainability is a key aspect of these issues.

Considerable knowledge exists concerning farming, food systems and their environmental impact, but often there is **inadequate communication of specialist research to other sectors, and there is a lack of integrated research** looking at the overall environmental impacts of agricultural systems from farm to plate.

Recognised, scientific methodology

A key aspect of the methodology was ensuring that the participating **practitioners and experts were representative of relevant stakeholders**, areas of expertise and research knowledge. The practitioners were all from organisations directly involved in food production, covering agrochemicals, feed and food industry, supermarkets, trade associations and relevant NGOs and regulatory authorities and agencies. The researchers were all involved in recognised NERC (National Environment Research Council) programmes, and were selected to cover competence in soils, biodiversity, crop ecology and health, livestock, the food industry and whole farming systems.

The authors emphasise that the results of such an exercise depend above all on the **selection of participants**. In this case, participants were proactively selected to ensure a representative balance of different areas of competence and of interest, and it was ensured that the group was inclusive, that is covering all major relevant stakeholders and specialisations.

Representative, open, applicable

The initial list of knowledge needs was generated by asking each of the 46 participants to submit 10 proposed research need areas. **Proposals were invited to be precise, but open to cover any environmental aspect of food production**. 13 examples of 'knowledge needs' proposals were provided as illustrations, drawn from previous research agenda prioritization exercises. Participants were incited to consult colleagues. Participants indicated a total of 239 people (not including participants) who had been consulted and had given an opinion.

The long list of proposals received was compiled (grouping of duplicates) and structured into 9 categories (no category was created for areas with <15 proposals). This generated a **long list of 264 knowledge need areas, which was submitted to online voting by participants**, using the online survey tool Qualtrics.

In a second stage, each of the 9 categories was discussed at a workshop (at which 38 of the 46 experts participated), with the results of the first vote and comments received visible to participants. Participants were asked to identify the knowledge needs which, if met, would **enable their organization to change practice or improve agricultural sustainability**. This stage selected a list of 53 knowledge needs, submitted to a final plenary discussion, where voting identified the 26 finally selected knowledge needs. Statistical analysis was used to identify questions scoring significantly differently, and to correlate between practitioners and scientists. Differences in scoring pattern between groups of scorers were searched for using an exploratory method of data analysis called Multiple Factor Analysis.

Phosphorus recycling scores highly

The knowledge need question "*How can phosphorus be recycled effectively for farming systems*" was scored third highest of the 26 priority questions. The first two priorities were the development of a sustainable animal feed strategy and understanding the trade-offs between different ecosystem services (including biodiversity and crop production). Making crop production more water efficient and optimizing nitrogen inputs (whilst minimizing nitrous oxide emissions) were 14th and 15th priorities.

Other priority questions addressed issues such as measuring sustainability, economic and market questions, impact of climate change, soil biodiversity and soil health, sustainability of increasing yields and intensive agriculture, livestock production systems and livestock feeds, pest losses.

The **re-integration of livestock and arable production was present in several initial proposals**, but did not reach the finally selected list of questions, but may be implicit in the three selected questions concerning animal feeds, in particular in the first priority question of developing a sustainable animal feed strategy. These questions on animal feeds also recognize the considerable environmental impacts of production elsewhere in the world of animal feeds imported into the UK (land use, biodiversity, …)

Next steps

The consulted practitioners and scientists will now consider **how to address the knowledge needs identified concerning sustainable food production**, using the same iterative and collaborative methodology, including looking at what actions can be engaged within participant organisations and outside this group by other stakeholders.

"What do we need to know to enhance the environmental sustainability of agricultural production? A prioritisation of knowledge needs for the UK food system", Sustainability, n° 5, pages 3095-3115, 2013 www.mdpi.com/journal/sustainability *Open Access.*

Funded by NERC Knowledge Exchange Programme, with contributions from Arcadia and the UK Global Food Security Programme.

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Greenpeace

Propositions for ecological livestock

Livestock production is one of the main drivers of land use change, deforestation, biodiversity loss, greenhouse gas emissions and to nitrogen and phosphorus pollution worldwide. Meat and dairy consumption also pose health issues. Greenpeace summarise impacts of meat and dairy production and consumption and present proposals for an ecological livestock system.

Greenpeace's definition of "***ecological livestock***" is farming which ensures healthy food for today and tomorrow, by protecting soil, water and climate, promoting biodiversity, and does not contaminate the environment with chemicals or genetically modified organisms. Ecological livestock integrate farm animals as essential elements in agriculture, contributing to use and recycling of nutrients, and in many regions providing a farm work force.

For Greenpeace, **ecological livestock production relies on grasslands/pasture and on crop residues for feed**, minimizing the use of land which could be used for human food production, and contributing to protecting ecosystems and biodiversity.

Greenpeace consider that scientific evidence shows that **less intensive beef and dairy production emits less greenhouse gases than intensive systems**, once impacts such as land use change related to feed production are taken into account (Bellarby et al. 2012).

Food production efficiency

Current estimates (Foley et al. 2011) suggest that **75% of the world's agricultural land is devoted to livestock production**, either through pasture or growing feed crops.

The amount of human food energy produced compared to food energy consumed by cattle can varies from 5%, for beef in feedlots, up to 70% for cattle raised on pastures (Pelletier 2010). Greenpeace consider that livestock should only be produced on "*default*" land use, that is **where the land cannot be used for direct human food production**, thus minimizing land consumption.

Pork and poultry production can also efficiently use various **agricultural, food processing and food wastes**, provided health safety precautions are ensured.

Greenpeace promote both "*land sharing*", where livestock production is combined with management of biodiversity habitats, and "*land sparing*", where intensive agriculture enables reductions in land use. However, Greenpeace underline that "land sparing" is not likely to result in land being returned to biodiversity conservation or to result in reduced deforestation under a market economy, **unless public policies ensure this** (eg. forest protection, incentives, …).

Livestock grazing can be important to maintain high-biodiversity habitats, such as extensive grasslands, but it is estimated that only 4% of Europe's dairy production and 20% of Europe's beef production comes from such grazing (Westhoek 2011). Also, grazed grassland can sequester carbon, but the potential capacity and long term fate are not today known.

Phosphorous

Greenpeace indicate that major actions are needed in both arable and livestock agricultural systems to **make phosphorus management more sustainable, to avoid resource depletion and reduce phosphorus losses** (and so eutrophication risks):

- **Minimizing manure wastage**, by returning manure to the land from which feed crops originate
- **Stopping overuse of phosphorus fertilizer** on arable land whilst optimizing land use
- **Avoiding phosphorus losses from soils** by improving soil management and improving soil quality. For livestock, avoiding overgrazing.
- **Adjusting livestock diets** to minimize phosphorus losses

Implications for diet: 250g meat per week

Greenpeace estimate that for global livestock production to be ecologically sustainable, using only "default" land, **average world meat consumption must be reduced from a business-as-usual scenario of world average 50 kg meat/person/year (around half current consumption in rich societies) to maybe 12 kg meat and 25 litres of milk per person per year (approx. 250g meat and ½ litre of milk per week).** Such a level of consumption would be sustainable and could contribute to maintaining high-biodiversity habitats and optimising nutrient and resource use in agriculture. This does not take into account the significant potential possible by reducing food wastage (maybe 20%).

Greenpeace suggest that such a reduction in meat and dairy consumption would have **health advantages in rich societies**, citing a study suggesting that a 30% reduction in animal products intake could reduce heart disease mortality by 17% (UK, Brazil, Friel et al.

2009). Greenpeace suggest that further research is needed into the health implications of eating grass-fed compared to intensive/feed-fed animal products.

"Ecological Livestock: Options for reducing livestock production and consumption to fit within ecological limits, with a focus on Europe", Greenpeace Research Laboratories Technical Report (Review) 03-2012, 36 pages:
http://www.greenpeace.org/international/en/publications/Campaign-reports/Agriculture/Ecological-Livestock/

The Phosphorus Challenge

Global TraPs and Global Partnership on Nutrient Management

Phosphorus stewardship stakeholders meet in China

The 1st "Global TraPs" project world conference was held in Beijing, 18 – 20 June 2013 (following 4 previous workshops in 2011 – 2012), in conjunction with the 5th conference of the Global Partnership on Nutrient Management.

Previous Global TraPs meetings discussed knowledge gaps: that is areas where more information (new research or better sharing of existing understanding) is needed to support sustainable phosphorus management.

The Global TraPs project is half way through its five-year process and intends to now move forwards **to define widely and openly agreed**:

- **proposals on priority focus areas for action and possible objectives,**
- **a research and knowledge sharing agenda**
- **and a toolbox of possible policies and actions**.

For information on previous Global TraPs meetings, see SCOPE Newsletters n° 80, 86, 91.

Global TraPs stands for "Global Transdisciplinary Processes for Sustainable Phosphorus Management." The Beijing meeting showed the value of knowledge sharing through the transdisciplinary approach.

The five-year project (2010-2015) integrates perspectives from participants who represent diverse parts of society, to allow for discussion and learning in a non-politicized and non-competitive arena, and with the overall objective of identifying options for more sustainable use of phosphorus. Transdisciplinarity involves joint leadership of research and case studies by scientists and concerned actors from society

(industry, users, NGOs …). Global TraPs is jointly led by **Prof. Roland Scholz of the Fraunhofer Alzenau IWKS Germany** and **Dr. Amit Roy, President & CEO, International Fertilizer Development Center (IFDC).**

Global TraPs "case studies"

The Beijing meeting's first day ('Mutual Learning Sessions') was devoted to critical questions identified in previous Global TraPs workshops and to the 14 case studies initiated to investigate **how transdisciplinarity processes may be applied to deal with specific questions** of sustainable transitioning related to phosphorus management. The preparation and running of the case studies is supported by a group of 14 PhD and Masters students, under the guidance of **Prof. Ulli Vilsmaier, Leuphana University, Germany**.

These sessions enabled stakeholders and other researchers to **discuss and exchange information** about the objectives and methods, with a number of field visits including Beilangzhuang piggery and crop production, Chagping vegetable farm (Science-Technology-Practice Backyard STP-BY approach) and Beijing Weijia sewage plant (Veolia, Malaysia Kerry, Beijing Drainage Group).

Weijia sewage plant, Beijing

The case studies discussed address:

- **Potential for sustainable phosphorus use and P-recycling in China**, looking at the examples of intensive pig production, sewage works, vegetable farming
- **Quantifying sources of phosphorus to Manila Bay**, Philippines, and possible mitigation policies
- **Testing recycled phosphorus products in tropical palm oil plantations in Vietnam**
- **Access to adequate fertilisers**, other production means and improving crop productivity in Kenya
- **Improving the sustainability of phosphate rock mining**
- **Possible policies** to move towards phosphorus sustainability
- **Technology options** for phosphorus recovery and recycling
- **Fertiliser subsidies**

A key outcome of the "Mutual Learning Session" on manure management was **agreement between some 20 Chinese and international scientists and practitioners on the following policy orientation**:

"*There is an increasing need for manure management and also new potential because of increasing numbers of CAFOs (Concentrated Animal Feeding Operations) in China. This calls for a re-coupling of animal and plant production on an altered scale, for technology development, for spatial planning, and even nutrient balances including utilizing the organic matter.*"

Global Partnership on Nutrient Management Conference on nutrient management

The conference was opened by **Ke Bingsheng and Fusuo Zhang, China Agricultural University, Roland Scholz, Fraunhofer IWKS, Germany, Anjan Datta, UNEP, Kenya, Amit Roy, IFDC, USA, and Klaus Töpfer, Institute of Advanced Sustainability Studies, Potsdam, Germany.**

Roland Scholz underlined **the complexity of the 'Phosphorus Challenge',** from exploration through mining, processing and use to dissipation or recycling. The anthropogenic phosphorus cycle is shows an overall human uptake efficiency of <10%. Increasing food production through intensive fertilisation poses environmental issues, including eutrophication, biodiversity and possible rebound effects or tipping points.

Roland Scholz indicated that although global demand for phosphorus is expected to increase, phosphate rock scarcity ("Peak P") is not expected in the short or medium term, as reserves are dynamic, and resources (potential reserves) will become economically exploitable in the future as price and demand increase and technology is developed (*see Scholz et al. in SCOPE Newsletter n° 91*).

Roland Scholz identified as key challenges **reducing the environmental impacts of phosphorus use and dissemination, ensuring phosphorus access for the poor (food security) and closing the phosphorus cycle**, emphasising that this necessitates a multi-stakeholder discourse and integration of knowledge (science) and society, which are the objectives of Global TraPs.

Hideaki Shiroyama, Tokyo University, presented the use of transdisciplinarity methods in bringing together scientific knowledge and public decision making, as relevant to global phosphorus management;

Anjan Datta, UNEP

Anjan Datta, UNEP (United Nations Environment Programme), underlined that combining food security and environmental sustainability is a key element of world sustainable development policies. Nutrient management is an important aspect, and the economic costs of nutrient losses must be taken into account.

Minus 20% by 2010

He presented the recommendations of "Our Nutrient World" (UNEP, 2013, see below). **The 20% reduction by 2020 objective** proposed in this document for increased nitrogen use efficiency could be considered as a starting point for deriving parallel objectives for sustainable phosphorus management.

UNEP policy framework proposals from 'Our Nutrient Planet" 2013

*There is **an urgent need to develop joined-up approaches to optimize the planet's nutrient cycles for delivery of our food and energy needs, while reducing threats to climate, ecosystem services and human health**. Such inter-connections require an international approach that takes account of local and regional conditions and focuses on a shared aim to improve nutrient use efficiency (NUE).Further efforts should be dedicated to quantifying 'Full-chain NUE', together with the component terms, to incorporate all influences and opportunities for improvement.*
International consensus is now needed that mandates a partnership of the key stakeholders to:

- *Establish a **global assessment process for nitrogen, phosphorus and other nutrient interactions** between air, land, water, climate and biodiversity, considering main driving forces, the interactions with food and energy security, the costs and benefits and the opportunities for the Green Economy,*
- *Develop consensus on the **indicators** including nutrient use efficiency, with benchmarking with which to compare progress in making improvements and in reducing the adverse environmental impacts of nutrient losses.*
- *Further investigate **options for improvement of NUE (nutrient use efficiency),** demonstrating social and economic benefits for health, environment, and the supply of food and energy,*
- ***Identify and address the major barriers to change**, fostering education, multi-stakeholder discourse and public awareness,*
- ***Establish internationally agreed targets for improved Nr and P management** at regional and planetary scales,*
- ***Quantify the multiple benefits of meeting the nutrient targets** for marine, freshwater and terrestrial ecosystems, mitigation of greenhouse gases and other climate threats, and improvement of human health,*
- *Develop and implement an approach for **monitoring achievement of the nutrient targets** within different time-scales, and for sharing and diffusing new technologies and practices that would help to achieve the targets.*

In a 'constant output scenario' it is estimated that the proposed aspirational goal for a 20% improvement in full-chain NUE by 2020 would deliver an annual estimated saving of 20 million tonnes of Nr globally. Based on initial estimates, this equates to a net benefit of $170 (50-400) billion per year, when counting the fertilizer savings, implementation costs and benefits for health, climate and biodiversity. The same scenario 20% improvement in NUE while maintaining current levels of N input would deliver smaller quantified net benefits $70 (15-165) billion per year, although this figure does not include the substantial additional benefits of increased food and energy production.
***Further efforts should seek to value the production benefits, P savings and other co-benefits**.*

"Our Nutrient World" (UNEP, 2013), see page 95: http://www.gpa.unep.org/index.php/global-partnership-on-nutrient-management/publications-and-resources/global-partnership-on-nutrient-management-gpnm/143-our-nutrient-world

Ke Bingsheng and Fusuo Zhang, China Agriucltural University

Ke Bingsheng and Fusuo Zhang, China Agricultural University, indicated that China's agricultural production has been considerably increased over the past 2-3 decades. Food consumption has also increased and consumer food quality has improved, and China is now a net importer of animal feeds / human food.

China faces widespread eutrophication problems and agricultural pollution, and actions are now underway to address this.

Cy Jones, World Resources Institute, underlined the **economic and environmental impacts of nutrient losses to surface waters, resulting in eutrophication problems**. These impacts are likely to be accentuated by climate change, as was detailed by Jan Willem Erisman, Louis Bolk Institute. He indicated that a personal nitrogen footprint tool is available at *www.n-print.org* and that the development of a similar tool for phosphorus would be important for public awareness of the phosphorus challenge.

Oene Oenema, Wageningen University, The Netherlands, summarised the main findings **of "Our Nutrient World" (UNEP, 2013)**, **see below**, and highlighted the issues relating sustainable nutrient stewardship to food security.

On behalf of Mark Sutton, the lead author of "Our Nutrient World", Oene Oenema proposed 10 key nutrient management actions:

- **Improve the nutrient efficiency** of
  - crop production systems,
  - animal production systems
  - manure management systems
- Develop and implement
  - low **nitrogen emission** combustion processes
  - and NO_x capture technology in combustion processes
- **Reduce losses along the food production – consumption chain**
- **Recycle organic matter and nutrients** from food and household wastes back to agriculture
- **Reduce energy consumption and transport**
- **Re-orientate human diet** to reduce consumption of animal protein
  - Optimise spatial integration of animal and crop production for local manure recycling

Industry and phosphate sustainability

Xuefeng Xiu, China Phosphate Industry Association, explained that China is today the world's largest producer of phosphate rock, and also represents 30% of world phosphate fertiliser use. China is moving to vertically integrate processing of phosphate rock and currently exports around 15% of the country's fertiliser production. **China recognises a need to address the environmental pollution relating to phosphate production and use**, and also to improve the distribution of more efficient fertilisers (e.g. compound fertilisers designed for specific needs).


Xuefeng Xiu, China Phosphate Industry Association, Patrick Heffer, International Fertiliser Association

Patrick Heffer, International Fertiliser Industry Association, explained that **phosphate fertiliser use has been increasing over past decades** despite the temporary reduction in 2008 related to economic downturn: +37% since the drop resulting from the collapse of Soviet Union consumption in 1993. Recent forecasts point to a +1.9% per year increase for the next five years.

Fertiliser production capacity is expected to increase in coming years, with an estimated total of some 150 billion US$ investment in the pipeline between 2012 and 2017, of which 23 billion US$ relating to phosphate rock mining and phosphate fertilisers.

The fertiliser industry sees a number of objectives as essential for the sustainability of farming:

- Improve **profitability** of farming and industry, to enable innovation and productivity
- **Address world hunger**
- **Prevent land use changes** which would accentuate climate change and biodiversity loss
- **Minimise nutrient losses** to the environment (and so eutrophication)

To move towards these objectives, **more efficient fertiliser use is essential**, taking into account that phosphorus stored in soils is not lost but can be used by future crops, provided that soil erosion is limited. This requires better understanding the phosphorus cycle, supporting nutrient stewardship opportunities, and transferring knowledge to farmers, among others.

IFA proposes the following actions:

- **Develop a better understanding of the phosphorus cycle** (pools and flows)
- **Support nutrient stewardship programmes**: IFA is working on eligibility criteria for recognizing "Nutrient Stewardship Initiatives" that meet a required level of performance
- **Encourage innovation** in the fields of fertilizer production, products and management, and avoid regulations that discourage R&D investments
- Pay more attention to the specific situation of **Sub-Saharan Africa**
- Join forces through **public-private partnerships**

Reyes Tirado, Greenpeace, showed a 5-minute film produced by Greenpeace China witnessing river and drinking water and dust pollution problems and population health issues at phosphogypsum stockpiles and the Jinhe phosphate processing company, Sichuan Province, China. This can be seen at *http://www.youtube.com/watch?v=jncEH1-ghPU*

Greenpeace's **call for industry expertise to address phosphate mining and processing pollution issues** met with a positive response from participants.

OCP Morocco has achieved, and continues to launch, ambitious operational transformation and sustainable innovation programs. OCP has organized this year largest Scientific Phosphate Symposium (SYMPHOS) around Innovation and sustainability of the Phosphate industry.

Other participants indicated the example of Cubatão, Brazil, where operations have been improved to state of the art.

Vaughn Astley, Dr Phosphate Co, presented a range of technology options, emphasising the tight pollution control limits in place in the USA, including regulations on phosphogypsum, which effectively prevent recycling.

Friedrich-W. Wellmer, formerly German Federal Geological Survey, and **David Vaccari, Stevens Institute of Technology**, explained the **issues behind natural resource supply security**, including the roles of primary (mined) and secondary (recycled) resources, the role of state intervention and policy,the mobile distinction between reserves (economically exploitable) and resources (uneconomic in today's conditions). They presented a number of examples from other natural commodities and concluded that there is a need for more transparency regarding phosphate reserves, resources, dynamics, and learning curves for coping with declining grades and increasing impurities, and for an organisational framework to monitor this.

Olaf Weber, University of Waterloo, and **Gerald Steiner, Harvard University**, presented the different factors which affect the price of fertilisers, including supply and demand, industry investment, food prices. **Transport costs can be the crucial factor in developing countries** without adequate infrastructure and logistics, and addressing this would here be more effective than subsidies in enabling farmers to use the fertilisers they need and so improve productivity.

Yang Baoheng, Keytrade China, explained that China's considerable increase in fertiliser production has resulted in a **significant over-capacity** today, compared to China's market, leading to exports.

The question of humanity's dependence on extraction of rock phosphate for survival was raised. The proposal by some participants that **organic farming**, without mineral fertiliser input, could support today's world population was disputed by others present. This question has been addressed for nitrogen, which can be fixed from the atmosphere by cultivated plants (see Badgley et al. referenced below) but no such assessment is available for phosphorus, although an approach is made by K. Ragnarsdottir et al. 2011 (see SCOPE Newsletter n° 80). This appears as an area where further investigation and exchange of opinions is needed.

Phosphate recycling

Hisao Ohtake, Osaka University, presented experience in P-recovery and P-recycling technologies in Japan, where phosphorus recycling has been in operation for over 15 years and currently at 11 sites:

- **Fukuoka, 1997 and Matsue 1998 sewage works**: Unitika struvite recovery, both 100 – 140 tonnes struvite per year
- **Gifu 2010 and Tottori 2013 sewage works**: alkali extraction from sludge incineration ash, both c 500 tonnes calcium phosphate per year
- **Nippon Phosphoric Acid**: wet process phosphoric acid production from sewage sludge incineration ash (max. 5% ash / phosphate rock at present)
- **Senboku**: household black water, c. 20 tonnes calcium phosphate per year
- **Kyowa Kakko Bio Co** (fermentation), J-Oil Mills Inc (vegetable oil production), Kanesada Kosan (flame retardants) and **Japan Synthetic Alcohol Co**: P-recovery in effluents
- **Miyazaki Biomass Recycle Co** (poultry manure).

Other promising P-recovery routes currently being investigated or tested include P-recovery from steel making slag (P content c. 1%, or 3 million tonnes P/year worldwide) and the use of A-CSH (amorphous calcium silicate hydrates) to recover phosphates from wastewaters by adsorption (the phosphorus containing A-CSH-P can then be used as a fertiliser).

The Phosphorus Recycling Promotion Council of Japan, which brings together some 150 companies, sewage authorities and regulators, is promoting P-recovery as a route to meet stringent effluent standards and waste disposal costs. Although there is no established market at present for recycled phosphate products and no government financial support or regulatory incentive for P-recovery, the Council has as principles to "try everything without delay and try everything possible", with the aim of developing, testing and demonstrating technologies that can bring benefits to industry. **A key implementation challenge is finding local solutions for use of recovered phosphates**, often through SMEs (local fertiliser blenders – distributers).

Conference participants indicated the interest to produce case-studies presenting the technologies, logistics, local socio-economics and **lessons to be learned from these different experiences in Japan**, to complete the case study analysis already carried out on six P-recycling sites in Japan (see SCOPE Newsletter n° 91).

Leo Morf, Canton Zurich Switzerland, explained that in Switzerland agricultural use of sewage biosolids is forbidden since 2008, mainly because of concerns about contaminants. In 2006 it was realised in the Zurich canton that capacity bottlenecks are to be expected from 2015 with the existing disposal routes (mainly to municipal waste incinerators and cement kilns). Also **awareness increased that phosphorus is a limited resource and an important** nutrient.

Both factors were then used as an opportunity to define a new sludge recycling strategy based on the goal of **modern waste and resource management with optimized conservation of phosphorus**, that is treatment enabling maximum P-recovery. After evaluation of different options, it has been decided to organise centralised treatment of sludge from the region's sewage works by mono-incineration (dedicated incinerator, not mixed with municipal refuse or other wastes), with the objectives of optimising energy recovery and either recovering phosphorus or storing the sludge incineration ash in such a way that phosphorus could be 'urban mined' in the future.

The centralised sludge incinerator is now in place, and **a process to recover phosphorus from the ash produced is being tested**, with the objective of avoiding the ash storage which costs c. 100 €/tonne (storage then retrieval of the ash). A full scale evaluation is currently underway for the Leachphos (BSH) Process: leaching with sulphuric acid to recover phosphorus and separate heavy metals followed by precipitation of calcium phosphate in a form which can be used as a fertiliser

This process is being compared in detail with two possible alternative processes: Ashdec, Outotec (thermal treatment of ash, plus chlorine donor for heavy metal removal) and Recophos (chemical treatment of sewage sludge ash with phosphoric acid to achieve a P-fertilizer *http://www.recophos.de*).

The objective is to achieve 80% recycling of P in sewage, with low contaminant levels.

Phosphorus management in agriculture

Gerard Velthof, Wageningen University, emphasised the importance of management of organic wastes in the phosphorus and nitrogen cycle: manures, sewage, and food wastes. The current tendency towards geographical concentration of livestock production, usually linked to intensive "factory farming" of livestock, requires costly technological solutions to avoid environmental phosphorus and nitrogen losses and pollution, and to recover and recycle nutrients. These could be avoided by **moving back to proximity (spatial integration) between livestock production producing manure rich in organics and nutrients, and crop production where such inputs are needed**.

Tom Sims, University of Delaware, further emphasised the importance of manure management with 4Rs: right source, right application rate, right place, right time for crop needs. Although there are already many studies, **further data are still needed on the availability to plants of phosphorus in different manures**. Important issues are the mode of application of manure to land (injection of solidified manures can improve nutrient management) and manure storage, to enable application of manure according to crop needs. Although treatment processes exist for manure from intensive livestock production units, **the cost of manure treatment is a major obstacle** to their implementation.

Marco Roelcke, Technische Universität Braunschweig, explained that China now also faces a major nutrient management challenge because of intensification of livestock production, with landless livestock farms, often situated in periurban areas. Many biogas production plants have been built to treat intensive livestock manure, but most are not operating efficiently. There is a **considerable potential for phosphate recovery by struvite precipitation from liquid biogas digestates**. Without treatment phosphorus in these effluents will be released to surface waters or via irrigation to over-supplied croplands. Nutrients should therefore also be exported out of the periurban regions in form of organic fertilizers, e.g. by composting the solid phase of animal excreta. As with previous speakers, Mr Roelcke emphasised the **need to geographically integrate animal and crop production**, at different scales, aiming at re-coupling the interrupted nutrient cycles and reuse of the organic matter.

Hongyan Zhang, China Agricultural University, underlined the environmental challenges resulting from intensification of agriculture: China has 9% of the world's arable land, but produces 20% of the world's meat and cereals. Issues include, in many regions, **over-fertilisation and eutrophication problems**. Technologies and agronomic methods which enable improved productivity and better nutrient management, but training of farmers and advice (extension services) are lacking.

Krishnan Vijoo, Indian Smallholders Farmers Association and **David Nyameino, Cereal Growers Association, Kenya**, and **Rhoda Birech, Egerton University, Kenya**, presented the viewpoint of small farmers in these countries (see summary in SCOPE Newsletter n°86). They emphasised the **importance of small farmers and of women in agriculture in developing countries**, the continuing need for targeted fertiliser subsidies to enable poor farmers to improve productivity, as well as infrastructure to reduce fertiliser supply costs, the need for training and technical support of farmers in the field, and the importance of providing specific fertilisers adapted to local crop and soil conditions.

Xingzhao Gao, China Ministry of Agriculture, also emphasised the need to **maintain subsidies to support the development of agricultural production in China, whilst improving environmental protection**. Subsidies are paid per hectare or with specific objectives, for example to support soil testing or develop organic matter in soil.

Christian Nolte, FAO, Food and Agriculture Organisation, underlined again the **need to regionally integrate intensive livestock production with crop production, so that manure can be recycled locally to crops**. He mentioned land tenure as a key element in developing intensified sustainable farming systems in developing countries, and pointed out the specific case of sub-Saharan Africa where the low use of nutrients is leading to low yields and biomass production, which erodes the soils' organic matter content and causes soil degradation.

Policies to address the phosphorus challenge

Greg Crosby, US Department of Agriculture, emphasised the need for science-based policy, but that policies would not change unless the socio-economic benefits of phosphorus stewardship are demonstrated. Global TraPs can contribute to this, by innovative thinking between stakeholders. He considers that a global policy for nutrient management is not feasible, but that **a policy framework can be defined by UNEP and a toolbox of policy tools proposed to decision makers**.

Arnoud Passenier, Netherlands Ministry of Infrastructure and Environment, emphasised the importance of leadership and exemplary front runners. The Netherlands, along with other participants at this conference, can play such a role and believes that this will bring advantages in terms of innovation and recognition for Netherlands companies and knowledge institutes. The Netherlands is already moving forward on phosphorus sustainability, and now so also is Europe with the launch of the European Sustainable Phosphorus Platform, with the objective of taking practical steps now, including **developing business value-chains, addressing regulatory obstacles, and exchanging practical experience**. Regulation and policy intervention is only required if needed to ensure that business cases and local employment are sustainable and are not undermined by pollution or wastes which do not pay their real societal costs.

Debate and discussions

Reyes Tirado, Greenpeace, Roland Scholz, Fraunhofer IWKS, Amit Roy, IFDC

The **discussions with conference participants and around the case-study projects underway** suggested that a framework of focus points should be developed, to be identified as shared priorities and to be subject to regional adaptation – **see below**.

Sources of further information:

Global TraPs website: http://www.globaltraps.ch

Organic agriculture and the global food supply, C. Badgley et al., Renewable Agriculture and Food Systems: 22(2); 86–108, 2007 http://dx.doi.org/10.1017/S1742170507001640

Greenpeace information on phosphate mining and processing in China: http://www.greenpeace.org/eastasia/news/stories/food-agriculture/2013/living-with-danger-sichuan/ *and film* http://www.youtube.com/watch?v=jncEH1-ghPU

"Our Nutrient World" (UNEP, 2013), see page 95 for "20/20" objectives cited above: http://www.gpa.unep.org/index.php/global-partnership-on-nutrient-management/publications-and-resources/global-partnership-on-nutrient-management-gpnm/143-our-nutrient-world

Sino-German research collaboration project on "Recycling of organic residues from agricultural and municipal origin on China": www.organicresidues.org

Global TraPs case study proposed focus points, Beijing, 19th June 2013

An initial list of possible examples of focus points was proposed at the Global TraPs meeting 19th June 2013, to be reworked, completed and assessed:

- Efficiency of phosphate rock mining and processing
- Implementation of good practice in mining and processing
- Potential for P-recovery from phosphogypsum
- Assessment of phosphate rock reserves
- Resilience of phosphorus supply
- Importance of animal manures as a phosphorus resource
- Spatial organisation of liestock production to enable local reuse of manure on crops
- Avoidance of pollution from intensive livestock *production, including energy and P-recycling*
- Improved technology for phosphate recovery from liquid manures and biogas digestates
- Access of poor farmers to fertilisers, both financial and logistics/infrastructure
- Understanding and optimising long-term crop P efficiency
- Avoiding over-fertilisation where this occurs, e.g. often in vegetable production
- Soil P testing to enable targeted agronomic P management
- Training and outreach to farmers, including field presence of agricultural knowledge institutes
- Food waste and crop spoilage losses
- Restoration or organic matter and productivity of soils, in particular in Africa
- Role of women farmers, land tenure
- Extending and improving sanitation worldwide, including eco-sanitation systems
- Including P-recovery in sewage treatment objectives
- Ensuring safety of recycling of sewage derived biosolids and phosphates
- Where appropriate, carefully designed fertiliser or farm subsidies
- Developing biosolids – mineral fertiliser combination products
- Improved composting methods to produce transportable and marketable organic fertilizers
- Targeted complex fertilisers adapted for specific regional soils and crops
- Fertilisers to enable more efficient delivery of nutrients to crops
- Global need to address phosphorus losses and eutrophication problems
- Assessment of the different phosphorus sources to water bodies to support mitigation policies
- Define knowledge gaps or dissemination gaps (sustainable P research agenda)
- Need for involvement of shareholders, open exchange, working with other networks
- Synergies between sustainable phosphorus and other environment and employment policies
- Importance of identifying a shared set of priority questions
- Develop a policy framework in coherence with UNEP and policy toolbox for decision makers
- Value of examples, business cases, demonstration
- Action now with frontrunners and innovators to prepare the future

US Research Coordination Network

Consultation on priorities for phosphorus research questions

The US Research Coordination Network Science, Engineering and Education for Sustainability (RCN-SEES) "Coordinating phosphorus research to create a sustainable food system", see SCOPE Newsletter n° 94, has published an internet stakeholder consultation to identify priorities within 35 questions/projects for integrative research into phosphorus sustainability.

The proposed questions are grouped into five themes: global P demand (4 questions), water quality impacts (7), agricultural production (5), P-flow reduction, recovery and recycling (7), economics, policy and communication (12), plus the option to propose other subjects or questions perceived as more important than the 35 proposed.

35 proposed research questions / projects

Response to the online survey is invited from all non-academic stakeholders with an interest in phosphorus: food producers, fertilizer interests, government agencies, non-profits, international agencies, international NGOs, etc.

The RCN network indicates that the objective of the online survey is to gain input concerning which questions are considered most relevant to stakeholders and society, in order to prioritise and refine the proposed topics and so orientate projects for the US RCN network for the coming two years and contribute to **influence the direction of phosphorus research** at the international level.

Online survey

The online survey takes around 10-15 minutes to complete. Personal and identifying information provided online will be kept confidential and all participants will be entered in a draw with the possibility of winning a copy of the book "Phosphorus, Food, and Our Future" (Oxford University Press).

To participate in the survey:
http://asuoue.co1.qualtrics.com/SE/?SID=SV_7aOAr2I0SDxVUCp

US RCN questions for prioritising research

The 35 questions/projects proposed by the RCN survey are given here below:

➢ What Controls Global P Production and Consumption (Demand) ?

- What are the global, regional, and country historical and **forecast trends in P demand drivers?** What do these trends of demand suggest about **total global phosphorus demand** when coupled with population growth forecasts? (data synthesis, modeling)
- **How does P price affect food affordability and availability** in different countries and regions? (econometric analysis)
- **How resilient are farming, food, and phosphate systems** to temporal disturbances in price? (econometric analysis)
- What are the temporal and geospatial implications of development of various **biomass energy strategies** for P flows and prices? (data synthesis, modeling)

➢ Watershed and Water Quality Impacts

- **What can we learn from past P management efforts** and subsequent system response in watersheds, lakes, and estuaries? (case studies)
- **How long does it take for soil P to decline** after implementation of P management measures? (meta-analysis)
- **How long does it take for watershed P export to decline** after implementation of P management measures? (meta-analysis)
- **How long does it take for receiving water quality to recover** after implementation of P management measures? (meta- analysis)
- **What is the role of hydrological variation** in influencing and moderating magnitudes and timing of system response to P management measures? (meta-analysis)
- **How much P is stored in agricultural hotspots** (such as stream buffers, mill ponds, farm ponds and, impoundments)? What is its fate? **Can it be seen as a future P resource** if returned to agricultural soils? (data compilation)
- What is the efficacy of grassland strips, constructed wetlands, two-stage ditches and other conservation practices? What is the lifespan of this effectiveness? (meta-analysis)
-

➢ Agricultural Outputs and Environmental Impacts (Efficiency)

- How do the problems of and solutions for **low soil P availability and P overuse** vary globally by cultural context and economic status? (case studies/global state-of-the-art review)
- **How closely does the capacity for crop production match actual crop production** across high and low P use scenarios? In what areas is fertilizer a limiting factor? (data compilation/analysis)
- How do **conservation practices** (e.g., no till) and their effects (on P uptake, AMF, microbial root interactions, etc.) influence P application and efficiency compared to conventional methods? (modeling, review)
- How do **different cropping systems** (e.g., monoculture, rotation, inter-planting, permaculture) affect soil P and fertilizer needs? Given economic constraints, how can cropping systems be used as a tool to reduce P in high P fields? (case studies)
- What is the status of global research in developing crop varieties and genetically modified (GM) crops with improved phosphorus use efficiency (PUE)? (review)

➢ P Flows in Human, Animal, and Waste Systems: Reduction and Recovery for P Sustainability (Recycling)

- What are the most promising strategies for reduction and recovery of P flows in Human, animal, and waste systems? (review)
- What emerging systems are available for **reduction and recovery of P from food waste?** What are their synergies with water quality, bioenergy production, and other benefits? How are these systems relevant and cost-effective for countries of different development status levels and/or in countries with P scarcity? (review/synthesis)
- How do P flows change across all scales of concentration and of spatial distance from local to global? (phosphorus material flow analyses)
- How efficient are various waste management strategies in retaining and returning P to food production?
- What is the **comparative Life Cycle Analysis (LCA) of urban manures, farm residues, and livestock manures** for proximate and distant farms and other reuses? (comparative LCA systems analysis)
- What are the economic, social, and environmental implications of P recycling from local to regional scales? (modeling)
- What technologies are available for "low" concentration (in- stream and in-lake) remediation/recycling of P? (review)

➢ Economic and Policy Perspectives on Phosphorus Sustainability

- What are the economic, social, institutional, and informational **barriers and opportunities** for conservation practices, adoption of new technologies, and acceptability of P efficient crops and recycled fertilizer? (review)
- How does socio-economic development and growth affect P cycling? (modeling)
- **How have ongoing trends in urbanization affected P cycling?** What are the likely future impacts? (data synthesis, modeling)
- **What are the full economic costs/benefits of P recycling**, including disposal, recovery, value of conservation, distribution costs, benefits and welfare? How do these differ in different regions or countries? (review economic assessment studies)
- What are the overall global economic impacts of **P fertilizer overuse**? (review)
- Is price a stronger driver of P stewardship practices than direct regulation? (data synthesis, modeling)
- **What are the positive and negative influence of other policies** (agricultural, environmental, local governance, municipality) on P policies and outcomes? (case studies)
- **What policy instruments and scales (local, regional, national, global)** would be the most acceptable and effective for addressing P stewardship? What are the motivations/arguments for and against coordinated P policies at different scales? (review)
- Globally, **what policy mechanisms are in place for fertilizer use and water quality management** in areas associated with high and low current P use, and how effective are they in impacting water quality? (review)
- How would policies that emphasize P stewardship / cycling affect urban settlement planning and zero waste systems, food processing, and the farm sector? (modeling)
- **How to communicate** progress while implementation of P management strategies is still underway and results are not yet obvious? What are the interim measurables? What are the indirect benefits? (white paper)
- What **policy measures** might promote or accelerate responses to P management practices? (white paper)

➢ Are there any projects, subjects, or questions that are missing that are as or more important than those listed?

To participate in the US RCN survey:
http://asuoue.co1.qualtrics.com/SE/?SID=SV_7aOAr2I0SDxVUCp

End-o-Sludg

Developing sustainable sewage sludge processes

The 5.5 million Euros, 14 partner, EU funded project End-o-Sludg, led by United Utilities PLC (UK) aims to reduce sewage sludge production, optimize sludge treatment to produce higher biogas (energy) yields, reduce capital investment and limit pathogens and to generate high-quality fertilizer products enabling recycling of sludge nutrients, compatible with farmers' existing equipment for fertilizer spreading.

The project's second newsletter presents progress, including **extraction of a phosphorus-rich biopolymer (Biopol)** which can be used for phosphorus recovery and recycling.

The End-o-Sludg projects takes a **five stage approach to sustainable sewage sludge management**: sludge reduction, sludge treatment, product transformation (creating high-quality end products), end of waste (addressing market, regulatory, economic issues) and sustainability (health safety, economic, environmental, resource and energy/CO_2).

Project progress

The second project newsletter presents developments in the different areas addressed by the project:

- **Improving primary settling in sewage works**, using Dissolved Air Flotation (DAF) combined with chemical flocculation. Tests carried out by Nijhuis Water Technology, The Netherlands, have shown that suspended solids primary settling can be enhanced from 25 - 66% (standard system) to 95 – 100%. COD removal in settling was enhanced from 6 -53% to 39 -79% and phosphorus removal from 4 - 15% to over 70%.
 Such high performance primary settling would mean that a much higher proportion of inflow organic carbon would go to digesters (in the primary sludge), so increasing biogas energy production potential, instead of being decomposed to CO2 in energy-intensive secondary treatment (this is coherent with Jim Hotchkies comments in SCOPE Newsletter n° 94).
- **Optimising biogas production from sludge liquors**, and mixtures with glycerin (biodiesel production byproduct), carried out by Uniovi, Spain.
- **Production of high-quality, granulated, end product (Organo Mineral Fertiliser OMF),** carried out by United Utilities, Waterleau and Valsave. Post-digestion cake was processed in a pilot plant using a combination of dehydration and granulation technologies.
 However, to date difficulties have been encountered producing granules with reliable size distribution and physical properties (crush resistance), both of which are essential if the product is to be used by farmers in their existing mineral fertilizer spreading machinery.
- **Three year field trials of the OMF product on wheat, oilseed rape, barley, beans and maze**, carried out by Cranfield University, UK. The OMF product showed crop performance as good as with conventional fertilisers, and soil heavy metal levels below permissible levels.
- **Ultrasonic sludge hydrolysis and enzymic hydrolysis**, carried out by Uniovi, with the objective of releasing soluble organics and so increasing biogas production in digestion
- **Probiotic control of E. coli development in sludge products**, by Cranfield University, UK. Harmless bacteria are being developed which can compete with problematic microorganisms such as E. coli, by consuming available nutrients.

Biopol

A further promising route being investigated by End-o-Sludg is the recovery of a biopolymer "Biopol" from sludge biomass, using micro-milling (zirconium oxide beads) to break open the cell walls, carried out by United Utilities PLC, UK. **The Biopol consists primarily of nucleic acids, and contains most of the phosphorus present in sewage sludge cells**, because of bioaccumulation of phosphorus by microorganisms during the sewage treatment process.

In present work, a minority of the Biopol is recovered, the remainder stays in the milled liquor but is highly available for biogas production, resulting in a low phosphorus digestate cake and a **high phosphate digestate liquor suitable for P-recovery**.

The Biopol can be co-precipitated with calcium salts, giving a product with a high phosphorus content (c 24%), in which the **phosphorus is readily available if recycled as a fertiliser**.

End-o-Sludg related publications:

L. Negral, et al., Short term evolution of soluble COD and ammonium in pre-treated sewage sludge by ultrasound and inverted phase fermentation, Chem. Eng. Process. (2013), http://dx.doi.org/10.1016/j.cep.2013.02.004

Deeks et al, A new sludge-derived organo-mineral fertilizer gives similar crop yields as conventional fertilizers, Agronomy Sustainable Development. (2013) http://link.springer.com/article/10.1007%2Fs13593-013-0135-z

End-o-Sludg website: http://www.end-o-sludg.eu/ *and 2nd project newsletter:* http://www.end-o-sludg.eu/es/wp-content/uploads/2013/06/End-O-Slug-Newsletter-No-2.pdf

END-O-SLUDG, 2011 – 2013, is coordinated by United Utilities Water PLC (UK) and is 63% funded by the European Union 7th Framework R&D Programme.

HAIX-Fe resin

P-recovery using hybrid anion exchange

HAIX is a strong-base anion exchange resin with immobilised metal particles, thus forming inner-sphere complexes with phosphate ions, and so selectively adsorbing phosphate in the presence of other ions such as chloride, sulphate or carbonate. HAIX-Fe resin used for this study, containing hydrous ferric oxide, is commercially available and has previously been tested for phosphate removal from both surface and waste waters.

This HAIX-Fe resin was tested for phosphate removal from: fresh urine, hydrolysed urine, household greywater, mix of greywater and urine, anaerobic digester supernatant and sewage works (secondary treatment) outflow effluent.

In a second paper, experiments were carried out in synthetic urine, prepared to correspond to fresh or to hydrolysed urine, with tests carried out to establish **kinetics, equilibrium, sorption models, competition** among sulphate, chloride and phosphate ions and co-removal of organic contaminants (pharmaceutical molecules).

P-removal experiments were carried out in triplicate using beakers shaken for 2 hours. pH was not controlled but depended on resin dosage, wastewater and P-removal reaction. Regeneration experiments were carried out after saturating HAIX-Fe resin in phosphate in a second anaerobic digester supernatant, selected to bring high organic contaminants.

For regeneration, the resin was put in beakers of 2.5% salt (NaCl) plus 2.0% sodium hydroxide (NaOH) solution and shaken for 2 hours.

90% P-removal

In all the waste streams tested, > 90% phosphate removal could be achieved at an appropriate resin dosage (eg. 150 ml resin/litre for anaerobic digester supernatant with phosphate concentration of c. 80 mgP/l).

The phosphate adsorption loading capacity of the HAIX-Fe resin showed to be greater in fresh urine > hydrolysed urine > anaerobic digester supernatant = greywater > biological sewage works effluent.

Langmuir and **Freundlich isotherm modelling** is presented, but is complex because of the variations in pH, other competing ions present, different ionic strengths, and because bulk solution data only were collected so missing local effects. The Freundlich isotherms provided a better fit to experimental results in all wastewater streams, suggesting that the resin adsorption sites have mixed energies.

The phosphorus recovery potential was greatest in fresh urine, because of precipitation of phosphates with calcium and other minerals in hydrolysed urine or in other wastewaters. If urine is diluted with tapwater, P-recovery potential is reduced both because of precipitation of some phosphate with calcium and magnesium ions in the tapwater and because the HAIX-Fe phosphate adsorption is reduced in more dilute phosphate solutions.

Potential for phosphorus recovery for recycling was estimated to be highest with hydrolysed urine mixed with greywater (1.1 kgP/day/1000 population) and lowest with sewage works effluent or anaerobic digester supernatant (0.4 or 0.09 kg/day/1000 population respectively).

The synthetic urine tests also showed up to 97% phosphate removal in < 5 minutes contact with the HAIX-Fe resin, in both synthetic fresh and synthetic hydrolysed urine, and no significant interference of sulphate or chloride ions with phosphate removal.

However, separative urine collection poses significant social, technical and infrastructure challenges, and storage of non-hydrolysed urine requires the addition of chemicals to inhibit urea hydrolysis.

Pharmaceutical contaminants

In the synthetic urine, diclofenec was added, at 0.2 mmol/l, as a typical organic pharmaceutical contaminant which is excreted in urine and is not generally eliminated in wastewater treatment. **Equilibrium experiments showed that this pharmaceutical was removed similarly to**

phosphate (>90% removal). Other negatively charged pharmaceutical molecules, such as ibuprofen, naproxen or ketoprofen, would be expected to behave similarly to the tested diclofenec.

In the synthetic urine experiments, regeneration of the HAIX-Fe resin was not tested, and **it remains to be clarified whether the pharmaceuticals would be released during regeneration and thus risk contaminating the recovered phosphate product**.

"Phosphate recovery using hybrid anion exchange: applications to source-separated urine and combined wastewater streams", Water Research (Elsevier), in press 2013
http://dx.doi.org/10.1016/j.watres.2013.05.037

J. O'Neal, T. Boyer, Dept. Environmental Engineering Sciences, Engineering School of Sustainable Infrastructure & Environment, University of Florida, P.O. Box 116450, Gainesville, Florida 32611-6450, USA thboyer@ufl.edu

"Phosphate removal from urine using hybrid anion exchange resin", Desalination 322, pages 104-112, 2013
http://dx.doi.org/10.1016/j.desal.2013.05.014

A. Sendrowski, T. Boyer, as above.

Both publications are based upon work supported by NSF CAREER grant number CBET-1150790. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the U.S. National Science Foundation (NSF).

Japan

Pharmaceutical and hormones in struvite

Struvite was precipitated from synthetic and real urine, in both cases spiked with 10 different pharmaceuticals, representative of different drug types, structures and physicochemical properties, and with one female sex hormone (17β-estradiol E2) at levels comparable to those found in sewage works.

Results were similar for synthetic and real urine (spiked with the organic contaminants tested).

Three pharmaceuticals detected in struvite

Seven of the pharmaceuticals and the hormone were below detection levels in the precipitated struvite, two (erythromycin, norfloxacin, both antibacterials) were present at 3.5 – 3.8 µg/l and one (tetracycline, an antibacterial) at 6.2 – 7.2 µg/l (concentration after redissolving the precipitated struvite from 1 litre of urine/synthetic urine in 1 litre of water).

The pharmaceuticals and the hormone were analysed by liquid chromatography – tandem mass spectrometry (LC/MS/MS). Limits of detection (LOD) and limits of quantification were established by analysis, with identified LODs ranging from 0.002 to 0.29 µg/l.

The struvite was precipitated by increasing pH to 9.6 with addition of magnesium and shaking for 12 hours. **Some of the organics might be decomposed by these reaction conditions**. After precipitation, the struvite was separated using 1µm filter paper, then rinsed in distilled water before preparation for analysis.

Seven pharmaceuticals and one hormone below detection limit

The pharmaceuticals below detection limit in the precipitated struvite were aspirin and ibuprofen (analgesics), atenolol and furosemide (cardiovascular drugs), amoxicillin, carbamazepine and trimethoprim (antibacterials). The female hormone estradiol E2 was also below detection limit in the precipitated struvite.

For erythromycin and norfloxacin, only 4 – 5% of the pharmaceutical present in the urine/synthetic urine samples was transferred to the struvite, but **for tetracycline 88 – 98% was transferred to the struvite**.

The authors indicate that chloramphicol (antibacterial), diltiazem (cardiovascular drug), caffeine, cyclophosphamide (antineoplastic / immunosuppressant) and triclosan (disinfectant) have similar physicochemical properties to tetracycline.

Further work is clearly required to extend this analysis to other organic contaminants, to better understand under what conditions such contaminants may be transferred to struvite precipitated in sewage works or other waste streams, and thus **to ensure if possible that P-recovery processes do not result in a risk of pharmaceutical contaminated product**.

Struvite precipitation from urine and piggery waste

In a previous paper (2011), Kemacheevakul tested struvite precipitation from human urine and from anaerobic effluent from an upflow anaerobic sludge blanket (UASB) reactor treating wastewater from a piggery in Saraburi province, 100 km northeast of Bangkok.

The wastewaters were dosed in beakers with sodium hydroxide or sulphuric acid to adjust to pHs from 9 – 11, rapidly mixed for 1 minute, then slowly mixed for 20 minutes.

23 – 26% phosphate removal was achieved from the urine using this method, and **83 – 86% phosphate**

removal from the piggery wastewater digester liquor. The authors suggest that the lower rates in urine correspond to low magnesium and ammonium concentrations.

X-ray diffraction and analysis of the precipitates showed them to be mainly struvite with various other complex compounds, and a phosphorus content of 3 – 7 %P.

Soil solubility of recovered struvite

The solubility of the precipitated struvite was tested in **acidic soil** (pH c. 6, 50% moisture content) in laboratory leaching experiments using tapwater. The leaching of phosphate (in this acidic soil) from the struvite was higher for struvite precipitated at pH9 than at pH11 (c. 60% and c. 50% solubility after 1-2 weeks respectively), probably because the struvite precipitated at pH9 tended to be amorphous powder and that at pH11 more crystalline in structure. In both cases **the struvite showed slow-release fertiliser characteristics**.

"Occurrence of micro-organic pollutants on phosphorus recovery from urine", Water Science & Technology, 66.10, 2012
http://www.iwaponline.com/wst/06610/2194/066102194.pdf

P. Kemacheevakul, National Center of Excellence for Environmental and Hazardous Waste Management, Dept. Environmental Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand patiya.kem@kmutt.ac.th

S. Otani, T. Matsuda, Y. Shimizu, Research Center for Environmental Quality Management, Kyoto University, 1-2 Yumihama, Otsu City, Shiga 520-0811, Japan

"Phosphorus recovery from human urine and anaerobically treated wastewater through pH adjustment and chemical precipitation", Environmental Technology, vol. 32, issue 7, 2011
http://dx.doi.org/10.1080/09593330.2010.510537

P. Kemacheevakul, Y. Shimizu, as above. C. Polprasert, Sirindhorn International Institute of Technology, Thammasat University, Rangsit Campus, P.O. Box 22, Pathum Thani 12121, Thailand.

Meetings

Brussels, 3 October 2013

Decadmiation workshop

Organised by Fertilizers Europe

With the European Sustainable Phosphorus Platform being launched, the new Fertilisers Regulation being drafted by the European Commission and the Green Paper on Phosphorus becoming available in the near future, phosphorus has become the centre of attention and feeds many discussions.

Together with the increased focus on phosphorus (P), came the attention for cadmium (Cd). Cadmium is a heavy metal that naturally occurs in phosphate rocks, albeit at different concentrations depending on the origin of the phosphate rock. Several cadmium removal (decadmiation) technologies exist but none is used at industrial scale for fertilizer production.

The objectives of this decadmiation workshop are to:

- **bring together** technology providers, companies active in phosphate fertilizer production or the agricultural sector, knowledge institutes and regulators (both at European as national level)
- **provide information** on the state of the art in decadmiation technologies and give the platform to P fertilizer producers to demonstrate their developments in this area.
- give an update of the current and future **cadmium balance in European agricultural soils**

To participate or for more information:
www.fertilizerstewardship.com

Technical – training meeting

Regulatory issues around recycled phosphates

The European Sustainable Phosphorus Platform is organizing a technical meeting addressing regulatory issues involved in recovering phosphates and in using recycled phosphate-containing products in agriculture.

Waste and water management opeators, agricultural organisations, fertilizer suppliers, will access **technical expertise** brought by WRAP (waste, recycling regulations), ReFaC (REACH registration of inorganic phosphates, chemical regulations), the European Commission, the UK Fertiliser Association, Bio-Refine, water company and other organisation participants.

The training will address:

- **Implications and implementation of existing regulations for recycled phosphate products**: REACH, waste regulations/end-of-waste status, fertilizer regulations, animal byproducts, digestate specifications, organic farming standards, safety of recovered P products/contaminants …
- **Current developments of regulatory context and proposals** to facilitate uptake of phosphorus recycling (probably not define proposals at the meeting, but maybe identify some directions to be taken forward by a working group, based on work already underway eg. by P-REX project see *www.P-REX.eu* and *http://www.asio.cz/en/p-rex-workshop*). FHNW Switzerland, leader of this work in P-REX with participate.

The number of participants is limited to around 30 and priority will be for European Sustainable Phosphorus Platform partner companies, plus organisations bringing specific expertise

Tuesday 24th September 10h00 – 17h00
central London
(venue to be announced)

To participate: contact info@phosphorusplatform.eu

Nutrient Platforms

Europe: *www.phosphorusplatform.org*

Netherlands: *www.nutrientplatform.org*

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

Agenda 2013 - 2014

- 27-28 August, Helsinki:
  A greener agriculture for a bluer Baltic Sea
  www.gabbs.eu
- 9-13 September, Uppsala, Sweden:
  7th International Phosphorus Workshop
  http://www-conference.slu.se/ipw7
- 17th September, Poděbrady near Prague
  P-REX stakeholder workshop on markets and legislation *www.P-REX.eu* and *http://www.asio.cz/en/p-rex-workshop*
- 24th September, London,
  Technical - training on regulatory issues for phosphorus recycling in agriculture
  www.phosphorusplatform.eu
- 3rd October, Brussels,
  Fertilisers Europe decadmiation meeting
  www.fertilizerstewardship.com
- 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/*
- 6-7 November, Braunschweig , Germany
  Re-Water *www.re-water-braunschweig.de*
- 19-20 November, Manchester
  Biorefine *http://www.biorefine.org/*
- 5-6 December 2013, Bruges:
  ManuResource 2013
  (manure management and valorisation)
  http://www.manuresource2013.org/registration
- 7-10 January 2014, Phoenix Arizona
  2nd **Sustainable Phosphorus RCN** (US Research Coordination Network) meeting.
  http://sustainability.asu.edu/research/project.php?id=704
- 23-25 March 2014, Paris: **Phosphates 2014** (CRU) *www.phosphatesconference.com*
- May 2014, Morocco: **SYMPHOS**
  www.symphos.com
- 25 Aug – 3 Sept. 2014, Montpellier, France
  4th world **Sustainable Phosphorus Summit**
  http://sustainablepsummit.net/