SCOPE NEWSLETTER

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Phosphate resources and uses

Phosphates 2012

Major industry conference

The CRU "Phosphates" conferences are the unique point at which the major actors of the phosphate industry from the mining, fertiliser, feed and industry sectors come together. "Phosphates" 2012, titled 'Maximising global phosphate resources', included a range of presentations of expected future phosphate supply and use and showcased companies efforts to optimise phosphate production.

OCP Morocco

Sustainable phosphate production for today and tomorrow

OCP, responsible for Morocco's phosphate resources and the world's leading producer, presented its policies for sustainable development and resource stewardship to two international conferences in El Jadida, emphasising the development of more efficient fertilisers by moving closer to farmers specific needs

Global TraPs

World stakeholders identify knowledge gaps for Phosphorus (P) stewardship

International organisations, NGOs, farmers' organisations, scientists and industry representatives met to discuss phosphorus stewardship and define knowledge gaps. Up to 25 transdisciplinary case studies will be launched to develop information and stakeholder consensus on issues and proposals.

P in the environment

EU Nitrates Directive

France taken to European Court for nitrate pollution

The EU Commission has referred France to the European Court of Justice for failure to protect waters from agricultural nitrate pollution.

Reinforcing EU water policy

EU public supports better water protection

Two surveys show that Europeans support more water protection and want and more implementation guidance.

P-recovery technologies

Seaborne Process

Full-scale testing of phosphorus and nitrogen recovery

The Seaborne process enables recovery of phosphorus (as struvite) and nitrogen (as ammonium sulphate) from sewage sludge digester effluent. A full-scale plant was constructed and tested at Gifhorn municipal waste water treatment plant (near Hannover) Germany

P and N recovery

MBR and ion exchange

An integrated system composed of a membrane bio-reactor (MBR) and two ion exchange columns was tested (using synthetic wastewater) to assess potential for phosphorus and nitrogen recovery.

Microbial fuel cells

Struvite and hydrogen production by electrolysis

Electrolysis of synthetic digester liquors showed cathode struvite precipitation and hydrogen production.

Swine wastewater

Microbial fuel cell production of struvite and electricity

Two 70 millilitre single-chamber cells were tested using swine wastewater, producing struvite precipitate on the cathode and electrical energy

Microbial fuel cell

P-recovery from iron phosphate

Electron and proton flow generated by microbial activity enabled mobilisation of orthophosphate from ferric phosphate. Struvite precipitation then enabled recovery of the phosphate in a useful form.

Conferences

Harbin, China, 23-25 September 2012

3rd IWA Nutrient Removal and Recovery 2012

Netherlands, 1 November 2012

Sustainable Phosphorus Management

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Phosphates 2012

Major industry conference

Some 500 delegates from the phosphate industry, engineering and expertise, science and media met for the CRU "Phosphates" 2012 Conference in El Jadida, Morocco, 19 – 22nd March 2012. The conference was hosted in style by Moroccan national phosphate mining, fertiliser and chemical company OCP, who presented their actions to make phosphate mining and production more sustainable, to double production and to produce fertilisers adapted to farmers specific needs (so improving phosphate use efficiency) – see below.

Overall, the Conference showed that **the phosphates industry has changed significantly over the last five years**. After the price spike in 2008, phosphates prices have moved to a firm level significantly higher than in the 20 years prior to 2008. This is both encouraging the development of new resources and enabling the industry to invest in more efficient production and in improved fertiliser products.

Robert Perlman introduced the conference by underlining that **phosphate price volatility can be expected to continue**, but within a more normal range and without peaks like 2008. Volatility is inevitable because phosphate prices are linked to world food prices, and stocks of major crops are all very low, resulting in a risk of significant price increases if any harvest is not as good as expected.

Phosphate consumption and production outlooks

Paul Burnside, Chairman of CRU, presented outlooks for phosphate consumption, supply and prices. Phosphate consumption has been growing at c. 2.6% per year on average since 2001, with the growth mostly in China. OCP Morocco currently holds 14% of world capacity, with plans for considerable expansion over coming years. **Growth of world phosphate consumption can be expected to continue**. Prices are currently falling and this may continue in 2012 before a small increase in 2013. Prices remain nonetheless close to their highest ever (if 2008 is excluded).

Mike Mendelsohn of CRU also emphasised that **fertiliser and crop prices are linked**. Production of commodity crops (wheat, maze, rice, soybean) accounts for nearly half of world phosphate fertiliser consumption. He considers that a key driver of future phosphate demand will be the increased demand for meat in diets in Asia and elsewhere, because 2 kg of grain are necessary to produce 1 kg of poultry, 4 for pork and 7 for beef. Grain production is expected to continue to increase +1% per year. World grain stocks are dangerously low, leading to price volatility, partly due to increased meat demand, but also due to rapid rises in biofuel production in the last decade. Biofuel production, increased 10 times between 2005 and 2010, but is expected to increase only +30% over the next five years, or lower as governments reduce support. He expects crop prices to decline slightly over the coming 5 years, but to remain higher than before 2005.

Ken Nyiri of CRU presented the outlook for fertilisers. **Phosphate fertiliser (P_2O_5) production was the highest ever in 2011 and is expected to increase again in 2012**. Prices are expected to fall slightly in 2012, but remain the 3rd highest year ever. This downward move of prices is temporary and is the result of the coming onstream of the new Saudi Arabia Ma'aden phosphate mine and fertiliser production site (1 million tonnes P_2O_5) and of reduced demand in India.

Ashok Singh of CRU presented the outlook for industrial phosphates. **Industrial, food and detergent applications are currently estimated to represent c. 6% of global phosphate use and demand is linked to growth in GDP**. Around 0.7 million tonnes P_2O_5 are currently used in detergents, and this is expected to remain stable, with phase out in household detergents in Europe being compensated by increases in other regional markets. Around 1.4 million tonnes P_2O_5 are currently used in other industrial applications, foods, etc. This is expected to increase +4.5%/year to the horizon 2020.

Andy Jung of CRU indicated that **animal feed phosphate consumption is expected to grow significantly over coming years**, from c. 7% of world phosphate use currently, with the increase in meat and fish in diet in much of the world, in particular in Asia. An increasing or improved use of phytase, to render phosphorus present in vegetable matter more available to non-ruminants, could reduce the growth rate.

John Sinden, JSA Ltda, also addressed the **outlook for animal feed phosphates**, looking at different regional and sector markets and at the different calcium phosphates used as animal feed additives: DCP, MCP, MDCP. China is overall the world's largest producer of animal feed phosphates, largely from thermal-route phosphoric acid – this may change with increasing energy prices. Overall world demand for animal feed phosphates is expected to continue to increase, with changes in diets towards more animal proteins. At the same time, there will be pressure to limit levels of contaminants.

These viewpoints were challenged by the only NGO present, I*za Kruszewska of Greenpeace International*, who considers that **the world should be closing the phosphorus cycle rather than producing and using more phosphate**, because of issues such as water consumption in phosphate production and eutrophication. Current models of high meat diets and concentration and intensification of livestock production should be reconsidered because unsustainable. She believes that industry should be developing phosphate recycling.

Charles Neivert, Dahlman Rose, presented a Wall Street trader's view on food and fertiliser markets, explaining how portfolio managers assess company activities and risks. He emphasised that "futures" makes little final difference to market prices, which are **fundamentally dependent on food demand and supply**. The principal traders in "futures" are farmers themselves, who take decisions on what crops to plant, how much fertiliser to use, and often also sell the harvest for a given price on the date they plant.

Phosphate resources

Andrew Drummond, Minemakers, presented a project to 'mine' **phosphate from the seafloor off the Namibian coast**. He presented the project as "almost ready to go". Two years ago at Phosphates 2010, he also presented a project for a new phosphate mine in Australia.

Steve Jasinski, USGS, presented an assessment of phosphate deposits in Iraq. **Iraq's total phosphate reserves are estimated at 9.5 billion tonnes**, of which only 0.4 billion are located in the current mined site of Akashat.

Raza Soomar, RNZ International, presented the situation **in India: increasing fertiliser use, fertiliser import, fertiliser production and phosphate rock import**. India also has around 300 million tonnes of phosphate rock reserves. To feed India's population of 1.3 billion by 2020, fertiliser consumption will have to increase +80%.

Luiz Guilherme, ANDA, presented phosphate use in Brazil. **Fertiliser consumption has been increasing in Brazil** on average +6% per year since 1990, with Brazil consuming 8.5% of world phosphate (4th largest consumer country). Intensive production on existing land can reduce the pressure for further deforestation. Significant areas of Brazil offer high potential for discovering new phosphate rock deposits.

Dr Michael Rahm, Mosaic Company, presented the US phosphate outlook. **World demand for phosphate and fertilisers is expected to continue increasing in coming years,** but this demand and the new capacity to respond to it will be largely outside the USA. Nonetheless, the USA is investing in production, to improve cost efficiency and quality, and will remain a large scale and stable player as both a phosphate producer and exporter.

New challenges, new technologies

Antoine Hoxha, Fertilisers Europe, indicated that the EU is updating and modifying its fertiliser legislation, in order to harmonise varied legislations currently existing in different countries. The new regulation should cover both mineral and organic fertilisers, as well as soil improvers, growing media and plant biostimulants. This is **liable to lead to limits on heavy metals and cadmium in fertilisers**, with Sweden currently proposing a very low limit of 20 mgCd/kgP_2O_5, which the fertiliser industry considers neither feasible nor justified. These and other developments mean that phosphorus recycling is beginning to be implemented in Europe and should become generalised.

Denis Geoffroy, Phostech Lithium (Clariant), presented lithium metal phosphate batteries. **Lithium iron phosphate or lithium iron manganese phosphate offer advantages as cathode material in batteries**, because they do not release oxygen when heated as do materials currently used in lithium ion batteries when charged. This release of oxygen explains why current generation lithium ion batteries can spontaneously ignite if they overheat or if overcharged. At present, these new materials are being considered for new battery applications (cars, energy storage), in particular for high voltage systems, but not yet for existing applications (such as laptops) where production capacity is already in place for traditional lithium ion batteries. The market for battery cathode materials is estimated at 250 000 - 630 000 tonnes in 2020.

Theodore Fowler, JDCPhosphate, presented current development of the "**Improved Hard Process" (IHP)** by the company. A pilot kiln has been tested and a 12 000 tonnes/year demonstration plant is planned for commissioning in 2013. The kiln process uses the thermal reduction process to generate phosphorus and calcium silicate slag from phosphate rock, petroleum coke and silica, without using sulphuric acid. The phosphorus is then reacted in the furnace to P_4O_{10} thus releasing energy, in the kiln, and this energy is used to feed the reduction process, so reducing energy consumption considerably compared to "thermal" acid processes. The P_4O_{10} is then reacted with water to produce phosphoric acid. Most rock contaminants are trapped in the calcium silicate slag, and not volatised into the phosphoric acid, so that a relatively pure acid is produced. The calcium slag is stable and can be valorised, and the process does not produce phosphogypsum waste.

Thomas Baroody, K-Technologies Inc, presented **Minor Element Reduction (MER) in phosphoric acid**. A combination of ion-exchange, adsorbents and solvent extraction can be used to reduce levels of minor elements (iron, aluminium, magnesium) or contaminants in phosphoric acid, whilst minimising the resulting loss in phosphate content.

Industry and phosphorus stewardship

Roland Scholz, ETH Zurich, presented the 'Global TraPs' project (see in this Newsletter). He emphasised the need for all stakeholders, and in particular industry, to think and act globally to move towards sustainable phosphorus production and use. He considers that the models suggesting phosphate will, in the short-medium term, become physically scarce ("Peak P") are not justified, but that **there is a real issue of economic scarcity relating to price and access**.

Chris Thornton, Global Phosphate Forum (detergent phosphate industry), presented the various different initiatives currently underway, often involving key stakeholders and regulators, concerning phosphate stewardship. Whilst it is generally accepted that phosphate rock is not "running out" in the foreseeable future, there is significant concern about questions such as price and access for many small farmers, food security, contaminants, regional supply security. He explained that **the detergent phosphate industry has been actively promoting P-stewardship, and in particular phosphate recycling, since the 1990's, and that Thermphos and Amfert (ICL) are both now recycling phosphate in their production sites in the Netherlands.** He recognised the engagement of the fertiliser and mining industry in today's initiatives and suggested that the whole phosphate industry, including sectors such as animal feed and industrial applications, should coordinate actions and positions on phosphorus stewardship.

"Phosphates 2012" included 20 main presentations, covering a range of subjects from mining new phosphate resources through to developing new fertilisers and industrial and animal feed applications, plus nearly 20 technical workshop presentations of new technologies, products and services.

All speakers' and technical presentation slides are available online for "Phosphates 2012" Conference Delegates only on the CRU website. Information concerning the next "Phosphates" Conference will be posted on the CRU website:

More information: http://www.crugroup.com/events

OCP Morocco

Sustainable phosphate production for today and tomorrow

In March 2012, the Morocco phosphate mining and production organisation, Office Chérifien des Phosphates (OCP), hosted two international conferences on phosphates in ElJadida, Morocco, (the Global TraPs 4th Workshop and the CRU-organised industry conference Phosphates 2012, see this Newsletter). OCP presented its own strong policy of sustainability, under implementation since the late 1990's. OCP considers that it has been entrusted, by the Moroccan State, with a resource which belongs to the nation and to future generations.

At these conferences, OCP's **policies for phosphate production development, for sustainable development and social policies, and for providing fertilisers to respond to farmers' and crop needs**, were presented by Mhamed Ibnabdeljalil, Executive Vice President Sales, Marketing & Raw Material Procurement; Wissal Mouhsine, Project Manager specialist fertilisers; Taha Balafrej, Director for Sustainable Development; Nour Benomar, Deputy Director for Sustainable Development.

Morocco has larger reserves of phosphates than any other country in the world (estimate: 51 billion tonnes of phosphate rock), and is the world's largest phosphate exporter (with around 25% of the world phosphate trade market) and OCP has a responsibility both to make these available to its customers, and to the world which needs them for food security, but equally to promote their efficient use and to minimise waste.

OCP sustainability policy

OCP's sustainability policy is enacted in three directions:

- Improving mining, transport and processing of phosphate rock
- Minimising environmental impacts and improving social benefits
- Innovating in the promotion of more effective fertilisers and better fertiliser use

The company's current investments in improved beneficiation and transport of rock and improved chemical processing will **reduce phosphate losses** by 6-8%, allow use of lower grade ore (enabling use of c. 2.5x more of the mined layers, so extending reserves), and save energy and water.

Transport will be radically improved by the installation of a **187 km pipeline to move phosphate rock in a slurry from the Kouribga mines to the chemical processing complex and port of Jorf Lasfar** (instead of using trains), with a capacity of 44 million tonnes of phosphates rock per year, to be commissioned in December 2012.

Pipelines

This pipeline will **reuse 5 million m3/year of water obtained by treating sewage from the city of Kouribga** (200 000 population) and water piped from mountain dams, to avoid using groundwater. Energy savings are calculated at 900 000 tonnes of CO2/year.

Water lost and energy used currently in drying the rock slurry after beneficiation and before train transport will be saved, and water used to transport the rock in the pipeline will be recycled to other uses.

A second pipe of similar length is also planned to transport phosphate rock from the Gantour mines to the port and industrial complex of Safi. The two pipes will offer a capacity of 55 million tonnes of phosphate rock per year. This compares with OCP's total production of rock phosphate of 18 million tonnes in 2009.

Increasing production capacity

In parallel with the opening of the pipelines, OCP will open **three new mine sites near Kouribga** so doubling phosphate production capacity in this region, and one new mine near Gantour. A total of 20 million tonnes/year new mine capacity is planned, along with 5 new beneficiation plants, to bring total capacity to 50 million tonnes/year.

The chemical processing site a Jorf Lasfar is also being expanded and modernised, including recovering 60% more energy from sulphuric acid production and installation of a desalination plant (using this recovered energy) to provide water. This site offers "plug and play" opportunities, with a full infrastructure and logistics, to other companies wishing to install plants using phosphates, with the advantage of reliable supply directly from the OCP installations.

Overall, OCP is investing some 15 billion US$ over ten years.

OCP is also investing in social development, through the **OCP Skills" programme** (training 15,000 young people with skills to fulfil identified future employment profiles) and is investing in **environmental rehabilitation of the mine sites** (2.5 million trees and shrubs being planted).

Value added for agriculture

Finally and importantly, OCP has changed both its business model and its organisation, to become a **developer and supplier of added value fertilisers**. The company is opening offices and reinforcing its presence across the world, in order to be closer to farmers across the world, and to develop fertilisers **specifically adapted to regional crop requirements**, for example by including calcium or sulphur, adjusting nutrient ratios or including macro- or micronutrients.

Specific products are already launched or being tested for local markets (Morocco) and for crops such as cacao, rice, cotton. This contributes to **improving the efficiency of phosphate use and sustainable food production**, **as well as improving soil quality and structure, and so reducing soil erosion**.

OCP estimates for example that agronomic need for sulphur inputs to soil will be around 22 million tonnes in 2015, less than half of which would be provided if only 'standard' fertilisers were provided. OCP's **sulphur enriched fertilisers** (7%S) contain sulphur in a plant available sulphate form, and are already successfully marketed in Morocco and Latin America, with extension planned to further markets in Europe, North and South America, Africa, Asia and Australia.

The **OCP Teractiv © range** has been developed to provide targeted secondary and micro nutrients for specific crop or regional needs (Ca, Mg, S, B, Zn)

Further information: www.ocpgroup.ma

Global TraPs

World stakeholders identify knowledge gaps for Phosphorus (P) stewardship

The 4th workshop of the "Global TraPs" project was held in Morocco, 17th – 18th March 2012, hosted by OCP who participated as guests (see below).

The 3rd workshop was summarised in SCOPE Newsletter n° 80.

Around 100 participants from across the world including international organisations (FAO, United Nations Environment Programme/UNEP, European Commission), NGOs (Greenpeace), farmers' representatives, scientists working on food security, agriculture, phosphorus management, societal approaches, and industry (representatives from various fertiliser manufacturers and industry supported entities including the International Plant Nutrition Institute (IPNI) and the Global Phosphate Forum) met to discuss **the state of knowledge in the production and use of phosphorus**.

Global TraPs stands for "**Global Transdisciplinary Processes for Sustainable Phosphorus Management.**" The five-year project (2010-2015) follows a transdisciplinary approach, a process designed to integrate 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 the Swiss research institute ETH Zurich and the IFDC (International Fertilizer Development Center).

Guiding question

The 4th Workshop built on the work of the previous workshops in identifying "**knowledge gaps", that is areas where data or information is lacking and research is considered necessary** to understand how phosphorus, is produced and used, where opportunities exists to reduce losses or waste and what policies could be developed to address these various issues. This discussion follows the "guiding question" defined for the Global TraPs project in previous workshops:

> ***What new knowledge, technologies and policy options are needed to ensure that future phosphorus use is sustainable, improves food security and environmental quality and provides benefits for the poor.***

OCP in the field

Participants were invited by OCP to visit the company's largest mining centre located in the province of Khouribga. At the site of Sidi Chennane, the visitors saw several mining operations such as the excavation of phosphate rock by draglines and trucks, transportation by conveyer belt, ore storage and new ore beneficiation and water treatment facilities being built. The field excursion gave valuable impressions of the magnitude of the mining activities, the impacts on the landscape and environment, and **OCP's strategy for environmental protection and site restoration**.

Speakers began by reminding participants that phosphorus is essential for all living organisms and is crucial for agricultural production and food security, yet it is seldom seen as a priority. For example, for a loaf of bread valued at one US dollar, associated phosphate costs are around 0.1 cents compared to oil at 14 cents. One dollar spent on phosphate fertiliser can generate 4 (USA) to 9 (India) dollars through increased crop yield. Overall, every world citizen spends, on average approximately 6 dollars per year on phosphate embedded in food consumed.

Anjan Datta, United Nations Environment Programme (UNEP), opened the workshop via videolink and emphasised the importance given to **phosphorus stewardship and phosphate fertiliser availability** by UNEP. The UNEP recognizes phosphorus and phosphate fertilizers to be essential for global food security.

Vijoo Krishnan, All India Kisan Sabha (small farmers' organisation with over 22 million members) underlined the many **problems facing small farmers** in India, and linked the problems, primarily debt, to increasing suicide rates. Mr. Krishnan noted that India's Green Revolution was largely based on subsidised fertilisers, free water, subsidised electricity for irrigation and credit. While yields have increased substantially, subsidies are often not logical, and can result in challenges and misuse such as promoting the heavy use of nitrogen (N) fertilisers at the expense of phosphorus (P), potassium (K) and other nutrients. This policy has resulted in fertiliser misuse and soil degradation.

Timothy Busienie, Kenya Cereal Growers Association, also emphasised **problems resulting from inappropriate subsidy systems**, for example subsidising DAP (di-ammonium phosphate) due to its N and P nutrient content, but not other fertilisers (e.g. NPK fertiliser) which might be better adapted to prevailing crop needs. Despite fertiliser subsidies, many farmers cannot afford to use fertilisers, so their crop productivity remains very low. Delivering affordable fertilisers to smallholder farmers in a timely manner is a major issue in many developing countries, and is the result of many factors including limited demand for fertilisers, poor infrastructure, lack of finances, etc. Such situations can benefit from the use of "smart" subsidies that help farmers transition from subsistence to more intensive, commercial production. For a subsidy to be characterized as "smart, it should be targeted and accompanied by an exit strategy that provides for a reduction/removal of subsidies over time.

Christian Nolte of FAO (Food and Agriculture Organisation) presented the organisation's policy of "**sustainable crop production through intensification**" *. This is based on three objectives: food security, sustainable agriculture and rural development, and conservation of natural resources. Overall, FAO considers that crop production is generally P efficient, applied P not used by the crop is mostly stored in the soil as residual P, and P losses from cropping systems are primarily associated with topsoil loss and soil erosion Animal production, on the other hand, is viewed as highly phosphorus inefficient.

* http://www.fao.org/agriculture/crops/core-themes/theme/spi/en/

Crop phosphorus efficiency

However, there are **differences in expert opinions concerning the conditions under which phosphorus is used efficiently by crops**, and this certainly depends on specific regional and agronomic constraints.

Luc Maene of the International Fertiliser Association (IFA) presented this organisation which represents fertiliser manufacturers worldwide, including organic fertiliser producers. He emphasised IFA's **sustainability development work, in particular the "International Agri-Food Network"** www.agrifood.net He noted the need to address phosphates in the context of other nutrients, and that Global TraPs should fix a number of clear, targeted objectives and questions.

Ajay Vashee, former President of International Federation of Agricultural Producers, also emphasised the **need to consider all nutrients, not only phosphorus**. He underlined the issue of cost and that phosphorus efficiency should also be considered as cost-efficiency, and that society not only farmers must pay the bill for adjusting phosphorus management or for increased phosphate costs.

Elena Bennett, McGill University Canada, presented the importance of **communicating phosphorus issues to decision makers** and the difficulty of some of the issues in question. Many freshwater ecologies are so sensitive to phosphorus, that it is nearly impossible to reduce phosphorus run-off from agriculture to levels that will enable restoration. According to her analysis, phosphorus is one of the most critically modified global geochemical cycles, and significantly over the threshold for global cycle disruption.

Paul Speight, European Commission, explained that the Commission will present by mid-2012 an **EU "Green Paper on Phosphorus".** This will be a short document (10 – 20 pages), officially published (translated into the EU languages), outlining key questions concerning phosphorus management in Europe, and requesting stakeholder reaction and input. He indicated that Europe is also currently working on the question of cadmium contamination of soils related to cadmium in some mineral phosphate fertilisers.

Reyes Tirado of Greenpeace spoke of the importance of looking at long-term questions. **For a sustainable planet, phosphate management must be part of an**

integrated farming and food system, that is moving away from centralisation and concentration to locally "closing the loop". This must ensure soil health (bacteria and micro-fauna …), avoid soil erosion, restore soil organic matter, whilst ensuring the restoration of biodiversity and the avoidance of chemicals and GMOs. This can be achieved through small farmers, replacing intensive energy and chemical use by human presence and know-how. In her view, mineral fertilisers will not contribute to global food security in the long term because they are expensive, leading to farmer dependency, cause pollution and damage the soil. She considers that Global TraPs should contribute to the capacity building needed now to start moving towards this long-term vision. **She suggests that Global TraPs should particularly look at the problems of soil loss, and the sustainability questions of centralisation of sewage collection and treatment and the concentration of livestock productions.**

Knowledge gaps along the P-cycle

The current status of knowledge on the global phosphorus cycle, identifying areas where more data and investigation is needed, will be presented in a short **SpringerBrief book, currently under preparation**. A first draft text was discussed in plenary and node sessions, and is under finalisation. This will address phosphate reserves (exploration), mining and processing, agricultural and other uses of phosphorus, dissemination and losses, recovery and recycling, trade and finance.

In addition to the specific knowledge gaps identified at each level of the phosphate supply and use chain, a number of **global issues were raised by different participants**, including:

- Beyond the **quantity of phosphate reserves** (on which data is still lacking or needing clarification), how will other resource issues develop in the future: quality of rock, contaminants, supply security, geographical concentration of supplies ?
- How can **phosphorus efficiency** be improved (avoiding loss but also supplying adequate P for crop productivity) in parallel to soil management (maintaining soil fertility and quality, including biological activity, avoiding soil erosion) and management of other nutrients?
- How can phosphorus (and other nutrients) be **recycled regionally ("closing the loop")** and what are the implications (energy use, other contaminants …) ?
- How to change **societal attitudes**, to better manage phosphorus production and use, to accept and implement phosphorus recycling, and to avoid phosphorus wastage?
- **What does P stewardship imply** for the organisation of urbanisation, sewage collection and treatment, concentration of livestock production, intensification of farming – does it imply questioning current society models ?

Case studies

To address these general knowledge gaps, and the specific questions raised by the different working groups (representing different levels of the value chain including exploration, mining, processing, use, recycling & dissipation, and cross-cutting issues including trade and finance), Global TraPs will develop work on a range of transdisciplinary "case studies". These include both research already underway in scientific institutes involved, which can be brought in to illustrate and contribute to Global Traps conclusions, and **new questions for which the project will look for funding, partners and researchers**.

In all cases, the studies will involve relevant stakeholders, and aim not only to collect existing information, to further knowledge through research, but also to enable discussion between parties such as industry, consumers, farmers, NGOs, policymakers, etc. to develop a consensus vision or identify differences, and where possible identify feasible strategies and policies. **Up to twenty-five case studies are expected to be launched in 2012/13, to run for 2 years**.

Next steps

Global TraPs will be moving forward with the publication of the SpringerBrief book and the list of case studies by mid 2012.

A **world conference in February 2013** will enable presentation of the first work done in the case studies (collation of existing knowledge, summary of current situation) and a first involvement of policymakers to discuss the project's proposed questions.

Finally, this will lead to a **Conference which aims to involve the United Nations in 2015**, at which the project's conclusions will be presented and possible global policy frameworks discussed.

A **Global TraPs transdisciplinary training** will take place at Leuphana University Lüneburg (near Hamburg, Germany), September 3-12, 2012 for interested researchers and participants in the project and its associated case studies.

Global TraPs website: http://www.uns.ethz.ch/gt

EU Nitrates Directive

France taken to European Court for nitrate pollution

The European Commission is taking France to the European Court for failure to deal with agricultural nitrate pollution of ground waters and surface waters, because of inadequate implementation of the EU Nitrates Directive 1991/676/EEC. Poland has also received a final warning from the Commission for failure to correctly monitor water quality as required by the EU Water Framework Directive 2000/60/EC.

These actions again show the EU Commission's determination to ensure implementation of European water protection Directives

The EU Nitrates Directive requires Member States to monitor groundwater and surface water and identify zones **potentially susceptible to be affected by agricultural nitrate pollution**, to then designate the catchments of these zones as "Vulnerable Areas", and to introduce action programmes for these areas. These programmes must include closed periods (when mineral and organic fertilisers cannot be spread), limits to fertiliser application, and manure storage capacities.

The EU Commission notes that although the Nitrates Directive has been in force since 1991, **France has still designated a number of zones** which are vulnerable to nitrate pollution.

Agricultural nitrate pollution

The EU Commission therefore intends to oblige France to designate these areas as vulnerable to nitrate pollution, and to introduce appropriate action programmes to reduce the agricultural nitrate pollution.

The EU Commission also considers that **the action programmes France has introduced are inadequate**, for example with insufficient closed periods (periods when fertiliser use is banned), and insufficient limits on manure and mineral fertiliser application.

The referral to the European Court follows a Reasoned Opinion sent by the EU Commission to France on 26th October 2011. The Commission considers that France's action following this warning is too slow and does not offer adequate changes in regulations.

The European Commission has also send a **Final Warning to Poland concerning failure to implement the European Water Framework Directive's provisions concerning monitoring of water quality**, which is a necessary first step to prepare water protection programmes.

EU Commission press release IP/12/170 dated 27th February 2012: "Environment: Commission takes France to Court for failing to combat water pollution by nitrates" http://europa.eu/rapid/pressReleasesAction.do?reference=IP/12/170

Reinforcing EU water policy

EU public supports better water protection

A survey published by the European Commission shows that a large majority of Europeans support more stringent actions to protect water quality and reduce water consumption. The Commission has also published conclusions of its stakeholder consultation on updating EU water legislation, showing a division between ONGs who want changes to plug gaps and weaknesses in current laws, and other stakeholders who consider existing legislation adequate but that more expert guidance is required to implement it.

The European public opinion survey '**Eurobarameter'** interviewed over 25 000 EU citizens. Respondents supported policies such as better information on the environmental consequences of consumption, incentives for efficiency and fines for polluters.

Public opinion support for water protection policies

Only a minority of respondents (37%) considered themselves well informed about water pollution problems, whereas a majority (68%) think that **water quality and quantity problems are serious**. 23% think that water quality has improved over the last decade, 25% think it has not changed, and 44% consider that it has deteriorated.

Agriculture is most strongly identified as impacting water quality and quantity (90%), followed by households (85%). Chemical pollution, climate change and changes to water ecosystems are identified as the main threats.

Most respondents think that **water should be metered** (paid for as a function of use), and that price should reflect environmental impacts.

Respondents support **better information, heavier fines for polluters, fair pricing policies, financial incentives and better enforcement of existing water legislation** as actions to improve water protection.

Stakeholder consultation on EU water laws

The EU Commission is currently preparing a paper on water protection, which will propose measures to **better integrate EU water policy** (currently covered by a number of different Directives) and to ensure **better implementation of water quality objectives**. In this context, a public and stakeholder consultation was organised by internet end 2011-early 2012, resulting in 115 responses, mainly from national administrations, water basin organisations, industry and NGOs.

Respondents consider that **EU water legislation has significantly improved since 1970** and addresses well some issues (biodiversity, human health, flood risk, industrial pollution, hydromorphological modifications, protection of river basins). However, **current legislation is seen as failing to address leakages from distribution systems, agricultural pollution and agricultural over extraction, innovation, climate change, droughts and sustainable land use**.

Most respondents consider that there remain gaps in EU water policy legislation which should be addressed. Respondents tend to consider that there is **insufficient coherence** between EU water legislation and other areas of EU policy, in particular for agricultural policy.

Legal obligations fixed by EU water policies are generally considered sufficient, except for **the nitrates directive which is considered inadequate to address agricultural pollution**. Costs are generally considered to be lower than the benefits water legislation provides.

Regarding future legislation, industry and official organisations suggested that existing legislation should be given more time to achieve objectives fixed (in particular the EU Water Framework Directive (2000/60/EC). Other proposals include better integration of water protection into agricultural policies (in particular, in reforming the Common Agricultural Policy CAP), targeting the maintenance of infrastructure, and cross sectorial measures such as renewable energy plants and water conservation.

NGO positions

The European Environmental Bureau (EEB) has published a "**Blueprint to safeguard Europe's water**". The association underlines that the Water Framework Directive's objectives to achieve good water quality across Europe are being undermined by widespread use of exemptions and deadline extensions by Member States, which postpone application of this objective from 2015 to 2027. **The EEB considers that the EU Commission must act to refuse these attempts to delay the benefits of the Water Framework Directive for the environment and for society**.

EEB also emphasises the significant problems of **hydromorphological deterioration (artificialisation) of rivers, because of dams and navigation**. Rivers which are straightened, dammed, simplified, show much reduced capacity for natural water purification and a tendency to eutrophication problems, as well as considerable biodiversity loss.

Also, **agricultural pollution remains a "huge challenge"** for EEB, with a strong need to integrate water protection policy into the Common Agricultural Policy. In particular, the EEB underlines problems of agricultural nutrient and pesticide pollution, failure to make farmers pay the real costs of agricultural pollution, inefficient water consumption in agriculture and excessive development of irrigation.

The EEB has also published a **review of water protection for 10 of Europe's largest rivers**: Allier, Danube, Ebro, Elbe, Guadalquivir, Haringvliet, Mur, Rhine, Vantaa, Vistula. This concludes that despite some progress made through the Water Framework Directive, agriculture nutrient and pesticide pollution, and agricultural water extraction, remain major problems, as well as artificialising of the rivers by dams and navigation.

European survey of public opinion on water policy:
http://ec.europa.eu/public_opinion/flash/fl_344_sum_en.pdf

EU Commission - summary of stakeholder response to consultation on water policy, march 2012:
http://ec.europa.eu/environment/water/blueprint/pdf/public%20consultation%20report.pdf

EEB press release
http://www.eeb.org/EEB/index.cfm/news-events/news/european-rivers-being-sold-downstream/

P-recovery technologies

Seaborne Process

Full-scale testing of phosphorus and nitrogen recovery

The Seaborne process treats municipal sewage sludge digester effluent, to enable recovery of phosphorus and nitrogen, heavy metal separation, and energy recovery through incineration of solids. A full-scale plant was fitted in 2005 to the 50,000 p.e. Gifhorn municipal waste water treatment plant, lower Saxony, Germany (near Hannover), with a capacity of c. 1 000 tonnes dry solids per year. The plant is still operating today.

The papers summarised here present the operating results and experience of the start-up phase. **A scientific evaluation of the operation is expected to be published by mid 2012**.

P and N recovery

The Seaborne technology includes the following steps, treating sludge digester effluent:

- **Acidification of sludge by sulphuric acid** addition in order to dissolve solids and release phosphate and heavy metals
- **Separation of remaining solids** (centrifuge, filter) which then go to sludge incineration
- **Use of sulphur-rich digester gas to precipitate heavy metals** from the effluent liquor, thus also reducing the sulphur content of the digester gas and so improving its value for energy production (the plant's digester gas is high in H_2S because of high grease load in the digester) (currently the heavy metals are precipitated by the addition of Na_2S)
- **Precipitation of phosphorus as struvite**, by addition of magnesium and pH adjustment (sodium hydroxide)
- **Recovery of nitrogen by air stripping of ammonia, followed by production of ammonium sulphate** with sulphuric acid

Start-up difficulties

Initial operating problems encountered in the installation included:

- Breakage of the **stirrers** in the mixing vessels
- Need to find **polymeric** flocculants compatible with the acidic conditions of the solid-liquid separation (following sludge acidification)
- **Calcium carbonate precipitation** in the ammonia stripping column
- Difficulties effectively separating the precipitated **heavy metal sulphides**, because these tend to form as colloids which do not settle

Also, iron dosed in the sewage works (when the biological process was not ensuring adequate phosphate removal) inhibited the dissolution of heavy metals.

Mass balance

Phosphorus, carbon and nitrogen balances were carried out for the existing water treatment plant line (without the Seaborne process), after establishing flow measurements throughout the plant. This indicated that **around 80 kg/day phosphorus and 170 kg/day nitrogen are potentially available for recovery** from the sludge.

It was estimated that around 90% of these nutrients (P, N) could be recovered by the Seaborne process, the phosphorus as struvite, the nitrogen for just under a third in struvite and the remainder in ammonium sulphate. This would result in **daily production of around 580 kg of struvite and 1300 kg of 41% ammonium sulphate solution**.

The return nutrient loads in the sludge filter press liquor to the waste water treatment plant would be reduced by 85 – 100%.

Further description of the Seaborne process is in the PhD Thesis of T. Esemen, Institute of Sanitary and Environmental Engineering, Technical University of Braunschweig, Germany "Untersuchungen zur technischen und wirtschaftlichen Optimierung der Nährstoffrückgewinnung aus Klärschlamm" (in German) which is currently submitted and expected to be published in late 2012.

Seaborne website: http://www.seaborne-epm.de

"Technical and scientific monitoring of the large-scale seaborne technology at the WWTP Gifhorn", Water Practice & Technology, Vol. 3, No 1, IWA Publishing, 2008 http://www.iwaponline.com/wpt/toc.htm

L. Günther, T. Dockhorn*, N. Dichtl*, J. Müller**, I. Urban***, L-C. Phan***, D. Weichgrebe***, K-H. Rosenwinkel***, N. Bayerle*****

"Nutrient Recycling from Sewage Sludge using the Seaborne Process", IWA 2007 Specialist Conference, June 24-27, 2007, Moncton, New Brunswick, Canada http://www.bvsde.paho.org/bvsaar/cdlodos/pdf/nutrientrecycling629.pdf

*J. A. Müller **, L. Günther *, T. Dockhorn *, N. Dichtl *, L-C. Phan ***, I. Urban ***, D. Weichgrebe ***, K.-H. Rosenwinkel ***, N. Bayerle *****

Empirical evaluation of nutrient recovery using Seaborne technology at the wastewater treatment plant Gifhorn. International Conference on Nutrient Recovery from Wastewater Streams. May 10-13, 2009, Vancouver, IWA Publishing, pp. 567-577

*L.C. Phan***, D. Weichgrebe***, I. Urban***, K.H. Rosenwinkel***, L. Günther*, T. Dockhorn*, N. Dichtl*, J. Müller**, N. Bayerle*****

Ergebnisse und Bewertung des Seaborne-Verfahrens in Gifhorn. DWA Klärschlammtage 2011

*J. Müller-Schaper**, T. Esemen*, T. Dockhorn*, N. Dichtl*, D. Weichgrebe***, KH. Rosenwinkel***, N. Bayerle*****

Nährstoff-Remobilisierung und –rückgewinnung aus Faulschlamm –Erfahrungen aus großtechnischem Anlagenbetrieb. In: 3. Internationales Symposium Re-Water Braunschweig, Veröffentlichungen des Instituts für Siedlungswasserwirtschaft, TU Braunschweig, Heft 81, S. 301-314

T. Esemen, T. Dockhorn*, N. Dichtl*, J. Müller-Schaper**, D. Weichgrebe***, K.H. Rosenwinkel***, N. Bayerle*****

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P and N recovery

MBR and ion exchange

A laboratory scale innovative wastewater treatment system was tested, combining a 4 litre capacity membrane bio-reactor (0.2 m^2 membrane surface) for organic carbon removal and two c. 0.02 litre volume ion exchange columns respectively for phosphate and nitrate recovery. The system was primed with mixed liquor from a municipal sewage works (Sydney, Australia), then fed with synthetic wastewater consisting of ethanol (organic carbon) with nitrogen and phosphate mineral salt solutions.

The MBR was run for 45 days before starting the experiments to ensure **stabilisation** (analysis showed stabilisation at 30 days). The synthetic feed to the reactor contained 23 mg DOC / litre with a COD:N:P ratio of 150:5:1.

The MBR membrane had an average pore size of 0.1 µm. Air flow of c. 1 m^3/m^2 was passed over the membrane (in the reactor) to produce shear stress on the membrane surface and oxygen to the reactor.

The ion exchange columns were filled with **Purolite A500P**, which is intended to scavenge organic acids and was found to be an effective phosphate exchanger, and with **Purolite A520E**, a base anion resin designed for nitrate removal. Both exchangers were regenerated using 20 bed volumes of 1% salt solution (NaCl).

Testing integrated nutrient recovery

The MBR was operated with a short hydraulic residence time (HRT) of 4 hours. The MBR effluent (after passing through the membrane) during the experiment showed 2 – 3 mgDOC/l, 2 – 4 mgP-PO_4/l, 9 – 11 mgN-NO_3/l, c. 1.3 mg N-NH_4/l and very low nitrite N-NO_2.

The Purolite A500P achieved **80 – 90% P-removal** from this effluent, falling to 50 – 60% after 1000 – 2000 bed volumes (and also c. 50% N-NO_3 removal). The Purolite A520E showed **> 90% N-NO_3 removal consistently through to 2000 bed volumes** (and also c. 30% P-PO_4 removal). For both exchangers, over 95% of retained N and P could be recovered by regeneration using 20 bed volumes of 1% salt (NaCl) solution, or 4 bed volumes of 2 – 3% salt solution.

The authors conclude that, in theory, **around 20 kg of P and 54 kg of N could be recovered daily from a 10,000 m^3/day municipal sewage treatment works.** The recovered salt – nutrient solution might however not be useable as a fertiliser because of high sodium concentrations, and the authors suggest to investigate other possible regeneration solutions, e.g. $Ca(OH)_2$.

"Removal and recovery of nutrients by ion exchange from high rate membrane bio-reactor (MBR) effluent", Desalination 275 (2011) 197–202 www.elsevier.com/locate/desal

M. Johir, J. George, S. Vigneswaran, J. Kandasamy, Faculty of Engineering, University of Technology, Sydney, P.O. Box 123, Broadway, NSW 2007, Australia and A. Grasmick, UMR Génie des Procédés Eau et Bioproduits (UMR–CIRAD 016), Université Montpellier II, CC005, Place Eugène Bataillon; 34095, Montpellier Cedex 05, France. s.vigneswaran@uts.edu.au

Microbial fuel cells

Struvite and hydrogen production by electrolysis

Four 28 millilitre experimental batch cells were used to test microbial electrolysis of synthetic wastewater digester supernatant using different cathode materials, different applied currents (including a control with no current = open circuit) and with or without addition of struvite ionic components (Mg, P, ammonium).

The cells were initially loaded with **synthetic wastewater containing organic matter, nutrients, vitamins and carbonate** levels comparable to sewage sludge digester effluents and were inoculated with microorganisms from operating microbial fuel cells to give biologically active anodes. After stabilising, one set of reactors were then fed **struvite ionic**

components (ammonium phosphate plus magnesium chloride). The other set of reactors were operated as controls, without ion addition. The reactors were then operated at **three different applied voltages**, plus control (no applied voltage). Heat treated graphite fibre brushes were used as anodes. Stainless steel was used for cathodes, in two forms: flat plates and (higher surface area) mesh. Electrical energy consumption, hydrogen production, phosphate removal from solution and struvite precipitation (crystal mass development on cathode) were measured. The crystals produced were shown to be struvite by EDS (Energy Dispersive Spectrometry).

P-removal

Phosphate removal (reduction of soluble phosphate concentration) was <10% in cells without applied current, and increased with voltage up to 40%. Also, struvite did not deposit when no current was applied, and the rate of deposit increased with higher voltages and on the higher surface area cathodes.

Struvite precipitated as needle shaped crystals growing off the cathode. Up to 0.9 g struvite / m^2 / hour were deposited.

Hydrogen energy

Hydrogen production was zero with no current and was also related to the current applied, reaching 2.3 m^3 H_2/m^3day. Controls without magnesium ions (no struvite crystallisation) gave the same levels of hydrogen production, showing that struvite precipitation did not reduce hydrogen production. In all cases, the energy content of hydrogen produced exceeded the electrical energy consumed.

The authors conclude that the positive net energy recovery reached nearly 2 kWh/kgCOD and so could potentially offset struvite precipitation costs in wastewater treatment plants.

"Phosphate recovery as struvite within a single chamber microbial electrolysis cell", Bioresource Technology, Volume 107, March 2012, pages 110–115
http://www.sciencedirect.com/science/journal/09608524

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Swine wastewater

Microbial fuel cell production of struvite and electricity

The microbial fuel cells tested consisted of a 70 millilitre anode chamber (47 cm^2 carbon felt anode in feed liquor with a polyester nonwoven cloth separator) and a cathode (carbon paper of the same area with platinum catalyst, with rear in contact with air).

The cells were fed with **swine wastewater** continuously pumped (20 ml/minute flow rate) through the anode chamber from 55 millilitre bottles of wastewater which were replaced every few days. The cells were inoculated with paddy field soil and a part of the content of the anode of a previously operated microbial fuel cell, and operated for 49 days and then, with modified cathode/separator set up, for a further 27 days. **The swine wastewater came from a pig farm in Miyagi Prefecture, Japan,** and was filtered at 0.7 mm mesh before use. It contained 60 000 mg/l COD, 780 total and 110 soluble mg/l phosphorus, 340 total and 26 mg/l soluble magnesium.

Phosphorus removal

The fuel cells removed 70 – 82% of total phosphorus from the wastewater. In the first phase run, most of the removed phosphorus was accumulating on and in the separator cloth (45 – 65%) with 5 – 10 % accumulating on the cathode, 25 – 30% on the anode. In the second phase run, with modified cell configuration, around 30% of influent phosphorus was precipitated on the cathode. XRD analysis suggested that the material accumulating on the cathode included **struvite crystals** (magnesium ammonium phosphate). Elemental ratios of ion removal suggested that calcium phosphates could be also being formed, possibly in amorphous forms not identifiable by XRD. The authors suggest that the struvite precipitation on the cathode is likely to be the result of locally increased pH because of oxygen reduction.

Electricity production

Electricity generated showed an increase each time the bottles of wastewater were replaced. Maximum power and current density were 1.7 W/m^2 and 6.0 A/m^2 in both fuel cells in the first phase operation, increasing to 2.3 W/m^2 and 7.0 A/m^2 following cell modification in the second phase runs.

The authors conclude that this microbial fuel cell set-up enables **removal of phosphorus from swine wastewater, generating electrical energy, and precipitating struvite** (and possibly other phosphates) on the liquid side of the air-cathode.

"Removal and recovery of phosphorus as struvite from swine wastewater using microbial fuel cell", Bioresource Technology, in press, 2012
http://dx.doi.org/10.1016/j.biortech.2012.02.124

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Microbial fuel cell

P-recovery from iron phosphate

A 2.5 litre reactor zone, 0.04 litre cathode zone, laboratory microbial fuel cell was tested to mobilise orthophosphate from pure iron phosphate and from iron phosphate in sewage sludge. The reactor zone used E. coli metabolism in a soy broth feed solution to generate electrons and protons. These were supplied to the cathode zone: for the electrons, from carbon electrodes in the reactor zone, via a circuit connection, to the carbon cathodes ; for the protons, directly through the membrane between the two chambers.

Orthophosphate is mobilised from the (insoluble) iron phosphate in the cathode chamber by shuttling of stoichiometric amounts of electrons and protons by methyl blue, added as a mediator. The iron cations are thus reduced (Fe^{3+} -> Fe) and replaced by protons (to give H_3PO_4 orthophosphate). Elemental iron was not identified on the cathodes, and the iron was mainly precipitated as compounds in slurry.

Reducing iron phosphate

Experiments used both pure iron phosphate at 15 – 970 mg $FePO_4$/l (3 - 220 gP/l) and **dried sewage sludge** containing 30 - 240 mg $FePO_4$/l (8 - 60 gP/l). The dried sludge was ground to different particle sizes.

Around one week reaction time was necessary to mobilise up to 48% of phosphate from pure iron phosphate, and up to 82% from the sewage sludge. The % mobilisation was strongly dependent on the size of the (iron phosphate) particles (small particles = better mobilisation, with grinding down to c. 120 µm necessary for effective operation). ^{31}P NMR showed that the mobilised phosphate was principally present as orthophosphate.

Struvite precipitation

After mobilisation of the orthophosphate from the iron phosphate in the cathode chamber, **struvite (magnesium ammonium phosphate) was precipitated by adding magnesium chloride and adjusting to pH 10** (using sodium hydroxide). SEM-EDX analysis showed that the recovered product's elemental composition corresponded to struvite.

The recovered struvite was analysed for the different heavy metals present in the sewage used, and these were not detected (As, Cr, Cd, Pb).

The authors conclude that this microbial fuel cell process potentially enables the recovery of phosphorus as a valuable fertiliser (struvite, free of heavy metals) from iron-containing sewage sludge using renewable energy (microbial culture).

"Microbial fuel cell enables phosphate recovery from digested sewage sludge as struvite", Bioresource Technology, 102 (2011) pages 5824–5830
www.elsevier.com/locate/biortech

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Conferences

Harbin, China, 23-25 September 2012

Nutrient Removal and Recovery 2012

International Water Association's third conference on nutrient removal in sewage works (following two first conferences in Poland in 2005 and 2009), with sessions on phosphorus recovery and low carbon nutrient recovery. Biological nitrogen removal processes

- New technologies of biological phosphorus removal and recovery
- Bioreactors applied for NRR
- Low carbon technology involving nutrient recovery
- NRR in wastewater treatment plants (WWTPs)
- Emerging molecular methods of identifying microorganisms in NRR processes
- Round tables including: Nutrient Removal and management in China, Nutrient Removal and Recovery technologies of the future: new challenges and new concepts

http://www.iwanrr2012.org

Netherlands, 1 November 2012

European Conference on Sustainable Phosphorus Management

Looking at European policies, including the legislative framework and business cases).

Organised by the Dutch ministries of Economic Affairs, Agriculture and Innovation, Infrastructure and Environment and Foreign Affairs with the Dutch Nutrient Platform and within the Netherlands Value Chain Agreement.

www.nutrientplatform.org