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SCOPE NEWSLETTER

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The partners of the European Sustainable Phosphorus Platform

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BlueTech® Research Analysis report

Market landscape for nutrient removal and recovery

BlueTech Research's **Nutrient Removal and Recovery Market and Technology Overview** Insight Report addresses the growing focus on the importance of recovering nitrogen (N) and phosphorus (P) from wastewater and recycling them as part of a more sustainable wastewater treatment process. It provides a comprehensive look into the nutrient removal and recovery market, providing key information on market drivers and barriers, technology providers, and the regulatory landscape within major markets, including the European Union, USA and China.

Key findings from the BlueTech Research Insight Report include:

Nutrient recovery is already happening - through land application of sludge

Depending on the type of wastewater treatment plant, **about 50% of the phosphorus is removed from the water and ends up in the primary and secondary sludge. In many locations, this sludge is then applied to agricultural land, effectively recycling the phosphorus content**. However, there are challenges in terms of availability of land, regulatory pressures and stakeholder concerns. Nutrient recovery is complementary to land application and to other forms of sludge management.

Struvite recovery could presents a sound investment

Recovering phosphorus as struvite (magnesium ammonium phosphate) prevents struvite from forming in and blocking pipes and pumps. Also, taking phosphorus out of the wastewater treatment line can reduce the cost of wastewater treatment. Struvite recovery is typically performed as a side-stream treatment on the water recovered from sludge dewatering. **The struvite can then be sold directly as fertilizer or sold to SME fertilizer companies**. The key setback for the fertilizer companies is the [small] quantity and guaranteed continuity of supply.

The best market for struvite recovery technologies is currently **wastewater treatment plants with biological phosphorus removal and anaerobic digestion (AD).** The biological phosphorus removal results in phosphorus in the sludge, and the AD results in phosphorus release into the sludge dewatering liquor.

Opportunities Exist for Phosphorus and Ammonia Recovery Technologies

Second generation phosphorus recovery technologies capable of removing phosphorus directly from wastewater down to the discharge requirements will be highly disruptive if they can be developed. Ammonium recovery will also be highly disruptive. The world price of ammonium (fixed nitrogen) is increasing rapidly, as is the world price of phosphorus, so income from selling recovered nitrogen and phosphorus will increase. The cost of energy to power biological removal of nitrogen and phosphorus from wastewater, which is the "conventional solution," is also rising and the carbon footprint of that energy is a second penalty. Overall, there is **an ideal combination of drivers for adopting recovery technologies that are both reliable and efficient**.

More details for this BlueTech Research Insight Reports include:

- **Global market** sizing and forecasts
- How **regulatory compliance** within the EU, USA and China is affecting market direction
- **Market activity and company profiles** for nutrient recovery technologies from companies such as Ostara, ThermoEnergy Corp, Multiform Harvest and more
- **Innovative pre-commercialisation nutrient removal technologies**, such as electrochemical recovery of struvite from the Fraunhofer Institute

and PBR for phosphorus removal from the Battelle Memorial Institute

- **Why sidestream treatment is the "low hanging fruit"** in nutrient recovery

Additional detailed analyses on nutrient and removal market are provided in BlueTech Research's Nutrient Removal and Recovery Market and Technology Overview Insight Report.
To purchase this Insight Report and learn about other available Insight Reports, please visit
http://www.bluetechresearch.com/tools/reports/upcoming-bluetech-insight-report-advanced-nutrient-removal-and-recovery/?utm_source=Scope%20Newsletter&utm_medium=Email&utm_campaign=Scope%20Nutrient

Switzerland
Phosphate recovery likely to be made obligatory

The revision of the Swiss federal ordinance on waste treatment OTD.RS.814.600, currently open to comment from local authorities, includes the obligation to recover phosphorus from sewage sludge and animal meat and bone meal.

The proposed ordinance does not fix required levels of phosphorus recovery, indicating that at present technologies are under development. **P-recovery must be done using "the most recent technologies"**.

It is noted that chemical and biological P-recovery processes for P-recovery offer the advantage of low energy use compared to incineration, but at present only recover a small proportion of the total P content of waste streams.

It is proposed that the **obligation to recover phosphorus be applicable 5 years after publication of the ordinance** (expected end 2015), with a possibility for sewage sludge incineration ash to stock these separately then treat them within a 10 year delay.

The ordinance also includes dispositions concerning waste management plans and a general obligation to valorise waste where possible, specific obligations regarding landfill sites, incineration of wastes in cement factories, demolition waste, biodegradable waste, metal wastes.

For municipal waste incineration, the proposal requires that heavy metals be extracted from both bottom ash and fly ash before landfilling (by acid washing).

Switzerland net phosphorus import

The detailed accompanying document presents a **phosphorus flow diagram for Switzerland**, concluding that the country imports annually 16 500 tonnes P, used for 90% in agriculture, and exports only around 4 000 tonnes (mostly transported in rivers to neighbouring countries). P-recovery and recycling is considered important "unanimously by actors consulted" because phosphate rock is a non-renewable resource, for which quality and contaminant levels (cadmium, uranium) are expected to increase and which will face pressure with world population growth and food demand, whilst at the same time phosphorus is a critical factor in water quality because it plays a determining role in eutrophication of many lakes.

In developing P-recovery and recycling, ecological factors, but also population acceptance and economic viability must be considered. It is noted that certain technologies are still in the development phase, which is why no minimal fraction to be recovered is fixed: the proposed preferred technologies and criteria for recovery and related environment impact will be defined later in implementation documents. Also, **incineration and temporary storage of P-rich wastes is proposed as an option**. In this case, P-containing wastes must be mono-incinerated (not incinerated mixed with other wastes), then stocked in a dedicated, separated site. Switzerland already incinerates nearly 100% of its sewage sludge following a ban on agricultural spreading in 2006 (a small part is treated by other processes, e.g. phragmicomposting producing a soil amendment product). In 2006, 44% of the sewage sludge was mono-incinerated in a total of 14 installations (Binder, de Baan, & Dominic, 2009)

Funding mechanisms must be defined to cover P-recovery and recycling, at least initially to fund construction of necessary P-recovery installations. Funding could come from a tax on P-rich waste streams or a tax on mineral fertilisers.

OTD Bulletin n°4 (26/6/2013) and draft ordinance
http://www.bafu.admin.ch/abfall/02202/12415/index.html?lang=fr *(French) or*
http://www.bafu.admin.ch/abfall/02202/12415/index.html?lang=de *(German)*

Binder, C. R., de Baan, L., & Dominic, W. (2009). Phosphorflüsse in der Schweiz. Stand, Risiken und Handlungsoptionen. (B. für Umwelt, Ed.) Umwelt-Wissen Nr. 0928 (p. 161 S). Bern
www.bafu.admin.ch/publikationen/publikation/01516

Denmark

Aarhus Aby P-recycling plant opens

Denmark's Environment Minister, Ida, Auken, inaugurated the country's first full scale phosphate recovery installation at Aaby municipal sewage works (Aarhus Vand), on 11th November 2013.

The installation treats sludge dewatering liquor from drum filters upstream of the plant's anaerobic sludge digesters (5-10 m^3/h) combined with dewatering liquor from downstream of the digesters (3 - 5 m^3/h after centrifuges), that is a total of 10 – 15 m^3/h, which is 100% of the sewage works sludge stream return liquors. **The removal of phosphorus here avoids operating problems and costs resulting from deposits in digester, pipes and pumps**.

The struvite is produced in a fludised-bed reactor, using magnesium dosage, aeration (CO_2 offgasing) and alkali as necessary to control the process.

P-recycling as fertiliser

Around 0.5 tonnes/day of struvite are produced, as 1-2 mm round granules, 99% purity. The product will be sold to local farmers, plant nurseries and fertiliser wholesalers.

The process is developed by the utilities Aarhus Vand (AV), Herning Vand and Horsens Vand, with Danish pump manufacturer Grundfos, the Danish Knowledge Centre for Agriculture and consultants Norconsult.

Denmark's Environment Minister stated: "The Danish government wants a greener Denmark. **This project is an example of what green transition is all about**. We develop solutions to environmental problems while also creating new products which can generate income in the future. Phosphorus discharge into the aquatic environment is not only a challenge in Denmark, it is a global problem, so there are great benefits in finding a method to solve it."

WWT/WETNews 6/12/2013: http://wwtonline.edie.net/news/danes-test-phosphorus-extraction-technology-

Sewage sludge ash

Plant availability of thermally recovered P

The plant availability of thermochemically recovered sewage sludge ash P was studied in pot trials with rye grass using radioactive ^{33}P tracer-techniques. The plant availability of recovered P was comparable to the availability of water soluble P in acidic or slightly acidic soil conditions for P recovered using magnesium chloride (not calcium chloride) during the thermochemical treatment.

Sewage sludge incineration ash was collected from the electro-filters of a mono-incinerator burning only municipal sewage sludge from plants using iron salts for phosphorus removal. **Recycled P products were recovered in a thermal process (950°C, chloride), based on that described in Mattenberger et al. 2008** (modified SUSAN / ASH DEC process, see ESPP/SCOPE Newsletter n°s 78 and 89), in a 9 kg capacity batch operation lab-scale pilot. In this process, either calcium chloride or magnesium chloride is used as a chlorine source. The chlorine enables heavy metal removal from the ash. The recovered products were ground to mean particle size < 100 µm before testing.

Fertiliser tests

The recovered P products contained 6% P, 15% iron, 5% aluminium, 16% calcium (using calcium chloride) or 5% magnesium (using magnesium chloride) and showed 53% or 43% crystallinity respectively.

Plant availability tests were carried out using Italian rye grass (*Lolium multiflorum*) grown from seed in three different soils with pH of 4.5, 6.5 and 8.2. Plant growth (above ground plant dry matter), total P content of plant (P uptake), and radioactive P content of plant were assessed in harvests at 33, 61 and 97 days after seeding. The radio-labelling enabled the distinction between P taken up from the soil and the recovered P products (or water soluble fertilizer).

Prior to sowing, the available soil P was radio-labelled by mixing the soil with carrier-free ^{33}P orthophosphate solution and storing at 18°C for 7 days to reach equilibrium. Test results using radioactive labelled potassium phosphate solution as fertiliser enabled an estimation of uptake of P from the rye grass seed phosphorus store to be taken into account.

Results show that **P availability from the recycled P product produced using magnesium chloride in the thermal process is similar to the availability of water soluble orthophosphate i**n the soils with pH 4.5 and pH 6.5, but not in the alkaline soil. Even the water soluble orthophosphate is not fully plant available. The plant availability of the recycled P product using calcium chloride in the process is marginal. The authors suggest that this may be due to the lower solubility of calcium phosphates in this product and to its higher crystallinity.

The tests suggest that **the recycled P product, recovered from iron containing sewage sludge incineration ash using magnesium chloride/thermal process, offers good plant availability in non-alkaline soils**, which covers 90% of Europe's soils.

"The plant availability of phosphorus from thermo-chemically treated sewage sludge ashes as studied by ^{33}P labeling techniques", Plant and Soil, 2014, http://dx.doi.org/10.1007/s11104-013-1968-6

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Lab simulation

Anammox plus struvite recovery

Biological ANAMMOX treatment of sludge dewatering centrate (see SCOPE Newsletter n° 89) was combined with struvite precipitation to assess a possible combined process for abatement of ammonia-N and soluble P with phosphorus recovery for recycling. This thesis has interest as a first assessment of the potential of combining ANAMMOX denitrification with struvite recovery to remove nutrients and recycle phosphorus from sludge dewatering liquors.

Tests were carried out using pure ionic solutions (nutrient and other ion concentrations dosed to simulate effluent from ANAMMOX treatment of centrate), partially nitrified real centrate, and **real centrate after lab-scale batch ANAMMOX treatment**.

Real centrifuge dewatering liquor was collected from a municipal sewage works operating biological nutrient removal. This was subjected to batch, jar-scale ANAMMOX reactions (seeded with sludge, reaction time 2-4 hours). Struvite precipitation was tested using first batch, jar-scale experiments, then using three identical continuous flow fluidised bed reactor (total reactor volume 2.6 litres, height 1.2 m) operated for 24 hours after stabilisation.

The work concluded that ANAMMOX reduced ammonia nitrogen in sludge dewatering liquor by up to 85%, also resulting in an increase in soluble phosphorus of over 20%. **When combined with struvite precipitation, ammonia nitrogen removal improved to 91%** (some of the remaining ammonia nitrogen was precipitated into the struvite) and **overall soluble phosphorus removal was 88%** (compared to initial centrate values). Operating parameters for the struvite precipitation were also assessed (pH as adjusted using NaOH, magnesium dosing ratio, reactor hydraulic parameters).

Phosphorus and ammonia removal

The thesis concludes that the **ANAMMOX + struvite precipitation combination enables effective ammonia-N and phosphate removal from sludge dewatering liquor**, and recovers around 90% of the initial centrate soluble phosphorus as struvite, which can be recycled as a fertiliser. The struvite crystals precipitated from the ANAMMOX treated centrate were larger (90 – 160 µm) than from the untreated or partially nitrified centrate. Caustic soda (NaOH) and magnesium (dosed as magnesium chloride) consumptions were assessed and it was concluded that the chemical consumption costs were slightly higher using the ANAMMOX centrate than the untreated centrate, however this can be considered to be set against the advantages of abating ammonia-N. The revenue of the two processes is currently under further investigation.

"Simultaneous management of nitrogen and phosphorus in dewatered sludge liquor by combining ANAMMOX process with struvite crystallization", P. Hassan, Masters Thesis, Civil Engineering, Univ. British Columbia, Canada, Sept. 2013
https://circle.ubc.ca/handle/2429/45119

Phosphorus in the environment

Environmental monitoring obligations
Phosphorus in groundwater

EU Member States representatives have decided to add phosphorus to Groundwater Directive listed substances. This means that Member States will have to consider both to monitor concentrations of phosphorus (P) in groundwater and to define Threshold Values, and to implement these wherever phosphorus poses a risk to groundwater quality.

The amendments to the Directive will now be subject to a three-month scrutiny period in the European Parliament and Council of Ministers. Member states will then have to implement within two years of the modified Directive entering force. The amendments are proposed in response to a situation where **existing threshold values for different substances in groundwater are hard to compare between Member States**, partly because of differing interpretation of guidance on background levels, and the quality of groundwater reporting was low in the first round of Water Framework Directive river basin management plans.

It has generally been considered that phosphorus is not an issue in groundwater, because in most soils it will be retained by adsorption (to minerals such as calcium or iron, or to clay particles) and so will not migrate downwards into groundwater – **unlike nitrates and some pesticides/herbicides which are mobile in soils resulting in significant groundwater contamination** in many areas of Europe.

However, in some places, **low levels of phosphorus in groundwater have been identified as contributing to eutrophication risks** in sensitive surface waters (eutrophication is nutrient fertilisation above natural levels, and can result in problematic algal growths or ecosystem modifications).

Significance of groundwater P in some areas

Homan et al. (2008) assessed phosphorus in groundwater in the UK and Ireland, concluding that concentrations were "ecologically significant" in 10 – 30% of cases, that is P concentrations in groundwater exceed the "Eutrophication Thresholds" proposed for surface waters (e.g. thresholds of 30 µgP/l for Ireland, Lucey 2007, or 40 – 120 µgSRP/l for England).

The authors also compared land use statistics (Corine land cover data) to groundwater phosphorus (median log concentrations), concluding a significant correlation, so suggesting that **groundwater P concentrations are at least partly the result of human activities**. Groundwater P concentrations were highest in areas with urban, grassland and arable land use.

Scientists consulted informally by the European Sustainable Phosphorus Platform nonetheless **questioned the interest of adding P to groundwater monitoring obligations**, except in specific areas of high surface water sensitivity to eutrophication and significant groundwater inflow, or where soils have low phosphorus adsorption. In particular, they note that it will be difficult to use groundwater P monitoring results to define policies or actions, because the origins of groundwater phosphorus are very difficult to identify as phosphorus generally has a long residence time and low mobility in soils. Also, some geological soil and rock strata are rich in phosphorus, so that groundwater P concentrations will naturally be relatively high.

Variation or confusion ?

UK Environment Agency data on groundwater phosphorus, for example, suggest **very considerable differences between groundwater masses**, with a variation of <0.02 – 2706 µgP/l.

However, some of the published reports give values in mgP/l not µgP/l, probably incorrectly, as this would mean levels 1000x higher. This confusion seems to be widespread, and the documents circulated by the European Commission ("Explanatory Note accompanying the draft proposal" for the Groundwater Directive amendment) indicate existing Threshold Values in Member States as 0.04 – 9 mg/l, for orthophosphate, reactive phosphate or total phosphorus. These figures should presumably be read as µg/l (1000 times lower) and may mean orthophosphate-P ($P\text{-}PO_4$) not "orthophosphate" or "phosphate" (a factor of 3-4 x).

The current Groundwater Directive amendment proposal would oblige Member States to consider phosphorus monitoring in groundwater and define Threshold Values, but does not specific whether these should be defined as "phosphates or total phosphorus" (presumably this means orthophosphate/SRP or total phosphorus). The difference would probably be small (unless the groundwater contained significant levels of organics), however **it would be preferable to require the same measurement for all Member States and to specify clearly exactly what should be measured**, to enable comparison of results across Europe and to avoid the sort of confusion indicated above.

European Commission DO31851/01 (2013) proposed amendment to Annex II of Directive 2006/118/EC on the protection of groundwater against pollution and deterioration" and "Explanatory Note accompanying the draft proposal for a Commission Directive amending Annex II to Directive 2006/118/EC …". Documents apparently not publicly available to date.

"Phosphorus in groundwater—an overlooked contributor to eutrophication?", Hydrol. Process. 22, 5121–5127 (2008) Wiley InterScience www.interscience.wiley.com *DOI: 10.1002/hyp.7198, I. Holman (Natural Resources, Cranfield University, UK) et al.*

UK Environment Agency:
- *"Groundwater quality reporting" and* http://www.environment-agency.gov.uk/business/topics/water/118737.aspx
- *"Baseline report series. Science Summary SC990024/SS"* http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/scho0207blxy-e-e.pdf
- *"Information about your groundwater quality analysis results"* http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/geho0807bnao-e-e.pdf

"Changes to groundwater directive approved", ENDS, 17th February 2014 http://www.endseurope.com/34827/changes-to-groundwater-directive-approved

OECD agri-environmental indicators
Agricultural nutrient losses

The OECD 2013 "Compendium of agri-environmental indicators" summarises status and trends in nitrogen, phosphorus and pesticide losses from agriculture and related water quality status. Although nitrogen and phosphorus losses from agriculture have fallen over recent years, water pollution levels from nitrates and pesticides are continuing to deteriorate, because of the time lag between adoption of better management practices by farmers and measurable improvements in water quality (legacy problem).

OECD **agricultural nutrient surpluses (N and P) have been continuously moving downwards** over the 20 years 1990 – 2009, both in absolute tonnages of nutrients, and as nutrient surpluses per hectare of agricultural land. The rate of reduction increased in the years 2000. In particular, the growth in agricultural production has been decoupled from changes in nutrient surpluses.

Reductions in nutrient surpluses

The OECD average reduction in agricultural phosphorus surpluses has been more than twice as rapid as for nitrogen over these 20 years, reflecting understanding by farmers that soils had **high levels of accumulated phosphorus** on which crops and grass can draw.

The total annual phosphorus surplus for 33 OECD countries is nonetheless over 2 000 tonnes P/year (average 2007-2009), that is 6 kgP/ha agricultural land/year, down from over 4 000 tP/y (1990-1992). For comparison, nitrogen surpluses were over 34 000 tonnes N/year (2007-2009), down from 40 000 tN/y (1990-1992).

Much of the improvement results from increasing adoption of nutrient management plans on farms, encouraged by **agri-environment measures**. Gains in phosphorus efficiency have also resulted from changes in livestock husbandry, in particular changing animal feed composition.

The report notes that within national averages there are **considerable variations in regional nutrient surpluses and trends**, particularly related to concentration of intensive livestock production and to certain crops which require high nutrient inputs (e.g. maize, rice), as well as climate or soil factors. As a result there are regions in Europe, USA, Canada, Mexico and Australia where excess nutrients place a considerable burden on the environment.

Water quality deterioration

In the OECD countries which monitor surface- and ground- water nutrient and pesticide concentrations, half of these countries show **>10% of monitoring sites in agricultural areas with concentrations exceeding drinking water limits**. Nonetheless, most of the OECD population consumes water which is well within drinking water standards.

In Europe, **agriculture is estimated to contribute more than one third of nutrient discharge to surface waters**, despite the trend to reduce agricultural losses in many countries. However, **one third of EU15 surface water and groundwater monitoring stations show an upward trend in nitrate levels and eutrophication remains a significant problem**.

In the USA, **agriculture is estimated to contribute 60% of river pollution**, 30% of lake pollution and 15% in estuaries and coastal waters, as well as contributing significantly to groundwater contamination. Agricultural nutrient losses are the principal cause of the Gulf of Mexico's hypoxic "dead" zone.

The report includes detailed tables and graphs for these different points, as well as a range of other agri-environment factors.

"OECD Compendium of Agri-environmental Indicators", 2013, ISBN 978-92-64-18621-7 (PDF)
http://www.oecd.org/tad/sustainable-agriculture/agri-environmentalindicators.htm *or* http://www.oecd-ilibrary.org/fr/agriculture-and-food/oecd-compendium-of-agri-environmental-indicators_9789264186217-en

Intensive agriculture
Closing the phosphorus cycle

Different options are modelled for closing the phosphorus cycle in intensive agriculture, in particular livestock production, including modification of animal feeds, manure treatment for phosphorus recycling and radical reduction of livestock production to correspond to regional demand only (no export of animal products).

The MITERRA environmental impact model was used to assess a number of **different scenarios to close the phosphorus cycle in the Netherlands and in Northwest Europe** (defined as UK, Ireland, Netherlands, Belgium, Luxemburg, France, Germany and Denmark). Crop phosphorus efficiency, animal phosphorus use efficiency and eternal phosphorus inputs to the agricultural phosphorus balance were assessed in five scenarios for the Netherlands and seven for Northwest Europe.

The report uses the **MITERRA model**, which estimates nutrient balances, soil carbon and greenhouse emissions, and data on crop areas, livestock manure production and animal feed (derived from CAPRI and NUTS2 for Northwest Europe and from more detailed data in the Netherlands).

The different options considered for the Netherlands and/or for Northwest Europe are:

- Reduction of mineral fertiliser and/or manure application to balanced P fertilisation
- Reducing P in livestock feeds so reducing P excretion
- Maximum recycling of human organic wastes and replacement of mineral fertilisers by P from waste streams
- No export of animal products outside NW Europe (reduction of livestock numbers to correspond to demand for animal and dairy products)
- Partial replacement of soybean and feed phosphate by meat and bone meal
- Production of livestock feed from grass refinery
- Large scale manure treatment

The **balanced fertilisation scenario** for Northwest Europe estimates P removed by crops and P available in manures, and assumes external (mineral) fertiliser application is the difference only. Across Northwest Europe, implementation of balanced fertilisation (reducing P fertiliser doses to not exceed phosphorus removed from fields in crops) could reduce annual excess application to soils by 26% and mineral fertiliser consumption by 20%, but it would have little impact in the Netherlands because fertiliser use is already low because of manure applied to fields.

The **biowastes recycling scenario** assumes recycling to agriculture of 80% of sewage sludge phosphorus (compared to c. 42% at present in Northwest Europe) and 70% of phosphorus in other biowastes (household organics and food industry wastes, compared to c. 15% through composting at present).

Large scale manure processing in the Netherlands would not help close the national phosphorus cycle, but would enable the P in manure products to be exported to regions of Northwest Europe (or beyond) where it could be usefully applied to farmland to replace imported phosphorus mineral fertilisers.

Optimising animal feed P

The **reduced P in livestock feed scenario** assumes -20% total P in feeds for pigs and poultry, achieved in part by an increased use of phytate (added enzyme which improves enables monogastric animals to absorb more of the phosphorus in plant materials) and -10% for cattle. This is estimated "without any cost or productivity effect" to offer the potential to reduce soil

P application surpluses by 23% in Northwest Europe. For the Netherlands this option could reduce P import (from outside the EU) by 15% and export of manure P by 18%.

The **scenario of using MBM** (Meat and Bone Meal) in livestock feeds, whereas this is currently banned in Europe, is estimated to replace 3-5% of phosphorus in livestock feeds.

The option of **adjusting livestock production to regional demand** for meat and dairy products (no export of animal products) is, as could be expected, the most effective in closing the phosphorus cycle, but this would mean reducing livestock numbers in this wide Northwest Europe region by 10% and reducing in Netherlands by 38% (closing the phosphorus loop at the national Netherlands scale). This would have considerable economic and employment impacts.

The report concludes that the **implementation of all 5 options considered for Northwest Europe would enable a 50% reduction in total phosphorus imports** (in animal feeds and in mineral fertilisers) but that it is not possible to close the agricultural phosphorus cycle without a significant reduction in livestock production numbers.

"Options for closing the phosphorus cycle in agriculture. Assessment of options for Northwest Europe and the Netherlands", Wageningen, Statutory Research Tasks Unit for Nature and the Environment. WOt-werkdocument 353. 47 pages. Commissioned by the Netherlands Environmental Assessment Agency (PBL), funded by the Dutch Ministry of Economic Affairs (EZ). December 2013. http://edepot.wur.nl/289653

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Digesters, composts and P-recycling

Interreg North West Europe
Nutrients in digestates

The Transnational Advisory Board meeting of the ARBOR Interreg IVb (North West Europe) brought together 35 experts, researchers and stakeholders in Brussels on 4th March 2014, on the theme of nutrient recovery and recycling from manure digestates. Questions put to participants showed that most consider that regulatory obstacles are hindering nutrient recycling, in particular the Nitrates Directive limit to application in "vulnerable zones" of nitrogen from "processed manure". Most participants considered that modifying the regulatory framework is the most important action to increase manure digestate nutrient recycling. Further information on ARBOR: see ESPP/SCOPE Newsletter n° 100.

Sacha Oberweis, Staffordshire University, England, and ARBOR coordinator, explained that the project's objectives are to accelerate the use of biomass for renewable energy. Anaerobic digestion of wastes, bio-wastes and other non-food crops is a key element of this objective. Valorisation of nutrient values in digestate is important both to improve the economic feasibility of biogas production and to prevent nutrient content being an obstacle to digestate disposal. He emphasised that reuse of nutrients from manures is necessary for sustainable livestock production in Europe, and so for food security, which is a key objective of EU Horizon 2020 and Interreg objectives.

Caroline Ruebens, Interreg Contact Point Flanders, indicated that ARBOR is one of 5 strategic projects identified under Interreg North West Europe (NWE), considered as priorities for the NWE objectives of making the region attractive to live to work.

Environmental protection

Francesco Presicce, European Commission DG Environment, emphasised the concentration of livestock production in certain regions in Europe, resulting in local manure nutrient excesses. He summarised the achievements of the Nitrates Directive and EU water policy: reductions in surface water (and to a small extent groundwater) nitrate pollution, improved storage of manure, increased efficiency of nitrogen use on farms, some reduction in manure surpluses, recognition that manure is a resource. Through the Water Framework Directive, Europe has reinforced and confirms ambitious objectives for surface and ground-water quality.

A study carried out for the EU in 2011 *www.europa.eu/environment/water/water-nitrates/index.html* indicates that **around 8% of the EU's total manure production is processed** (c. 110 million tonnes/year) and emphasises the need for nutrient removal/recovery in manure surplus regions.

Mr Presicce indicated that digestate production in Europe is increasing with the development of renewable biogas production. **Variation of substrates and digestion processes results in very variable composition digestates**. Further research is needed to characterise different digestates and collate information.

Circular economy

He presented the European Commission's work on sustainable phosphorus, underlining that phosphorus management concerns many sectors as well as agriculture and provides an important case-study for practical implementation of the circular economy for a non-renewable material.

Viooltje Lebuf, VCM (Flanders Coordination Centre for Manure Processing), explained that there are currently around 40 large-scale anaerobic co-digestion facilities in Flanders, most of which already separate digestate into solids/liquid then carry out some form of treatment (biological denitrification, drying, evaporation). The objective is to move to nutrient recovery processes to separate nutrients from the organic digestate matrix, so enabling transport to regions without nutrient excess and improving plant availability. **VCM has reservations about incineration/pyrolysis processes because the nitrogen is lost in these**, and considers that technical treatment systems using membranes or ammonia stripping and scrubbing offer significant development potential.

Erik Meers, Ghent University, presented the Biorefine Cluster (see ESPP/SCOPE Newsletter n° 100), which brings together projects related to bio-resource processing and nutrient recovery from bioresources and from agriculture and food industry wastestreams. Concerning anaerobic digestion bioresource treatment, the cluster aims to develop added-value outputs including water recovery and nutrients.

Fertiliser tests

Bart Ryckaert, Inagro, presented field trials carried out as part of ARBOR, comparing performance of different processed digestate fractions to mineral fertilisers for maize (3 year field trial at 4 sites). Results showed no significant dry matter yield differences between mineral fertiliser, ammonia sulphate recovered from digestate, whole digestate and digestate liquid fraction. Despite the addition of some organic carbon in the whole or liquid digestate fractions, no increased soil carbon content was detectable.

Ivona Sigurnjak, Ghent University, presented greenhouse trials of carried out as part of ARBOR, growing lettuce for 4 weeks, comparing mineral fertiliser, struvite, ammonia sulphate recovered from digestate, potassium-containing liquor from constructed wetlands, liquid fraction of digestate. Results were comparable for the different products, except the wetlands effluent which was very dilute. However, the liquid digestate inhibited initial growth of lettuce, maybe because it led to an increase in soil salinity.

Economic and ecological viability

Daniel Koster and **Viola Huck, CRTE Luxemburg**, presented assessments of economic feasibility and Life Cycle Analysis of different digestate processing options carried out as part of ARBOR. The economic study shows that composting of digestate is, under current economic conditions, the only generally economically viable treatment. Specific local situations may make other treatment processes viable. The Life Cycle Assessment showed different impacts for various digestate processing options. The study results suggested that the most complex treatment system, including reverse osmosis, offered a somewhat better LCA, but this was based only on results from a pilot not a full-scale plant.

Barry Caslin, Teagasc, Ireland, emphasised that anaerobic digestion development is highly dependent on renewable energy feed-in tariffs or other financial incitation, such as Renewable Obligation Certificates in the UK. Consequently, development is currently at a standstill in Ireland. He also emphasised the necessity of quality assurance systems, to ensure complete food safety if digestate from manures or other wastes are to be used on farmland, and in particular for dairy.

How to develop nutrient recovery ?

A question/opinion session was then organised, asking participants to vote on 6 questions concerning how to develop nutrient recovery and reuse from manure digestates:

- A large majority of participants considered that **the critical obstacle to such nutrient recycling is regulation**, followed by economics. Only very few participants considered technical knowledge or end-user acceptance to be the most significant issues.
- Similarly, a large majority considered that the priority action to be **modification of the regulatory framework** (to enable bio-fertilisers to compete with mineral fertilisers), rather than subsidies or quotas.
- Opinions were divided as to **whether incineration should continue to be authorised**, without nitrogen and phosphorus recovery, for nutrient containing manure products. The destruction and loss of organic carbon, which is important for soils, was cited as an issue by some participants.
- Most participants consider that the **Nitrates Directive limitations to use of manure**, including also "processed manure" products, is an urgent obstacle for manure nutrient recycling,
- Most also consider that **the Nitrates Directive should be modified** to take into account the real nutrient efficiency of products, not the substrates from which they are produced
- Regarding **REACH (European Chemical Regulation),** 2/3 of participants considered themselves not informed of this question, whilst the remaining third considered that digestates should be exempted from REACH (see ESPP/SCOPE Newsletter n° 101 for more information on the question of REACH, compost, digestate and other recovered nutrient products)

Nitrates Directive

The issues of the Nitrates Directive and REACH Regulation were discussed at some length. Participants noted the **ManuResource Conference Declaration** (see ESPP/SCOPE Newsletter n° 100) calling for a coherent and stable legal framework for nutrient recovery from manure.

The European Sustainable Phosphorus Platform (ESPP) underlined that changing the Nitrates Directive is neither feasible nor desirable, given the inherent risk of destabilising Europe's water quality legislation. It is feasible to work with the existing Directive text and at the same time facilitate the appropriate use of processed manure products as fertilisers. In some cases, "derogations" are allowed by the Directive (Member States must request these) and **interpretation needs to be defined as regards what is considered "processed manure"** (it could be proposed that this should not be applicable to products with reliable and demonstrated high "nitrogen efficiencies" or made from substrates of which manures are only a part).

The European Commission underlined that further research and scientific work would be welcome on the characteristics and performance of products obtained from manure processing.

Horizon 2020

ESPP also suggested that scientific work is also needed to address the question of REACH application or exoneration for digestates and products extracted from digestates, making the parallel that yeast (dead or alive) is not subject to REACH (because it is a biological material, as is digestate) whereas yeast extract is subject to REACH (similarly at some stage of processing concentrates or products extracted from digestate will full under REACH).

The Horizon 2020 call for projects WASTE 7-2015 (deadline 16/10/2014) "**Ensuring sustainable use of agricultural waste, coproducts and byproducts** …" includes "**nutrient, energy and biochemical recovery from manure and other effluents**".

http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-climate_en.pdf

ESPP indicated that this could be **an opportunity to carry out the scientific work, in coordination with digestate producers and users, and regulatory experts**, to support coherent proposals for consideration of digestate/digestate products under both the Nitrates Directive and REACH.

ARBOR biomass for energy EU Interreg IVb project, 26 pages, April 2013 www.arbornwe.eu

AD Europe 2014
Anaerobic digestion

The European conference on anaerobic digestion and composting, AD Europe, Dublin 20th-21st February 2014, brought together 200 professionals in renewable energy, organic waste and agricultural residue treatment, regulators and scientists.

The conference concluded that anaerobic digestion and composting offer considerable opportunities for job creation, renewable local energy production as biogas and sustainable waste treatment, but that industry development is hindered in much of Europe by the absence of clear and stable public policies. **The recycling of nutrients in digestate (nitrogen, phosphate) is essential for the sustainability of anaerobic digestion**, but currently faces significant regulatory obstacles which need to be addressed.

Ireland's Prime Minister, Enda Kenny, in a short minute video message to the conference (watch at: *http://www.youtube.com/watch?v=Hhjzgg0nDnA*) underlined his support for the development of anaerobic digestion, to produce renewable energy and make waste into a resource, and so create sustainable jobs in the local economy and contribute to ensuring the sustainability of Ireland's farm system.

Fergus O'Dowd, Ireland's Minister of State in the Department of Communication, Energy and Natural Resources, opened the conference, stating that he intends bioenergy (biogas, renewable energy crops, wood) to contribute a significant portion of Ireland's renewable energy target of 16% by 2020, and that this necessitates coherent public policy support for biogas and coordination of waste and energy policies. Ireland's government estimates that anaerobic digestion and composting could create thousands of jobs.

Richard Howell, from Ireland's Ministry of Agriculture, Food and Marine, presented opportunities for funding in the EU's Horizon 2020 R&D funding programme, opened end 2013. Calls cover waste – bio-industry – food security, including cross-sectoral approaches and the local circular economy. For further information see the European Sustainable Phosphorus Platform website *www.phosphorusplatform.eu* under "Opportunities".

Job creation potential from digestion and composting

Stefanie Siebert, European Compost Network, indicated that of c. 80 million tonnes of biowastes produced in Europe today (sewage sludge, household and food processing organic waste), only c. 24 million tonnes are currently recycled. If this waste is estimated to contain 1.5gP/kg, this means around 84 000 tonnes of phosphorus lost every year.

Dr Siebert indicates that there are at present some 14 000 anaerobic digestion plants in Europe, with 71 000 jobs. Current growth is 12% per year. Biowaste valorisation creates around 1 job per 800 tonnes of biowaste/year, and offers a potential total of 100 000 sustainable jobs in Europe.

Martin Eves, Chair of the Composting & Anaerobic Digestion Association of Ireland (Cré), indicated that anaerobic digestion (AD) biogas production could generate 2 000 sustainable jobs in Ireland, but that only one new plant has been built in the last 3 years because Government policy is inappropriate, despite Ireland's obligations under the Renewable Energies Directive 2009/28/EC.

Nora Goldstein, BioCycle, USA, indicated that the USA produces around 36 Mt/y of municipal/household food waste and 34 Mt/y of yard trimmings. Only around 3% of food waste is currently recycled. The American Biogas Council estimates that there are currently some 2 000 anaerobic digesters and landfill gas installations in the USA (treating sewage biosolids, manure, food & drink industry wastes), but that the potential is around 12 000 plants. The Innovation Center for US Dairy estimates that energy and co-products which could potentially be recovered from dairy digesters in the USA would have a value of c. US$ 3 billion/year.

Allison Costa, US Environment Protection Agency, US AgSTAR programme and Global Methane Initiative, indicated that there are currently around 250 anaerobic digestion plants operating on manure in the USA, with a potential of c. 8 000 for dairy and swine manure only. Digestate solids are used as a soil amendment and digestate liquids spread as a fertiliser. AgSTAR's objective is to promote anaerobic digestion in the livestock sector by bringing together actors in the organics, agriculture and anaerobic digestion sectors to develop dialogue between operators and regulators concerning barriers to development;

conducting outreach; and providing information and technical assistance about anaerobic digestion.

David Wilken, Fachband Biogas (German Biogas Association) indicated that there are currently nearly 8 000 biogas plants operating in Germany, most are using energy crops and manures, around 250 are using biowastes. Regions with excess animal manure nutrients now need to process digestates to produce transportable fertilisers. Digestate can be upgraded by composting and by solid/liquid separation, which modifies the nutrient partition. Solids can be dried and pelletised, or mixed with biological by-products (feathers, coconut shells) to produce balanced soil amendments. The liquid fraction can be upgraded by biological treatment, evaporation, membrane separation techniques or reverse osmosis or by ammonia stripping to produce liquid fertiliser, struvite precipitation for phosphorus recovery.

Reducing and recycling food waste

Odile Le Bolloch, Ireland Environmental Protection Agency, presented work on reducing food waste. 60% of Ireland's food waste is estimated to result from mismanagement of the food chain (passing consumption date, over-serving), 20% is avoidable waste (e.g. crusts, potato skins, which could be eaten) and 20% is unavoidable (e.g. banana skins). Avoidable losses are estimated to represent 700€/year/household, € 125 million /year for Ireland's restaurants and € 6-8 million for Ireland's hospitals.

Michele Giavani, ARS Ambiente and Italian Composting Council CIC, Italy, indicated that Italy's fertiliser legislation recognises compost as a product, subject to quality scheme criteria. Digestate produced from manure is considered to be a 'product', but digestate from waste to be a 'waste'. Recent Italy policies include attractive subsidies for biogas production on condition that it is used to power transport vehicles and an additional subsidy if nitrogen is recovered from digestate or if it is used as a bio-fertiliser. Consequently, food waste collection is developing rapidly in Italy. Milan now separately collects 90 kg/inhabitant food waste, so avoiding sending 130 000 tonnes/year to waste incineration. He estimates that food waste digestion could contribute 0.82% of Italy's total transport fuel requirements (compared to 5.5% currently supplied by biofuels and a national target of 10% from biofuels).

Policy and regulation

Enzo Favoino, Zero Waste Europe, explained that "zero waste" is a methodology or a progress path, rather than an absolute number. Experience in Europe shows that losses from mixed collected solid municipal waste can be reduced by 65% (recycled fraction) by sorting, further reduced to 70-75% by adding transparent plastic bag separation of food wastes in households and further to 80% by adding PAYT (Pay As You Throw) collection systems. The total costs of collection, separation and treatment of municipal solid waste fall from c. 65€/tonne at 20% sorting to 50€/tonne at 80% sorting. Incineration is not the solution, because fly ash and bottom ash generated are toxic and should go to landfill, and the installation of an incinerator results in a 'capacity which must be fed' meaning that there is no incentive to sort or recycle. Also, the calculated CO_2 reduction of incineration will progressively be reduced as incineration increasingly is replacing renewables not fossil fuels.

Dominic Hogg, Eumonia, England, outlined work currently underway to propose new Member State recycling targets under the Waste Framework Directive revision process. He underlined the difficulties posed by the absence of coherent data collecting, with different definitions of waste streams, recycling, collection, loss, and different monitoring methods, resulting in non-comparable data between Member States.

Kiara Zennaro, Renewable Energy Association, England, presented the currently-underway update of the BAT-BREF for "waste treatment", under the Industrial Emissions Directive (successor of the IPPC Directive). This covers anaerobic digestion and composting (installations above specified capacities). All new plants in Europe have to respect the BAT-BREF specifications, and all existing plants have four years to become compliant after its adoption. The BAT-BREF specifies operational criteria including best available technologies and emissions limits. Work started on this document in June 2013 and a first draft is currently out for consultation. Finalisation is expected by 2016.

Jack O'Keefe, Larchmont Consulting, explained the difficulty of financing manure anaerobic digestion development, because projects are often led by small players such as farmers or cooperatives. Long term stability of public policies and energy feed in tariffs is essential for economic viability. The UK's Green Investment Bank, which has UK£ 3.5 billion available for investment, with a priority for waste recycling and waste-to-energy is an interesting initiative. He suggested that a co-operative industry wide approach should be considered to help smaller projects to obtain funding. This could for instance see a combination of financing sources from an established program from the EIB or similar and funding contributions from public (in country) sources as well as private funding from pension/fund managers who might be more inclined to invest on a fund basis, rather than a single project basis, to spread their risk and match funding from the traditional banking sector.

Jan Stambasky, European Biogas Association, also underlined the necessity of stable and strong public policies to support anaerobic digestion development. Renewable energy FITs (Feed In Tariffs) and Feed In Premiums (Green Certificates) are effective, whereas quotas have not shown to be so to date. The reform of the EU's CAP (Common Agricultural Policy) is also important, and the CAP Rural Development Policy (RDP) funding is expected to continue to fund biogas investment from livestock manures, farm by-products or from crops which are not competing with food production.

Compost and digestate quality criteria

Susan Antler, Compost Council of Canada, indicated that key drivers for development of composting and anaerobic digestion are paucity of landfill capacity and regulations obliging diversion of organics from landfill. Compost benefits from federal guidelines for contaminant levels and for acceptance as a fertiliser product in Canada. Quality Compost Assessment specifications define how and where composts can be used.

Kristel Vandenbroek, Vlaco, Belgium, presented Flanders' experience promoting biowaste recycling, making waste a resource and in particular promoting composting and anaerobic digestion. Vlaco, the Flanders quality assurance organisation for composting and anaerobic digestion, has developed quality control assurance certificates for composts and anaerobic digestates (digestate as liquid, solid, dried, dried & pelletised). It is an integral chain control, with criteria that specify certain heavy metal and organic contaminant levels (but pesticides, for example, are not covered). Input materials to the treatment process must respect the same contaminant obligations as the final product. In 2012, over 200 quality control certificates were delivered for different products from 80 installations.

Maria Thelen-Jüngling, Bundesgütegemeinschaft Kompost (German Quality Assurance Organisation for Compost BGK),, indicated that quality standards today cover nearly 500 composting plants, and over 100 digestates, corresponding to nearly 10 million tonnes of organics processed per year in Germany. Criteria cover heavy metals, organic contaminants, physical/handling specifications, stability, viable weed seeds and physical impurities (e.g. plastics – specified by dry mass and by surface area in cm^2/l). Only green wastes and separately collected organic biowastes are accepted in the compost quality criteria (not sewage biosolids or manures). Nutrient contents must be indicated because they contribute to the agronomic value of the compost.

Recovery of added-value products

Christian Garaffa, Novamont, Italy, presented the biorefinery model of Novamont for the production of Mater-Bi, a biodegradable and compostable polymer used to make bags used for household organic waste collection. High food waste captures are essential to divert organic waste for biogas and compost production and biobags are a key tool in achieving high participation and capture rates, especially in metropolitan areas. The case study of the city of Milan was shown, by now the largest and most successful residential food waste collection scheme on the planet.

Adrie Veeken, Attero, Netherlands, presented anaerobic digestion of source separated household organic wastes. The company processes 40% of Netherlands solid municipal wastes through incineration, composting, digestion and/or separation. The company is currently looking at innovative material recovery processes including using bacteria to produce volatile fatty acids which can then be used to produce poly hydroxyl alkonate (a biodegradable polymer with characteristics comparable to polypropylene), production of fly larvae (dried to produce high-protein and nutrient-rich animal feed), precipitation of struvite from digestate (to recover phosphorus).

Nils Finn Lumholdt, Osle Waste-to-Energy Agency, presented the advanced anaerobic digestion plant developed and now operated by the city. Input is separately collected organic wastes. This is sorted, then subject to thermal hydrolysis (CAMBI THP process, 130°C at 4 atm. for 30 mins) to break down cellular material and maximise availability for methane production. The plant includes digestate evaporation and odour treatment. 1 kg of food waste input generates 0.13 litres of diesel equivalent as biogas, used to power the city's buses. The plant is situated on a site where landfill gas covers energy needs. Liquid digestate is used on c. 100 local farms. Operating cost is 70€/tonne food waste treated.

Returning carbon and nutrients to soil

Florian Amlinger, Austria Compost & Biogas Association, underlined the importance of soil as climate change carbon stock. Soil carbon is restored and built up mainly by changing agronomic methods (e.g. no or low tillage), but composts and digestates can also contribute. Humus in compost is important because it can store nutrients and reduce nutrient losses, improve water retention and so drought resistance, provide a support for soil microbial biodiversity. Carbon in digestate is not present as humus, so that composting of digestate solids is important to ensure that they have a real soil carbon value. The N/C balance in digestate is often too high, so that nutrient separation and recovery is necessary to enable appropriate agricultural application.

Munroo Prasad, Compost Research and Advisory, Ireland, presented a simple test kit developed to enable farmers to rapidly and cheaply, if approximately, test ammonia nitrogen concentrations in digestate (using colour strips costs <1 € each). This is important because nitrogen levels in digestate are generally quite high (up to 15% DM) and most of it is in ammonia form which may change very significantly during storage.

David Tompkins, WRAP (Waste and Resources Action Programme), England, presented the use of digestates in the UK. Digestate from manures is not normally regulated as a 'waste', whereas it is a 'waste' if food waste is used as input. However, this waste status is revoked if the digestate complies with national end of waste criteria, which include a Quality Protocol. This specifies quality criteria and limits uses (e.g. digestate cannot be used in growing media or by amateur gardeners). The commercial value of digestate is principally the nitrogen content, but this can only be applied to fields at certain periods of the year, when there is crop demand.

He presented a number of field trials of different digestates on sports fields, perennial wood and energy crops, use with compost to constitute new soil on mine restoration sites, use in growing media. Challenges identified were that ammonia in raw digestate could 'burn' plants, high variability, instability, bacterial growth on storage and irrigation equipment, potential loss of the nitrogen to air. Conclusions suggest the need for digestate to be completely stable (fully digested) and consistent. Composting of the digestate is an effective solution to improve its use characteristics.

Percy Foster, Composting & Anaerobic Digestion Association of Ireland (Cré), concluded the conference, underlining that there is general agreement that the efficiency of biowaste recycling must be increased, and therefore that compost and digestate use must be improved and waste-to-energy through biogas production must continue to develop.

Note: the conference included parallel sessions on biogas and on digestate-compost: this summary does not cover the biogas sessions as not directly relevant to nutrient management.

AD Europe conference, Dublin 20th-21st February 2014
www.adeurope2014.eu

Digestate
Possible industrial reuse routes for N and P

Masters thesis proposes a number of possible non-agricultural uses for different chemicals which can potentially be routes for recovering and recycling nitrogen and phosphorus from digestates in Finland.

The study looked at the different **chemicals which can be potentially recovered from the liquid fraction of digestate (after dewatering),** which contains soluble forms of phosphorus and nitrogen. Chemical precipitation of phosphate is considered using calcium, magnesium (struvite), iron or aluminium. Nitrogen recovery is considered by ammonia stripping following by condensation to produce ammonia water or acid reaction to produce ammonium nitrate or ammonium sulphate. Non-agricultural uses only were considered, because uses as fertiliser are considered to be addressed by existing literature. Food applications are not considered because these are expected to be excluded because of contaminant risks.

A short literature review of **anaerobic digestion processes and resulting digestate characteristics** is provided, in particular covering solid and liquid fractions after dewatering and nutrients (N, P) mass balance. The recovery technologies indicated above are summarised, as are properties of potentially recovered products.

Nutrient recovery

A literature review of **potential uses for the indicated recovered products** was carried out then 19 relevant companies in Finland were contacted to confirm or infirm the literature review proposed uses of the different potentially recoverable chemicals and to establish whether these companies might be interested to take such chemicals (quantities, technology compatibility or modifications required …).

The following potential uses of recoverable N and P chemicals were identified:

Phosphate precipitants

- **Iron phosphate: no potential uses identified**
- **Aluminium phosphate**: possible applications in adhesives and cements (not confirmed)
- **Calcium phosphate**: production of phosphoric acid for fertilisers and other applications
- **Struvite**: no industrial application identified, but is a valuable fertiliser

Nitrogen chemicals recovered via ammonia stripping

- **A wide range of industrial applications** including petroleum/refineries industry, industrial atmospheric effuent treatment (acid gas abatement), rubber industry (stabiliser to prevent premature coagulation), pulp and paper industry (casein dispersant, sulphite liquor production), nylon and rayon manufacture, textile dying, industrial catalyst (phenol resin production), metal treatment, electroplating, detergent ingredient, furniture production (staining wood), mineral ore processing, production of ammonium sulphate used as a flame retardant, leather industry, lead-acid battery manufacture, ammonium nitrate as an explosive or a cold-pack reactant, other chemical industry applications …
- **Use as a nitrogen source** in biological waste treatments, yeast culture
- **Production of nitrogen fertilisers**

The market survey identified that the ammonia chemical applications with highest potential in Finland could be:

- **Use in industrial flue gas cleaning** (eg. NO_x abatement), with a number of possible user sites, and in some cases acceptance of a product containing impurities
- **Use in pulp and paper mills** for flue gas cleaning. In this case, the nitrogen can then be recycled to "feed" the mills' biological wastewater treatment because the paper wastes do not contain adequate nitrogen

For all applications, however, **the low concentration of ammonia or ammonium chemicals recovered through stripping of digestate would pose problems**, both for transport and for the use.

No specific applications for the phosphorus chemicals were identified in the Finland market context, suggesting that **recovery for use as fertiliser** (e.g. as struvite or in an organic form) is likely to be the best solution.

"Potential utilisation ways of recovered chemical products from digestate", L. Moldakhovskaia, Masters Thesis, Environmental Engineering, Lappenrantra University of Technology, Finland, 2013 http://www.doria.fi/xmlui/handle/10024/94606

Phosphate chemistry and applications

Calcium phosphates
Chemistry, biology, medical applications

Sergey Dorozhkin has published an 850 page, complete reference book covering the mineralogy, chemistry, biology, medical applications and biomedical technologies of calcium orthophosphates, as well as history and perspectives for future developments. The book includes nano-forms and their applications, calcium phosphate cements and similar, biocomposites and hybrid biomaterials. Over 5 000 references are included.

The physical and chemical properties of different calcium phosphate compounds, including amorphous calcium phosphates, are presented in detail, in particular solubility, dissolution, crystal properties.

Different biological hard-tissues built of calcium phosphates are detailed: bone, teeth and deer antlers. This covers mineral, chemical, biological, cellular and physiological properties, structure, growth and pathologies.

Deer antlers offer valuable experimental data because they re-grow every year and, once the 'velvet' (skin rich in blood cells to feed the growing calcium phosphate tissue) has been shed, they are dead so can be removed without pain or damage to the animal. The growth speed of antlers is remarkable, such that over half of the calcium and phosphorus needed cannot come from the deer's food but is taken from its skeleton.

Medical applications

Pathological calcification, where unwanted precipitation of calcium phosphate can cause medical problems, can occur in urinary calculi, salivary stones, arthritic cartilage, pseudo-gout in synovium fluids (in joints), heart and artery calcification.

Nanodimensional and nanocrystalline calcium phosphates can occur biologically in bones, teeth and other tissues. Technologies for synthesis of nano calcium phosphates have received considerable attention because of the novel properties of these substances and numerous applications. Nano-forms developed to date include needle-shapes, solid and hollow spheres, hollow rods, layered structures, flower-like forms. They are used in coatings for medical implants, drug delivery, intra-cellular DNA/RNA delivery, dentistry and maybe soon as a base for bone replacement structures.

The development of **high-performance materials** as joint prostheses and for bone repair or replacement requires surface treatment with calcium phosphates to ensure compatibility and fusion with bone tissue in the body. Calcium phosphates can also be used as part of bioceramic materials, to provide both structural strength and biocompatibility.

Calcium phosphates are also developed in the form of cements, concretes, pastes and putties, with self-setting or hardening reactions, e.g. apatite cements, brushite cements.

Biocomposites of calcium phosphates with metals, glass, carbon, polymers, collagen, chitosan or other materials offer strong potential for bone substitution and repair, but also as biosensors, support for immune systems (adsorption of antibodies), and in electrical batteries.

"Calcium orthophosphates. Applications in nature, biology and medicine", Pan Stanford Publishing ISBN 978-981-4316-62-0, 2012, 853 pages. Contents list free at:
http://www.panstanford.com/books/9789814316620.html

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See also: "Review. Calcium orthophosphates in nature, biology and medicine", S. Doirozhkin, Materials, 2, 399-498, 2009,
www.mdpi.com/1996-1944/2/2/399/pdf

"Calcium orthophosphates. Occurrence, properties, biomineralization, pathological calcification and biomimetic applications", Biomatter 1:2, 121-164, 2011,
http://dx.doi.org/10.4161/biom.18790

Nutrient Platforms

Europe: ***www.phosphorusplatform.org***
Netherlands: ***www.nutrientplatform.org***
Flanders (Belgium):
http://www.vlakwa.be/nutrientenplatform/
Germany: ***www.deutsche-phosphor-plattform.de***
NAPPS North America: ***j.elser@asu.edu***

Partnership opportunities

US & Canada phosphorus networks

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

US P-RCN (Sustainable Phosphorus Research Coordination Network) *j.elser@asu.edu*

P-RCN student network: *rimjhim.aggarwal@asu.edu*

P as anti-tumour signalling agent

Initial research at the Second University of Naples, Italy, suggests that inorganic phosphates may play a role as a **signalling molecule in osteosarcoma cells** (the most common form of bone cancer).

The group is looking for partners to further this work, either through collaborative projects or joint grant proposal development.

Contact: Dr. Silvio Naviglio, Dept. Biochemistry, Biophysics and General Pathology, Second University of Naples, Italy
silvio.naviglio@unina2.it

Horizon 2020 funding opportunities

The EU's new R&D funding programme **Horizon2020** includes a number of areas relevant to phosphorus sustainability, with opportunities for research, demonstration, implementation.

Several Horizon 2020 funding calls now open offer opportunities for sustainable phosphorus management projects:

- **phosphorus in agriculture**: sustainable crop production – external nutrient inputs
- **raw materials**: sustainable exploration, extraction, processing
- **recovery technologies for minerals**, specifically focussing on SMEs and demonstration
- **cooperation with raw materials producing countries**
- **nutrient and energy recovery** from manures and agricultural wastes

The European Sustainable Phosphorus Platform therefore invites expressions of interest to *info@phosphorusplatform.eu* from:

- project consortia looking for stakeholder validation and support
- projects looking for European or global dissemination (Platform partners, conferences, SCOPE Newsletter emailing 60 000 worldwide)
- organisations interested in participating in a phosphorus-related Horizon 2020 projects

H2020 funding opportunities relevant to phosphorus management identified to date

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

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

***WASTE 7-2015** - deadline = 16/10/2014*
http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-climate_en.pdf
***"Ensuring sustainable use of agricultural waste, coproducts and byproducts"**, includes "nutrient, energy and biochemical recovery from manure and other effluents"*

***SC5-11(b)-2014** - deadline = 10/3/2015*
http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-climate_en.pdf
"New solutions for sustainable production of raw materials"
(b) 2014 "Flexible processing technologies"

***SC5-13(f)-2015** – deadline = 10/3/2015*
http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-climate_en.pdf
"Coordinating and supporting raw materials research and innovation"
"Strategic international dialogues and cooperation with raw materials producing countries and industry"

***EIP WG** - announced Feb. 2014, expected to be published soon*
http://ec.europa.eu/agriculture/eip/focus-groups/call-3-announcement_en.pdf
*European Innovation Partnership (EIP) "Agricultural Productivity and Sustainability", call to set up new Focus Groups – limited action, c 20 experts, funding for a few meetings and a report: **"Fertiliser efficiency – focus on horticulture in open field** – How to resolve the conflict between crop quality demands and legislative requirements through innovative fertilisation and nutrient recycling."*

***KIC Raw Materials** – deadline = 10/9/2014*
http://eit.europa.eu/newsroom-and-media/article/innovate-join-the-eit-and-spur-innovation-and-entrepreneurship-across-europe/
To address: raw materials – sustainable exploration, extraction processing, recycling and substitution.

Call for texts: perspectives for phosphorus futures

Send us your **vision for sustainable phosphorus in tomorrow's world**. ESPP is preparing a special SCOPE Newsletter edition, consisting of short texts presenting perspectives and expert opinion for different pathways to address the phosphorus challenge.

Experts, stakeholders and scientists are invited to **submit proposed texts, summarising their vision for the future of phosphorus stewardship** in the areas proposed below, or other areas suggested to be significant. Texts should present likely scenarios or perspectives for the coming 10-25 years, combining vision, game-changes, justified realism. The objective is not to address policy proposals or specific actions, but rather to assess structural questions and propose visions for the future.

This special edition SCOPE Newsletter will be circulated to 60 000 decision makers, stakeholders and scientists worldwide, and presented at the 4th world Sustainable Phosphorus Summit, 1 - 3 Sept., Montpellier, France *http://SPS2014.cirad.fr*

Possible themes and questions

- P resources and their use
- P mining and processing
- P in sewage treatment, nutrient removal, sludge treatment and management
- P in animal manures: origin, fate, treatment, management
- P-recovery from other waste streams, waterways, agricultural drains
- P in the bioeconomy, bioresources and biofuels production
- P in agriculture, soils, crops, animal feeds, forage crops, sustainable farming systems
- P losses to surface waters, eutrophication and water catchment management
- P and the human diet
- P supply stability or vulnerability, adaptive policies, P and food security
- Industry applications of P

Instructions:

Maximum 500 words. **Deadline 15th May 2014** by email to *info@phosphorusplatform.org*

- 1-2 photos may be included, inserted into the WORD text, with credit if required
- photos must be free of rights for web publication
- WORD or RTF document, main text in Ariel 11, titles and subtitles in Arial 14
- title = theme (max 6 words) + article title (max 10 words)
- include for each author(s): name, affiliation (organisation), position/title, postal address, email: at top, below title, Arial 9
- selection of texts by ESPP (European Sustainable Phosphorus Platform) is final
- ESPP may propose to authors to revise certain points before acceptance

Preference will be given to contributions which give a vision of the future, with originality, but with realism, and which take into account published ideas, such as "Phosphorus, food and our future" or the global phosphorus blueprint, both summarsied in ESPP / SCOPE Newsletter n° 97 at *http://www.phosphorusplatform.org/downloads.html*

Agenda 2013 - 2014

- 1-4 April, Amsterdam: **International Fertiliser Association Global Technical Symposium** *www.fertiliser.org*
- 1 May – 31 Oct. **Expo2015** Feeding the planet, energy for life, Milano *http://en.expo2015.org/*
- 6 May, 16h-18h, Munich, Germany: **phosphorus recycling conference at IFAT** (world trade fair for water, waste and raw materials management) *www.ifat.de*
- 4-6 June, Valladolid, Spain: 10th International **Renewable Resources and Biorefineries** (RBB) (5th June: Nutrient & Energy cycling sessions) *www.rrbconference.com*
- 5 June, 16h30 – 18h00, **Brussels Green Week event Closing the phosphorus cycle,** 16:30 – 18:00
- 19 June, Leeds, England, **Future options for food waste** *http://www.aquaenviro.co.uk/view-product/Future-Options-for-Food-Waste*
- 23 June, Brussels, **Biochar** safety, economy, legal harmonisation (REFERTIL) *biochar@3ragrocarbon.com*
- 26-28 June, Gödöllö Hungary, **ORBIT 2014 Organic Resources and Biological Treatment** *http://orbit2014.com*
- 29 June – 3 July, Dublin: **20th International Conference on Phosphorus Chemistry** *www.icpc2014.ie*
- 8-9 July, Rennes, Brittany, France, EU Commission/regions at work for the bio-economy **Converting bio-wastes to fertilisers**
- 13-17 July, Harbin, China: **IWA Science Summit on Urban Water** *http://www.iwahq.org/28f/events/iwa-events/2014/urban-water.html*
- 26-29 August 2014, Montpellier, France: **5th Phosphorus in Soils and Plants symposium** *http://psp5-2014.cirad.fr/*
- 1 - 3 Sept., Montpellier, France 4th world **Sustainable Phosphorus Summit** *http://SPS2014.cirad.fr*

- 27 Sept. – 1 Oct., New Orleans **WEFTEC2014** (Water Environment Federation) *www.weftec.org*
- 30 Sept – 2 Oct, Alkmaar region, Netherlands European Biogas Association Conference *http://www.biogasconference.eu/*
- 7-8 Oct., Manchester, UK, 8th European Waste Water Conference. Including: wastewater as a resource, nutrient factory. *www.ewwmconference.com*
- 20-24 Oct., Rio de Janiero **CIEC World Fertiliser Congress** *www.16wfc.com*
- 26-30 Oct, Kathmandu, Nepal **IWA: Global Challenges for Sustainable Wastewater Treatment and Resource Recovery** *http://iwa2014nepal.org*
- 3-5 Nov 2014, Long Beach, California **ASA, CSSA, SSSA** (US & Canada soil and agronomy) meetings, Water Food, Energy, Innovation for a Sustainable World *www.acsmeetings.org*
- March 2015, Berlin: **2nd European Sustainable Phosphorus Conference** *www.phosphorusplatform.org*

- 23-25 March 2015, Tampa, Florida: **Phosphates 2015** (CRU) *www.phosphatesconference.com*
- 29 March – 3 April 2015, Australia. **Beneficiation of phosphates VII** *http://www.engconf.org/conferences/environmental-technology/beneficiation-of-phosphates-vii/*
- May 2015, Morocco: **SYMPHOS** *www.symphos.com*