SCOPE NEWSLETTER

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Phosphate resources

EU report and expert meeting

Sustainable use of phosphorus

A report to the EU Commission and an expert meeting conclude that world demand for phosphorus resources will continue to grow over the next 30-40 years, with possible instability of supplies. Reducing waste and losses of phosphorus, particularly in agriculture and the food chain is therefore necessary, and phosphorus recovery and recycling should also be actively developed.

United Nations

UNEP Yearbook 2011: phosphorus and food

The United Nations Environment Programme 2010 Yearbook addresses phosphorus resources and futures as one of its three target themes. Key issues are identified as increasing global demand for phosphorus, resource availability, lack of access to P fertilisers for many farmers and the need to develop more efficient use and phosphorus recycling.

Netherlands phosphate balance

Report on developments and outlook for phosphorus

A report for the Netherlands Innovation Network (Ministry of Economic Affairs) assesses global phosphorus use, reserves and their outlook, the phosphorus balance in Netherlands, and options for P recycling and sustainable use.

Wageningen world P resources report

Global phosphorus resources, flows and trends

A report to the Netherlands Ministry of Agriculture looks at world's phosphorus rock reserves, consumption, P-flows and expected trends and developments

Nutrient management

Nitrogen cycles

European Nitrogen Assessment

A major EU funded expert report on nitrogen cycles concludes a new approach is needed to manage organic nitrogen, including recovery and recycling. Environmental and health costs of current nitrogen manage outweigh agricultural cost benefits.

Secondary nutrient resources

Global N and P sewage discharges

Environmental discharges of nitrogen and phosphorus are expected to decrease in Europe over coming decades, but to increase in the rest of the world.

EU infringement procedure

Inadequate P-removal from sewage takes Spain to court

The European Commission has referred Spain to the EU Court of Justice for failing to install phosphorus removal for 39 agglomerations.

Water quality

Phosphate dosing cuts copper pollution

Phosphate dosing of drinking water can reduce copper pollution in sewage plant discharges, contributing to achieving water quality objectives.

Seminar

Toulouse, France, 23rd November 2011

Recycling and reuse of phosphates from effluents

This seminar will look at the issues surrounding phosphate recycling, P-recovery processes, phosphate precipitation, uses of recovered phosphate products.

8h30 – 17h00, INSA Toulouse, France. In French. https://phosphor.cemagref.fr/events/FlyerP.pdf

Publications

The Phosphorus cycle

Chemosphere special issue

***Chemosphere journal (Elsevier publishers) is releasing a special issue on "The Phosphorus Cycle"** in August 2011. Articles cover the history of phosphorus; nutrient recovery and reuse ; phosphorus resources, cycles and flows ; global phosphorus security and phosphorus in food production.*

Chemosphere, Volume 84, Issue 6, Pages 735-854 (August 2011).

Articles can be purchased on the Elsevier ScienceDirect website: http://www.sciencedirect.com/science/issue/5832-2011-999159993-3440868 *or paper copies from* Journalscustomerserviceemea@elsevier.com

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Phosphate resources

EU report and expert meeting

Sustainable use of phosphorus

The EU Commission has published a report on "Sustainable Use of Phosphorus" and conclusions of an expert seminar "Sustainability of the phosphorus resource", organised around the presentation of this report in Brussels, 17th February 2011.

The report was produced by Wageningen University (Plant Research International), The Netherlands, and the Stockholm Environment Institute, Sweden, following an EU Commission Tender.

The report emphasises that **EU food security relies on imported phosphorus**, both in mineral form (fertilisers, phosphoric acid, phosphate rock, animal feed phosphates) and in food and animal feed crop imports (mineral feed additives, animal feed crops). The EU currently imports some 3 kg of phosphorus per person/year, compared to around 600 g per person/year consumed in the human diet.

Worldwide demand for phosphate rock has been growing over the last 20 years, since a drop in the 1980's related to the decline of the Soviet agricultural system, and is expected to continue to grow until at least 2040 – 2050. The report suggests that Europe cannot remain dependent on such a non-renewable resource, particularly when supplies pose significant risks of geopolitical instability (85% of currently known world reserves are in 4 countries, especially Morocco – Western Sahara and China).

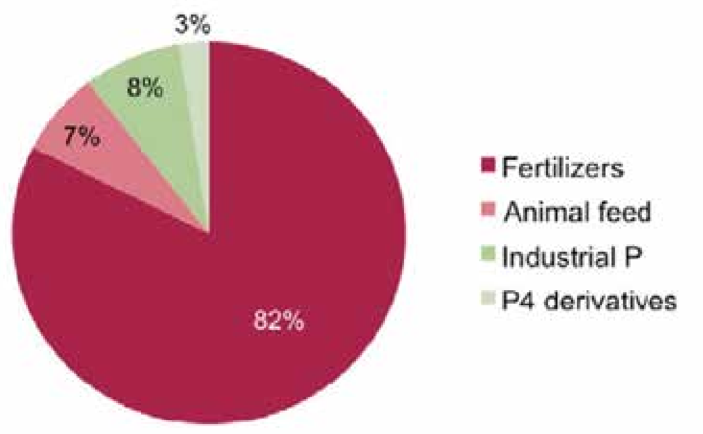
Although the lifetime of phosphate rock resources is not clear, the uneven distribution and rising demand mean that geopolitical tension and price volatility can be expected.

Europe's "food security" is thus a mirage, the report states, because the EU food system is in fact highly vulnerable to future phosphorus scarcity.

Agriculture

Much the largest use of phosphates is agriculture, consuming nearly 90% of phosphates worldwide: approximately 82% in fertilisers plus a further 7% in animal feed supplements (see pie chart, report page 19). However, there are considerable system losses, and 4/5ths of phosphorus is lost between the mined rock and the plate (human consumption).

Drivers of increased demand for rock phosphate include increasing world and European population, changes in diet with increasing consumption of meat and dairy products (already today, **one third of world cereal production goes to feed cattle**), development of bio-energy crops and of aquaculture.



Phosphorus end uses, worldwide. EU Commission report 2010 page 19. From Prud'homme 2010.

Authority commitment to P-recovery and recycling

Key actions to reducing phosphorus dependency must thus target the agricultural sector, but the report emphasises that an **integrated approach** is necessary, combining efficiency – loss reduction and recovery – reuse.

Maintenance of phosphorus soil status is important. Either P depletion or saturation can reduce crop P efficiency. Once adequate phosphorus status of soil is achieved, inputs can be balanced to outputs, provided that **erosion losses** are minimised. However, where soil P status is inadequate, significant "one off" consumption is necessary. For example 85 million tonnes of P are estimated to have accumulated in China's soils since 1985, as authorities promote agricultural improvement.

The expert seminar conclusions underline that to date there have been **few clear governmental or institutional statements that P should be recycled, and no legislative or political pointers in that direction**, and that it is therefore not surprising that phosphorus recycling efforts have been limited.

The experts also indicate the need to make it clear that **recycling of P is not a threat to phosphate rock producers**. The timescale for widespread development of phosphorus recovery is such that they will have time to adapt, given the likely rise in demand driven by population growth, the need to generate soil fertility in parts of the world where soils are still very undernourished with phosphorus, and because some system losses will always remain inevitable.

Action to reduce phosphorus losses

Principal actions identified by the report to reduce phosphorus losses and consumption include:

In agriculture:

- **Optimising land use**: that is finding the balance between intensive production (which reduces the area under production, and so losses through run-off and erosion and general inefficiency of crop take up) and extensive or organic farming (which minimise losses by keeping phosphorus contents in soils low)
- **Preventing soil erosion**, including water, wind and tillage erosion, as well as loss of soil particles with roots of harvested crops
- **Maintaining soil quality**: phosphorus uptake and use efficiency by crops is dependent on a wide range of soil quality parameters, including humidity, soil structure and organic content, pH, other minerals
- **Improving fertiliser management**, including phosphorus dosing levels (adjusting inputs to outputs) and delivery methods
- **Improving crop types**: this can include moving towards perennial crops and genotypes with more efficient phosphorus use, promoting crop root associations with beneficial soil fungi (micorrhizas) to improve soil phosphorus availability
- **Better reuse of phosphorus in manures**, either by spreading on fields according only to plant needs (avoid "disposal" spreading beyond crop needs, this may imply significant transport distance or readjusting livestock numbers on available land) or by recovery of phosphorus for recycling
- **Modifying livestock diets**, including use of phytate enzymes to enable animals to make better use of phosphorus in feeds

Actions targeting the food chain and other uses:

- The significant **losses from farm to fork** should be reduced, targeting losses in crop storage, processing and trade; food processing and trade; retailing; food storage, preparation and consumption
- According to the expert seminar changing detergent formulation will offer "*only minor gains in Europe*"

Phosphorus recovery and reuse from waste streams

Today, **over 40% of EU sewage sludge is spread to land**. The report indicates the need for attention to avoid contaminants in sewage sludge, but also that **plant uptake of phosphorus will be low if aluminium or iron salts have been used for chemical P-removal**. In this case, or if sludge is spread at levels higher than crop phosphorus needs, then part of the sewage phosphorus is not effectively recycled.

Sewage and manure P recycling can be developed both through small-scale, local reuse, adapted to rural contexts, and through more complex centralised systems in urban areas.

Policy changes

Several case studies of regional situations in the EU are examined. **For the Baltic Sea, by far the largest source of phosphorus is agricultural runoff**, depending on fertiliser and manure loadings, with Poland being the largest source because of its area and population. Reducing soil erosion will be essential to reducing phosphorus losses here.

The report notes that there are at present no EU policies taking into account the issue of phosphorus scarcity, and suggests that **an EU phosphorus and food security Directive should be developed**. There is also no global governance of phosphorus resources and supply.

Key policy actions are suggested to be **economic instruments to tax phosphorus losses and fund recovery and recycling**, the **reform of agriculture**, and encouraging of waste handling which is compatible with **phosphorus recovery**, in particular **moving away from iron chemical phosphorus removal in sewage works**.

"Sustainable use of Phosphorus", EU Tender ENV.B.1/ETU/2009/0025. J. Schrôder, D. Cordell, A. Smit,

A. Rosemarin, Wageningen University Plant Research International, Stockholm Environment Institute (SEI), October 2010, published February 2011 at: http://ec.europa.eu/environment/natres/phosphorus.htm

Conclusions of the Expert Seminar on the sustainability of phosphorus resources, EU Commission DG Environment, Brussels, 17th February 2011: http://ec.europa.eu/environment/natres/pdf/conclusions_17_02_2011.pdf

See also:

Prud'homme 2010 "World phosphate rock flows, losses and uses", International Fertilizer Industry Association, Phosphates 2010 International Conference, 22-24 March Brussels 2010.

United Nations

UNEP Yearbook 2011: phosphorus and food

The UNEP (United Nations Environment Programme) Yearbook examines global emerging issues and environmental trends. One of three priority issues targeted in the 2011 Yearbook is "Phosphorus and food production".

The Year Book calls for a global phosphorus assessment to more precisely map phosphorus flows in the environment and predict levels of economically viable reserves.

According to the Year Book, the **global use of fertilizers that contain phosphorus, nitrogen and potassium increased by 600 per cent between 1950 and 2000.** At the same time, phosphorus concentrations in freshwaters and terrestrial ecosystems have increased by at least 75%, often resulting in undesirable impacts on biodiversity and water quality in freshwaters, through eutrophication. Population growth in developing countries and increased levels of dairy and meat in the global diet are likely to increase fertilizer use further. "*While there are commercially exploitable amounts of phosphate rock in several countries, those with no domestic reserves could be particularly vulnerable in the case of global shortfalls*".

Essential for food production

The UNEP assessment starts from the fact the "*phosphorus is essential for food production, but its global supply is limited*".

High crop yields today depend fundamentally on mined phosphate rock, a significant departure from historical food production methods. The development of mineral fertilisers has led to **increase by 4x of the amount of phosphorus moving through the environment**.

UNEP expects demand for phosphorus to continue to increase, in order to feed the world's growing population, to address current problems of malnutrition, and because of increased consumption of meat and dairy products and cultivation of crops for non-food purposes (bio-fuels).

At present nearly 1 billion people in the world suffer from **undernourishment**, of whom many are **small farmers who cannot afford to purchase phosphorus fertilisers** necessary to increase their production, because of the cost of phosphorus and because they do not have access to credit (fertiliser needs to be purchased months before it will bring increased yields).

Improving phosphorus management

The remaining amount of viable phosphate rock resources and the lifetime of reserves have been the subject of significant debate over recent years. The Yearbook underlines the need for further research and coordinated information collection concerning phosphate rock reserves, demand and availability.

The Yearbook suggests that the **efficiency of phosphorus management** should be improved at each stage of the value chain, in order to lengthen the life of reserves: in mining and in fertilizer production, in fertilizer use, and particularly in land management in order to reduce losses through erosion.

Because nutrients are concentrated in topsoil, **surface soil erosion can greatly reduce soil productivity and result in significant phosphorus losses to surface waters**, damaging the aquatic environment. Soil erosion rates of near 0.5 tonnes/ha/year have been measured in Africa, and up to 4x higher in Asia. Erosion can be reduced by contour ploughing, planting of hedgerows, vegetation protection (mulches, cover crops) and soil fertility improvement.

P recover and recycling

UNEP emphasises the **need to develop phosphorus recovery**: "*Recycling phosphorus from excreta or other organic wastes also presents an important* *opportunity to recover this nutrient.*" Public policy is needed to support this.

The example is cited of **Sweden: an objective has been set to recycle 60% of phosphorus in municipal wastewater by 2015**.

Recovery and recycling techniques such as ecological sanitation (closing nutrient and water cycles locally) and recovery of phosphate from sewage (e.g. as struvite) are indicated.

An environmentally integrated set of policy options and technical measures is required to ensure more sustainable use of phosphorus.

Recommendations

UNEP's key recommendations include **further research and debate** about :

- the increasing global demand for phosphorus fertilisers
- long-term availability of phosphate rock
- lack of adequate phosphorus accessibility by many of the world's farmers
- more efficient phosphorus use in agriculture
- minimising losses through soil erosion control
- **increasing phosphorus recycling**.

Environmental solutions that **improve nutrient management and recycling, minimise phosphorus losses due to soil erosion, and foster sustainable production and consumption** should be promoted at the local, national, regional and international levels.

"UNEP Yearbook 2011: emerging issues in our global environment" (United Nations Environment Programme) "Phosphorus and food production", released 17th February 2011: http://www.unep.org/yearbook/2011/

Netherlands phosphate balance

Report on developments and outlook for phosphorus

The Netherlands imports large quantities of phosphorus in cattle feed and mineral fertiliser. Much accumulates in soils, and some leaches into surface water, where it can locally contribute to environmental problems (eutrophication). At the same time, the world's finite supply of mineral phosphate is being depleted.

This report, for the Netherlands Innovation Network (Ministry for Economic Affairs, Agriculture and Innovation) responds to growing awareness of the necessity to manage phosphorus more efficiently and more sustainably.

An essential, natural need

All living organisms depend on phosphorus, which is a part of every living cell. **No other elements can emulate or replace phosphorus in many physiological and biochemical cell processes** and crop production relies on a plenteous supply of phosphorus.

The report looks at:

- Global phosphate production, reserves and resources, and developments
- Global use and consumption, prices
- Trends for future consumption compared to resources
- The phosphate balance of The Netherlands
- Recommendations for phosphorus recycling and sustainable use

Phosphate consumption and reserves

The report summarises **current data on phosphate rock reserves and information on new resource exploration and development**. Current economic phosphate reserves are estimated to be 2 100 million tonnes P, and the reserve base (known deposits which are not considered exploitable at current prices) at 7 000 million tonnes P. The latter could double if phosphate prices were to return to near their 2008 peak level.

At higher prices, a range of lower P-content, lower quality phosphate mineral deposits could become of interest, including phosphatic chalk in the **Mons Basin area, Belgium**, and in the **Paris area, France**, with P contents of 3 – 6.5%, or sources in the **Central Iberian zone of Spain** (P = 6 – 8%).

This compares to **current global use estimates** of around 19 million tonnes P/year. The principal consumption of phosphate rock is for agriculture, and is expected to grow at 2.7 – 4.4% per year in coming decades, as a result of increasing world population and diets with more meat (a meat-rich diet uses about 3x more phosphate than a vegetarian diet).

A major uncertainty is the consumption of **fertilisers for bioenergy crops**: this currently accounts for 2.4% of world fertiliser consumption, but could increase considerably depending on land use availability, resulting in a growth of world phosphorus use of 12 – 16%.

Industrial and cleaning applications are considered "*marginal to insignificant in determining the need for phosphate rock*".

The authors estimate that **current, proven phosphate rock supplies will be exhausted** at some time between 2040 and 2070, but that as yet unidentified reserves may be found to extend this to 2100 – 2150. Increased consumption of phosphorus to fertilise the production of energy crops (biofuels) is an unknown which could modify these estimates.

Netherlands phosphorus balance

The Netherlands has a high population density and a very high density of intensive animal production agriculture. Total phosphorus imports were 433 000 tP/year in 2005, of which 65% was imported in organic materials in human food and animal feeds, compared to 378 000 tP exported. **80-90% of this net import accumulated in soils**, with some 9 000 tP/year being discharged to inland and coastal surface waters.

Recently, The Netherlands consumption of mineral fertiliser has been reduced as legislation has required farmers to limit nutrient applications (Fertilisers Act 2006, Meststoffenwet), driven by the EU Nitrates Directive. **Soil phosphate concentrations are currently so high** in most of The Netherlands that a good crop yield can be maintained for a number of years without renewing phosphorus application. The result of this, in the context of The Netherlands' intensive animal farming, is that the country has an **excess of animal manure phosphorus**, estimated at nearly 4 000 tP/year.

In order to reduce this phosphorus excess in The Netherlands, the authors indicate the need to reduce P content in animal feed concentrates, reduce the use of mineral animal feed phosphates and reduce the use of mineral fertilisers.

Phosphorus recovery and recycling

Processing of manure and sewage biosolids needs to be developed in order to **produce products containing nutrients adapted to plant needs and which can be stored and transported**, in order to enable application when and where plants need phosphorus.

Phosphorus recovery is one route for achieving this, often combined with energy recovery (methane, incineration), including routes such as precipitation of struvite, biochar pyrolysis, P-recovery from incineration ashes (e.g. at the Thermphos industrial phosphorus plant). National legislation needs to be adapted to allow the sale of recovered phosphate materials (e. g. struvite) as fertiliser.

The authors recommend **avoiding iron salts use in sewage nutrient removal processes** (prefer biological P-removal or aluminium salts), so that the precipitate or sludge incineration ash is compatible with phosphorus recovery (use as a secondary phosphorus source, e.g. at the Thermphos industrial phosphorus production unit in Vlissingen, Western Netherlands).

Phosphorus can also be recycled by reuse of organic materials harvested during management of natural areas or forests. **Harvesting of aquatic plants from eutrophic surface waters for use for bioenergy or as animal feeds** (e.g. duckweed) can contribute both to removing phosphorus and reducing eutrophication, and to recovering and recycling phosphorus

Overall, through **better phosphorus management in agriculture and P-recovery and recycling**, the authors estimate that The Netherlands could save 51 – 66 000 tP/year without major changes in policy or legislation.

"The phosphate balance. Current developments and future outlook", February 2011, for the Netherlands Innovation Network (Ministry for Economic Affairs, Agriculture and Innovation), Courage and Kiemkracht. ISBN: 978-90-5059-414-1.

Authors: R.van Enk, G. van der Vee (Geochem Research BV), L. Acera (Groningen University), R. Schuiling (Utrecht

University), P. Ehlert (Wageningen University and Research Centre). Project leaders: J. de Wilt (InnovationNetwork), C. de Vries (Courage), R. van Haren (Kiemkracht)

http://www.innovatienetwerk.org/en/bibliotheek/rapporten/458/Thephosphatebalance

Wageningen world P resources report

Global phosphorus resources, flows and trends

This report on phosphorus resources, flows and future trends was prepared by Wageningen University for the Netherlands Ministry of Agriculture. Current knowledge concerning global phosphorus (P) flows and P reservoirs is presented, and an assessment of information concerning phosphate rock reserves and expected trends for phosphorus consumption. The specific impacts of developments in population and urbanisation, diets, bioenergy crop production and aquaculture are examined.

Some **27 million tonnes of phosphorus are applied annually (MtP/y) to cropland worldwide** in fertilisers, manures and other biosolids, of which only around 3 MtP reaches humans in consumed foods.

P-flows

Approximately (c.) 12 MtP/y are present in manure from domestic animals and c. 3 Mt/yP in human excrements. This compares to c. 18 MtP/y applied to croplands in mineral fertilisers.

This shows that **phosphorus is not at present "cycled" but rather moves through a one-way system, with large final "losses" to the oceans**. Only a very small part of the c. 16 MtP/y lost to oceans is recovered (0.3 MtP/y in fish harvests), most ends up in ocean sediments where it will be unavailable for millions of years, that is until tectonic movements lift ocean floors up to dry land and then erosion of rocks renders the P accessible.

Reservoirs

Some 800 – 4,000 million MtP are currently estimated to be stored in ocean sediments, compared to 40-50,000 MtP in topsoils, 3,000 MtP in surface ocean waters, and 530-600 MtP in terrestrial biomass. **The human population is estimated to contain some 3 MtP**.

Reserves and demand

The report summarises available **data on phosphate rock reserves worldwide**. Estimates of minable phosphate rock deposits vary widely, and the authors suggest figures of 2,400 to 6,600 MtP. As with other reports (eg. IFDC, see SCOPE Newsletter n°77), the issue of geopolitical concentration of resources is emphasised: 70% of the world's phosphate resource base is in China and Morocco/Western Sahara.

Phosphate consumption is principally in agriculture, as fertiliser. The authors expect world demand for P to grow significantly over coming years, at +3% to +4% per year in most regions of the world. This will be driven by population increase, fertiliser use for production of bioenergy crops and increasing average income in Asia (leading to more meat and dairy products in diet).

The authors conclude that reserves of P rock will be exhausted in c. 75 years, and the reserve base exhausted in 170 years, which would imply considerable tension on phosphorus supplies significantly earlier.

Need for more phosphorus

A number of trends are considered susceptible to lead to **increasing global demand for phosphorus**, and so for phosphate rock, in addition to increases in human population:

- **Urbanisation**: the increasing concentration of human populations in cities and urban areas will result in reduced recycling of sewage biosolids to farmland. The authors note, however, that the opposite could also become true in the future: urban sewage works offer the opportunity to recover and recycle phosphorus (as fertiliser, or to industry), through precipitation processes or processing of sludge incineration ash.
- **Diet**: apparent human dietary phosphorus intake is estimated at 0.94 kgP/person/day (2.6 g/person/day) in less developed countries, compared to 1.39 kg/person/year (3.8 g/person/day) in developed countries. NOTE: this is not the actual dietary intake, but rather the P present in produced foods. This is largely due to increased meat and dairy products in diet. The consumption of fertiliser is even higher, because of systemic P losses when

crops are grown then used a s animal feedstuffs. For population growth to 7.7 billion, the authors estimate that +20% P-fertiliser would be required without changes in diet, but +64% if the whole population's diet evolved to resemble diets current in developed countries.

- **Bioenergy crops**: the authors estimated world consumption of P in fertiliser for biofuel crop production in 2007-2008 at 000.34 MtP/y, or around 2% of world fertiliser P use. If bioenergy crops were to develop to provide 10% of world transport fuel and 10% of energy consumption, then some 5MtP/y would be removed in bioenergy crops from fields (approx. 30% of current world P-fertiliser consumption), and actual fertiliser needs would be even higher because of P losses in fields. The actual need for P-fertiliser would depend on the degree of P-recycling, for example of crop or algae by products as animal feeds, or industrial P-recovery in crop processing plants producing biofuels or in crop combustion – energy plants.
- **Aquaculture**: the cultivation of algae either to feed fish farms or for biofuel production also requires P input. If 10% of world transport fuels were produced via aquaculture algae, P input required is estimated at 20% of current world fertiliser consumption, a figure similar to that for land biofuel crop production above.

Losses in the P-cycle

Global phosphorus consumption in fertiliser considerably exceeds the amount that finally ends up in human foods : only around 20% of world fertiliser phosphorus use finally reaches the human population in food. There are thus clearly **significant opportunities for reducing losses**:

- In **mining and processing**
- In **agricultural soil erosion**. Some loss of phosphorus to oceans occurs through natural erosion processes, but most results from agricultural management of croplands (15 MtP/y) and from overgrazing of pasturelands (15 MtP/y). This is part of an overall problem of loss of some 75 billion tonnes/year of agricultural topsoil.
- **Readjustment of P-balance in agricultural soils**, to move away from over fertilisation, and rely more on plants' ability to draw phosphorus out of soils.
- **Increasing recycling of P from sewage**. At present around 50% of phosphorus in human sewage, worldwide, is recycled to agricultural land, but this is decreasing with the installation of centralised sewerage and increasing urbanisation.
- **Recycling P from slaughter wastes** (abattoirs). These wastes used to be used as a source of phosphate (bone meal), but this has been reduced with incineration of animal materials following the BSE disease. New routes, such as P-recovery from incineration ashes need to be developed.
- **Reuse of P in DGSS (Distillers Dried Grains with Solubles),** a by-product of biofuel crop fermentation processes which contain some 0.8% P but have low value as animal feeds.
- **Recycling P from manure**: some 6 – 8 MtP/y are recycled from animal manures to agriculture, but intensive production leads to increasing losses to surface waters instead of recycling. Liu 2005 estimates that 50% of phosphorus in China's surface waters comes from manure, 36% for the EU.

Closing the P loop

The authors emphasise the **need to improve the efficiency of phosphorus use in agricultural systems**. Developments to achieve this can include reducing geographical concentration of livestock production, improved crop fertilisation, improving animal use of phosphorus in diets (for example, by the addition of phytase enzyme, to make available P in phytate in crops), plant breeding to improve crop uptake of soil phosphorus, and recycling of P from manures and crop wastes (including bioenergy crop ashes, distillery wastes, crop processing wastes).

Recovery and recycling of phosphorus from sewage, sewage sludge incineration ashes, slaughter wastes, is considered necessary to close the phosphorus loop.

The authors conclude that "sustainability" and "the planet's carrying capacity" are fully meaningful terms in relation to the finite nature of phosphorus resources. Whether these resources will last for tens or hundreds of years, at some time the world will face lower agricultural yields due to limits to phosphorus supply to soils. Can the planet then feed more than around one billion people?

More immediately, "time buying options" must be explored to **prolong the life of mineral phosphate rock reserves**, while continuing to feed the world's six billion growing population: reduce losses, reconsider diet, recover and recycle.

"Phosphorus in agriculture: global resources, trends and developments", September 2009, Report 282.

Report to the Steering Committee Technology Assessment of the Ministry of Agriculture, Nature and Food Quality, The Netherlands, and in collaboration with the Nutrient Flow Task Group (NFTG), supported by DPRN (Development Policy Review Network)

http://www.mvo.nl/Portals/0/duurzaamheid/biobrandstoffen/nieuws/2009/11/12571.pdf

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Nutrient Management

Nitrogen cycles

European Nitrogen Assessment

The European Nitrogen Assessment was produced by over 200 experts from 21 countries and 89 scientific institutes, funded by the European Union. It concludes that industrial production of reactive nitrogen (N_r) since the early 20th century, essentially for agricultural application, is the biggest anthropological modification to the global environment made to date. Annual health and environment costs of reactive nitrogen dispersal are 70 – 320 billion €/year for the EU, exceeding considerably the economic gains from nitrogen fertiliser use in agriculture. The report states that a new, holistic approach to the reactive nitrogen cycle is necessary, considering all sectors of activity, impacts in air, soil and water, reducing use, limiting losses and developing recovery and recycling.

At the global scale, anthropogenic nitrogen fixation (mainly by the Haber-Bosch industrial process, but also through NO_x release in fossil fuel combustion) and anthropogenic changes in reactive nitrogen release (mainly agriculture), have **modified the nitrogen cycle considerably more than have been modified the carbon or phosphorus cycles**.

Sectorial approach

The experts emphasise that **policies to date concerning the impacts of reactive nitrogen dissemination tend to address specific nitrogen species** (ammonia, NO_x, …), specific sources (agriculture, sewage works, …) or specific environmental compartments (air, ground water, surface waters, soil) without a holistic vision of the overall nitrogen cycle modifications and effects. They conclude that an integrated analysis is needed to identify priority areas for action.

The report emphasises the significance of secondary and indirect impacts, which are often not clearly understood and not quantified to date. For example, the use of only mineral fertilisers in cereal farming, combined with other intensification changes in agriculture, can result in a **decline in soil organic matter** which reduces the soil's buffer capacity to retain reactive nitrogen, so accelerating losses and leaching.

Phosphorus and nitrogen

Links with the phosphorus cycle are indicated, in particular as regards surface water impacts of N_r releases. In freshwater systems, phosphorus is generally considered to be the "limiting" nutrient, controlling primary production and algal growth, but in some cases **control of nitrogen inputs is also necessary if eutrophication is to be limited** and ecological quality restored.

Nitrogen releases to coastal waters have caused significant ecological deterioration, including algal blooms and anoxic zones.

The unbalance between (increased) N_r nitrogen levels and silica levels, in particular, causes problem algal blooms in estuaries (Rhine, Danube, Scheldt …) and on coastlines of the North Sea, Black Sea and Baltic.

Greenhouse and biodiversity effects

N_r emissions affect the **climate** through a complex variety of effects: N_2O contributes directly to the greenhouse effect, but N_r emissions also have indirect effects by increasing tropospheric ozone, changing methane fluxes and by modifying CO_2 sinks. The overall impact of European N_r emissions is thought to be a cooling effect.

N_r affects **biodiversity** by artificially increasing nutrient levels or acidification in sensitive habitats, probably acting in synergy with other stressors, such as climate change. Because of cumulative effects, N_r is considered to have been contributing to biodiversity decline for many decades, and that recovery will be slow.

Costs and benefits

Total N_r related damage in the EU-27 is estimated at € 70 – 320 billion/year (€ 150 – 750 per person/year), with the most significant costs coming from health impacts and air pollution. The estimated benefit for the farmer of nitrogen fertiliser application is € 1 – 3 per kg N_r, which is lower than the societal costs of this N_r use. If these costs were internalised into fertiliser prices, the authors estimate that N application for arable cropland in Europe would be reduced by approx. 50 kgN/ha/year.

"European Nitrogen Assessment" http://www.nine-esf.org/ENA , *ISBN: 9781107006126, 664 pages, Cambridge University Press 2011, by the Task Force on Reactive Nitrogen* http://www.clrtap-tfrn.org/

M. Sutton, G. Billen, A. Bleeker, J. Willem Erisman, P. Grennfelt, H. van Grinsven, B. Grizzetti, C. Howard, A. Leip

UNESCO-SCOPE Policy Briefs n°4, April 2007: "Human alteration of the Nitrogen Cycle, Threats, Benefits and Opportunities"
http://unesdoc.unesco.org/images/0015/001509/150916e.pdf

UNEP - The Woods Hole Research Center "Reactive Nitrogen in the Environment Too Much or Too Little of a Good Thing", 2007,
www.unep.org/pdf/dtie/Reactive_Nitrogen.pdf

Secondary nutrient resources

Global assessment of N and P sewage discharges

Releases of nutrients (N and P) into the environment from sewage depend on human populations, levels of sewage collection (often related to urbanisation), the levels of these nutrients in sewage (as a function of human diet, other phosphate uses, etc), and the installation of nutrient removal in sewage treatment.

This paper estimates these factors worldwide and at a continental level for today, and under different Millennium Ecosystem Assessment development scenarios for the horizon 2050. Environmental discharges are expected to decrease in Europe, as sewage treatment and nutrient removal installation continue to improve, but to increase elsewhere in the world by a factor of 2.5x to 3.5x (2000 to 2050).

Human diet nitrogen intake is estimated from human population and protein intake (average 16% N in protein), and protein intake is estimated as a function of GDP according to FAO figures. Human diet phosphorus is estimated as proportional to nitrogen (diet P = 1/6 x diet N), based on figures from sewage works, which gives a value of 1.4 gP/person /day for low income countries.

Phosphorus in laundry and dishwasher detergents is estimated at between 0.0 and 0.48 gP/person/day for 2000 - 2050, compared to human emissions of 1.9 – 3.6 gP, mostly from laundry detergents. Dishwasher detergent phosphate is considered to have "*only a minor effect on P effluents in many industrialised countries because of the efficient P removal in wastewater treatment*".

Sewage collection and treatment

Discharges from sewage are based on estimates of sewage connection rates, empirically related to urbanisation, and on treatment levels. Human waste from populations not connected to sewage systems is assumed to be collected in latrines or septic tanks, and to NOT discharge nutrients into surface waters. The authors consider that this may be realistic at least in rural areas, where there is extensive recycling of human nutrients, but that further work is needed to better assess the levels of nutrients reaching the environment from diffuse sewage emissions not connected to sewerage networks.

Nutrient removal in sewage treatment is estimated by considering wastewater treatment to be installed at one of four levels:

- no treatment,
- mechanical (primary) treatment: 10-25% N-removal, 10-30% P-removal
- biological (secondary): 35-55% N-removal, 45-90% P-removal
- advanced (tertiary = nutrient removal): 45-80% N-removal, 88-95% P-removal

The **Millennium Ecosystem Assessment scenarios** are used for 2050: Global Orchestration, Order from Strength, Technogarden, and Adapting Mosaic.

Conclusions

Overall, the authors predict **rapid increases in global sewage discharges**: for nitrogen, from 6.4 Mt million tonnes (6.4 Tg) in 2000 to 12.0 – 15.5 MtN in 2050; and for phosphorus, from 1.3 Mt in 2000 to 2.4 – 3.1 MtP in 2050.

This covers, however, significant regional variations. Sewage N and P discharges are expected to rise highest in Southern and Eastern Asia over this period, by 4 – 6 times. Even in North America, with comparatively high levels of wastewater treatment, sewage nutrient emissions are expected to rise. **Europe is the only region where discharges are expected to fall**, as a result of continuing improvements in sewage treatment.

"Global nitrogen and phosphate in urban wastewater for the period 1970 to 2050", Global Biochemical Cycles, vol. 23, GB0A03 (American Geophysical Union), 2009
http://www.agu.org/journals/gb/

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EU infringement procedure

Inadequate P-removal from sewage takes Spain to court

EU legislation ((EU Urban Waste Water Treatment Directive 1991/271) requires phosphorus removal to be applied to sewage from all agglomerations of > 10.000 p.e. (person equivalent, that is, population of approx. 6.000) discharging into surface waters which are potentially susceptible to eutrophication.

In 2008, the European Commission started a **legal procedure against Spain for inadequate P-removal** by issuing a "Reasoned Opinion" dated 1/12/2008 (see Scope Newsletter n° 73). Since then, Spain has made considerable investments to improve sewage treatment, but the European Commission considers that "*overall compliance is still poor*".

The Commission states that **at least 39 towns of > 10.000 p.e. in Spain are still discharging without nutrient removal their sewage into "Sensitive Areas",** that is surface waters potentially susceptible to eutrophication, and has therefore decided to refer Spain to the European Court of Justice.

The Commission has also referred Spain to the Court of Justice for failure to publish water basin management plans by December 2009, as required by the EU Water Framework Directive 2000/60.

Spain has also recently been condemned by the Court of Justice for **failure to collect and treat sewage from more than 30 agglomerations of > 15 000 person equivalents**.

European Commission press release IP/11/729 dated 16 June 2011:
http://europa.eu/rapid/pressReleasesAction.do?reference=IP/11/729&format=PDF&aged=0&language=EN

Water quality

Phosphate dosing cuts copper pollution

A paper published by experts from the UK Environment Agency, Atkins consultants, Severn Trent Water and United Utilities indicates that phosphate dosing in tap water supply can play an important role in reducing copper contamination in household drinking water, and more importantly, in treated sewage effluent.

This can enable achievement of environmental quality objectives fixed by the EU Water Framework Directive.

Based on statistics for nearly 2 300 water supply zones, they suggest that **phosphate treatment of public tap water supply can reduce copper levels both in household drinking water and in sewage works discharge**. Both reductions were proportionate to levels of phosphate dosing.

The reduction in drinking water copper (by 40%, from 65 to 35 µg/l Cu) is considered not significant, as copper levels in water are low compared thresholds of concern for human health (2 000 µg/l Cu), **but the 30% reduction in sewage works discharges to surface waters (rivers, lakes, estuaries) could be key to achieving environmental quality objectives**, which are of the order of a few microgrammes per litre.

Freshwater and marine water quality

The **European scientific committee SCHER** concluded in 2009 that "*The European-wide safe levels for copper in freshwater and marine waters are respectively 7.8 and 2.6 µg/l Cu*". Widespread inorganic phosphate dosing of drinking water could play a key role in achieving these levels.

Inorganic phosphate dosing is widely used by UK water companies in order to reduce solubility of lead (plumbosolvency) in old piping and solders, with the aim or respecting European limits for lead in drinking water (currently 25 µg/l Pb, moving to 10 µg/l Pb in 2013).

The authors note that **chlorination of tap water** may accentuate copper release, but were not able to find data concerning interactions with phosphate dosing. Also, no evidence was found of reductions in lead, zinc or nickel concentrations relating to phosphate dosing, probably because the principal sources of these contaminants are not water supply pipe corrosion (whereas this is the principal source of copper).

"Phosphate treatment to reduce plumbosolvency of drinking water also reduces discharges of copper into environmental surface Waters", S Comber, F. Casse, M. Gardner, Atkins Limited; Bruce Brown, UK Environment Agency; J. Martin, Severn Trent Water; O. Hillis, United Utilities.

Water and Environment Journal.n° 25, 2011, pages 266-270
http://onlinelibrary.wiley.com/doi/10.1111/j.1747-6593.2010.00219.x/pdf

Seminar

Toulouse, France, 23rd November 2011

Recycling and reuse of phosphates from effluents

This seminar will look at the issues surrounding phosphate recycling, P-recovery processes, phosphate precipitation, uses of recovered phosphate products.

The seminar will include a presentation of the Phosph'OR continuous process for precipitating and recovering struvite from treated pig manure (Cemagref), the LISBP process for recovery of phosphate by biological granulation, processes for recovery of phosphate from domestic sewage, methods and models for struvite precipitation, regulatory issues and plant availability of recovered phosphates.

Organised by INSA Toulouse, Cemagref, LISBP and Midi-Pyrénées Innovation.

8h30 – 17h00 Wednesday 23rd November 2011
INSA Toulouse, France
In French

https://phosphor.cemagref.fr/events/FlyerP.pdf

Publications

Phosphorus cycle

Chemosphere special issue

Chemosphere journal (Elsevier publishers) is releasing a special issue on "The Phosphorus Cycle" in August 2011.

Articles cover the history of phosphorus ; nutrient recovery and reuse ; phosphorus resources, cycles and flows ; global phosphorus security and phosphorus in food production.

Individual articles can be purchased on the Elsevier ScienceDirect website:

http://www.sciencedirect.com/science/issue/5832-2011-999159993-3440868

or paper copies of the full special issue can be purchased for €160,50 (ex VAT, inc. price for postage to Europe) from

Journalscustomerserviceemea@elsevier.com

Chemosphere, Volume 84, Issue 6, Pages 735-854 (August 2011).

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Conferences and networks

SNB P-recovery website

Phosphate recovery news and information

The Netherlands sewage sludge processing company SNB (N.V. Slibverwerking Noord-Brabant) has launched a website on phosphate recovery and phosphorus resource management :

www.phosphaterecovery.com

Global Phosphorus Network

Phosphorus stewardship, resources, recovery and recycling

The Global Phosphorus Network *www.GlobalPNetwork.net* is a new platform to exchange information, news, opinions between stakeholders, policy-makers and experts.

Join at: *http://globalpnetwork.net/user/register*

Phosphates 2012

Phosphate industry conference

The 2-yearly conference for the worldwide phosphate industry (rock production, fertiliser, animal feeds, food, detergents, other industrial uses) will take place in **El-Jadida, Morocoo, 19th – 22nd March 2012**.

Monday 19th March:
8h30 – 11h30: Site Visit to Jorf Lasfar Chemical Facility
15h00: Registration and exhibition
18h30: Reception

Tuesday 20th, Wednesday 21st:
9h00 – 17h00: Conference

Thursday 22nd March:
8h00 – 19h00: Site Visit to Khouribga Mine Facility

www.phosphatesconference.com