SCOPE NEWSLETTER

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Phosphorus recycling

75th "Darmstädter Seminar":

Phosphorus Recovery from Wastewater and Sewage Sludge

Summary of 2-day workshop. 120 participants addressed phosphorus recovery from wastewater and sewage sludge.

USA

Seeding struvite precipitation II

A second paper develops results summarised in SCOPE Newsletter n°60 showing optimal conditions for struvite precipitation from synthetic animal waste water.

Sewage treatment

EU Directive application

Scotland considerably increases designated "sensitive areas"

Scotland has increased the number of water bodies designated as nutrient input "Sensitive Areas", as defined by the EU Urban Waste Water Treatment and Water Framework Directives, from 7 to 164.

European Union

Eutrophication Guidance Document

The EU has adopted a Policy Summary document concerning eutrophication in implementation of the EU Water Framework Directive.

France

P-removal in small sewage works

Technical Guide to phosphorus removal from small municipal waste water treatment plants, for decision makers, covering techniques, practical aspects, costs and performance.

Nutrients and ecosystems

Baltic Sea

Eutrophication phase shift in the Greifswalder Bodden bay

Despite nutrient input reductions, recovery of the coastal ecosystem is difficult because of a steady-state phase shift resulting from a loss of macrophytes.

Arkansas

Nutrients in a waste water affected stream

Disruption of nutrient cycles in a small stream downstream of a relatively significant point source discharge

Phosphorus and nitrogen

Sources of nutrients to European waters

An European Environment Agency report presents updated data and trends on source apportionment of nitrogen and phosphorus sources

The Scope Newsletter

The SCOPE Newsletter is produced by the Centre Européen d'Etudes des Polyphosphates, the phosphate industry's research association and a sector group of CEFIC (the European Chemical Industry Council).

The SCOPE Newsletter seeks to promote the sustainable use of phosphates through recovery and recycling and a better understanding of the role of phosphates in the environment.

The SCOPE Newsletter is open to input from its readers and we welcome all comments or information. Contributions from readers are invited on all subjects concerning phosphates, detergents, sewage treatment and the environment. You are invited to submit scientific papers for review.

The SCOPE NEWSLETTER is produced by CEEP - a sector group of CEFIC,
avenue E. Van Nieuwenhuyse 4, bte 2, B1160, Bruxelles - Belgium.
Tel: (32) 2 6767211 Fax: (32) 2 67673 01 E-Mail: cja@cefic.be
www.ceep-phosphates.org
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Summary of the 75th "Darmstädter Seminar": Phosphorus Recovery from Wastewater and Sewage Sludge

12-13 December 2005. Darmstadt. Summary by: Peter Cornel, Martin Wagner and Christian Schaum

Concepts – Technologies – Developments

For the 75th time the "Darmstädter Seminar" was organized by the TU Darmstadt, Institute of Water Supply and Groundwater Protection, Wastewater Technology, Waste Management, Industrial Material Cycles, Environmental Planning ("Institut WAR"), this year in cooperation with the German Federal Environmental Agency (FEA), the seminar addressed phosphorus recovery from wastewater and sewage sludge.

Jürgen Hahn (FEA) and Peter Cornel (TU Darmstadt) welcomed more than 120 participants at the two day workshop, among them representatives of the fertilizer industry, research institutes, consulting engineers from the phosphate industry, and - because of the topic's practical relevance - numerous waste water treatments plant (WWTP) operators.

Introduction - Legal and Scientific Aspects

Jürgen Hahn (FEA, Berlin) presented legal, financial and technical options for promoting phosphorus recycling from waste water and waste. The objectives of phosphorus recycling are to reduce the dependency on imports, to extend the availability of the limited resource phosphorus and to reduce the environmental impacts of the phosphate industry (tailings, waste water, transport, migration of heavy metals into other media). Thereby, the decisive factor is ensuring proportionality, which is reflected in the measure's necessity, suitability and adequacy. One initial step is the combined initiative of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Education and Research (BMBF). This initiative supports research, development and large-scale technical demonstration projects, which deal with the recycling of phosphorus from suitable secondary raw material. The statements of the new federal government (federal chancellor Dr. Angela Merkel, federal environment minister Sigmar Gabriel, federal minister of education and research Dr. Annette Schavan) regarding the promotion of innovative technologies are a very positive signal towards phosphorus recycling methods which conserve resources.

Peter Cornel (TU Darmstadt) presented developments from phosphorus elimination to phosphorus recovery. Besides demonstrating the various techniques of phosphorus elimination and recovery potentials from waste water and sewage

sludge, the main topic was the understanding that phosphorus is a limited resource.

Phosphorus Balance and Requirements for the Use of Recovered Phosphate

Norbert Jardin (Ruhrverband, Essen) explained in detail the development of phosphorus balance in waste water. Since the 1970s there is a constant decrease of phosphorus in waste water, from originally 5 g P/PE·d to 1.8 g P/PE·d in 1998. During the last years one could observe once again a slight increase, due to the increased use of phosphates in dishwashers. A further topic was the influence of different techniques of phosphorus elimination on phosphate specification during anaerobic stabilization. Here, the increased precipitation of magnesium ammonium phosphate (MAP) during the digestion of sludge from WWTP with the enhanced biological phosphorus removal (EBPR) is of major interest.

Jörn Breuer (University of Hohenheim, Stuttgart) dealt with the requirements for the use of recovered phosphorus in agriculture. Though the use of phosphorus fertilizers has decreased since the 1980s the relative crop yields continued to increase strongly. Furthermore, he referred to the necessity of field studies, in order to estimate the actual availability of phosphorus for plants. The soil texture plays a decisive role in defining whether phosphorus is mobilised easily or rarely.

Willem Schipper (Thermphos, Vlissingen, Netherlands) presented the requirements for the use of recovered phosphorus in the phosphate industry (thermal phosphorus process). Due to the volatilization of ammonium, MAP, which was referred to several times during the seminar, is not suitable for direct recycling in a plant for thermal processing of phosphorus ore. In contrast, there are no problems in using calcium phosphates, which for example is produced in the Crystalactor or the P-RoC processes.

Phosphorus Recovery from Wastewater

Ute Berg (Forschungszentrum Karlsruhe) presented a technology for phosphorus recovery, the P-RoC process (P-Recovery from wastewater by crystallisation of calcium phosphate). Tobermorite stimulates the precipitation of calcium phosphate, as it increases the pH value (due to its chemical properties) and at the same time serves a crystallisation nucleus.

Andreas Giesen (DHV Water, Amersfoort, The Netherlands) dealt with the Crystalactor process: in a fluid-bed type of crystalliser (pellet reactor), phosphate is removed and recovered from the wastewater as calcium phosphate, by the use of sand as seed material.

Bernd Heinzmann (Berliner Wasserbetriebe) explained how a problem solving process may lead to the development of a recovery technique. Step by step problems with incrustation of pipes during the treatment of EBPR sludge were solved by systematically recovering phosphate in the form of MAP.

Phosphorus Recovery from Sewage Sludge and Sewage Sludge Ashes

*Karl-Heinz Rosenwinkel (*University of Hannover) explained how phosphorus recovery from excess sludge can be optimised by disintegration techniques. By means of a high-pressure (400 bar) homogenizer a disintegration rate of 60 % could be achieved. Thus the phosphate concentration in solution, increased from 40 mg PO_4-P/L originally to 240 mg PO_4-P/L.

Johannes Pinnekamp (RWTH Aachen) demonstrated that only slight procedural adaptations are needed to enable phosphate recovery (as MAP) in sewage treatment plants using EBPR (enhanced biological phosphate removal). It is possible to release one third of the incoming phosphate load in the thickener, under the condition that the thickening time is three days and mixing occurs daily. He estimated the recovery potential at approximately 35 - 40 % of the WWTP's inflow.

Christian Schaum (TU Darmstadt) explained the influence of chemical oxidative sewage sludge treatment on the dewatering potential and the release of phosphorus (Kemicond process). In cooperation with the Swedish company Kemira a significant improvement was observed in the dewatering potential of sludge, when using hydrogen peroxide at a pH value of approximately 4. Amongst others this phenomenon can be explained by the oxidation of von Fe^{2+} to Fe^{3+} ions, which form iron hydroxo complexes and precipitate at pH values of approximately 4.

Christoph Blöcher (Bayer Technology Services, Leverkusen) dealt with phosphorus recovery from sewage sludge by means of wet oxidation and nanofiltration, using the Bayer LOPROX system (Low Pressure Wet Oxidation). With this technology it is possible to eliminate pharmaceuticals, antibiotics, endocrine active substances and organic chlorine compounds. Furthermore, the sludge is sanitized and its amount reduced, and the nutrients nitrogen and phosphorus are transferred to the dissolved phase. By means of nanofiltration the separation of dissolved heavy metals and phosphorus should be possible.

Christian Schaum (TU Darmstadt), 2nd lecture, reported on the potential and limits of phosphorus recovery from sewage sludge ashes. The main topic of the lecture was the SEPHOS process (Sequential Precipitation of Phosphorus). This technique enables a near 100 % release of phosphorus from ashes by means of elution with acids (pH value < 1.5). In the process a large percentage of the heavy metals are dissolved, too. The subsequent sequential precipitation of phosphorus is made possible by increasing the pH value systematically. The SEPHOS product, an aluminium phosphate, is suitable for use in the phosphate industry (thermal phosphorus route). In a further step, it is also possible to treat the aluminium phosphate in a alkaline solution to recover phosphorus as calcium phosphate. The dissolved aluminium can recycled as coagulant at the WWTP.

Johannes Müller (Ingenieurbüro PFI, Hannover) explained how the Seaborne Technology has been implemented in the WWTP of Gifhorn (Germany). Due to economic reasons parts of the Seaborne technology were adapted. The process included an acidic treatment of sewage sludge with a separation of heavy metals and a phosphorus recovery as MAP.

Gerald Prinzhorn (ASH DEC Umwelt AG, Wien) presented a technology to produce phosphorus fertiliser from sewage sludge ashes with thermal removal of heavy metals. By adding chloride and acid, chlorides of heavy metals are formed, which are transferred into the gaseous phase during the subsequent thermal treatment (< 1,000°C), whereby a phosphorus silicate, comparable with the Rhenania process, with a low heavy metal content, is produced.

Martin Faulstich (TU München) dealt with the potential of phosphorus recovery by treating sewage sludge, sewage sludge ash and meat-and-bone meal in the iron baths of the steel industry. Due to high investment costs this technology is economically sensible only with existing infrastructure in the steel industry.

A panel discussion was presided by *Harald Irmer* (Environmental Agency of North Rhine-Westphalia). The main topics addressed were the proportionality of the presented technologies and the future formulation of a law text to promote phosphorus recovery. Furthermore, it became clear that it is necessary to improve the coordination between research organisations and potential users of the recovered phosphate regarding the required quality of the products.

The full proceedings (in German) of the Seminar may be purchased at the TU Darmstadt (Tel.: +49 6151 16 3648, Fax: +49 6151 16 3758 or **a.cevik@iwar.tu-darmstadt.de***) at 35 €.*

Technische Universität Darmstadt, Publication WAR 167 "Rückgewinnung von Phosphor aus Abwasser und Klärschlamm Konzepte – Verfahren – Entwicklungen" 75. Darmstädter Seminar Abwassertechnik– am 12-13th December 2005, TU Darmstadt, 2005, ISBN 3-932518-63-2 http://www.iwar.bauing.tu-darmstadt.de/bibliothek/schriften.htm

Peter Cornel, Martin Wagner, Christian Schaum, TU Darmstadt, Germany m.wagner@iwar.tu-darmstadt.de

USA

Seeding struvite precipitation II

This paper further develops the laboratory struvite precipitation experiments presented in a 2003 WEFTEC paper summarised in SCOPE Newsletter n°60. Synthetic wastewater (magnesium, ammonium, phosphate, sulphate, chloride ions combined at concentrations comparable to anaerobic lagoon treated piggery waste water) was tested in 2-litre beaker experiments. Mechanical and air-bubble mixing, with different mixing energies and times, and 3 different seed materials were tested (quartz, sand, struvite, plus no seed).

The previous paper concluded that struvite crystals of size 75-150 µm offered the best performance for struvite precipitation, possibly because smaller seed crystals were resulting in the loss of precipitate as "fines".

This paper provides microscope photos of precipitated struvite, as longish crystals. Results show that increasing mixing energies increase struvite precipitation, and in larger precipitate crystal sizes (for no seeding) up to a mixing strength of G = 76/second. This mixing strength allowed a reaction time of 1 hour or lower.

With seed material, optimal mixing strength depended on the type of seed used. **Seeding significantly reduced the necessary reaction time compared to unseeded experiments** (5x better struvite precipitation with struvite seed compared to unseeded). Struvite appeared as the best material tested for use as seed. At mixing strength G = 76/s, struvite crystals grew to approx. 350 µm in one hour reaction time (no significant growth beyond this time).

Estimates of seed size needed to achieve effective settling (to enable recovery) in a full scale reactor suggested that only through seeding would this be feasible.

"Effect of seeding materials and mixing strength on struvite precipitation", Water Environment research, Volume 78, Number 2, February 2006, pages 125-132
http://www.ingentaconnect.com/content/wef/wer

J. Wang, J. Burken, Dept. Civil, Architectural and Environmental Engineering, University of Missouri-Rolla, Rolla, MO65401, USA, X. Zhang, Dept. Civil and Environmental Engineering, University of Massachusetts Lowell, Lowell, MA 01854, USA. burken@umr.edu

Sewage treatment

EU Directive application

Scotland considerably increases designated "sensitive areas"

The Scottish Environment Agency has considerably increased the number and extent of designated "Sensitive Areas" from 7 to 164, that is increasing the length of designated rivers from 101 to 2184 km and the number of lochs from 2 to 17. The previous designations only included water bodies affected by larger sewage works, whereas the updated designations now aim to cover all water bodies which are effectively nutrient sensitive, as required by the combined implementation of the EU Urban Waste Water Treatment Directive 1991/271 and Water Framework Directive 2000/60.

Both these two Directives require Member States to review the designation of "Sensitive Areas" every four years, and these new designations are the result of this review process. The Agency report recalls the obligations of the Urban Waste Water Treatment Directive that a water body should be designated if it **"is eutrophic, or may become eutrophic"** but also if **"discharges into the water body require enhanced treatment in order to comply with other EU Directives"**. The latter clause now means that designation is required if enhanced water treatment is necessary in order to achieve the Water Framework Directive objective of "good quality" status by 2015 (mitigation measures to be in place by 2012). This clause can also require designation of "Sensitive Areas" because of objectives fixed by the Habitats Directive, the Drinking Water Directive, Nitrates Directive or Freshwater Fish Directive.

The Agency therefore states that discharges into "Sensitive Areas" from all settlements for which sewage collection is obligatory (2,000 pe) require more stringent treatment of nutrients. In fact, the Agency has identified all sewage works > 250 pe in the designated "Sensitive Areas", considering that nutrient removal will be necessary before 2012 under the Water Framework Directive for all such sewage works.

Factors of nutrient input which will need to be addressed, in order to mitigate eutrophication risks and so achieve "Good Quality" status under the Water Framework Directive include not only urban waste water, but also diffuse inputs of agricultural phosphate and nitrates, diffuse urban runoff, fish farming, refuse tips and forestry activities, and even in a few cases roosting wildfowl.

Designation criteria

Water bodies have been designated as "Sensitive Areas" wherever one of the following criteria occurs:

- increased nutrient inputs or concentrations above background levels, for example +50% above background for coastal waters
- algal development: macroalgal growth, algal community balance, or an increase in chlorophyll (+50% above a background concentration of 10 µg/l)
- reduced dissolved oxygen concentrations (< 4 mg/l)
- disturbance of benthic ecology (river bed)

"Eutrophication Assessment of Scottish Coastal, Estuarine and Inland Waters", Scottish Environment Protection Agency, December 2005 http://www.sepa.org.uk/pdf/publications/technical/eutrophication_assessment_2005.pdf *and press release* http://www.sepa.org.uk/news/releases/view.asp?id=356&y=2006

European Union
Eutrophication Guidance Document

The European Union Water Framework Directive ("WFD" 2000/60) strategic implementation group, made up of Member States water directors, has agreed a document providing technical guidance on eutrophication: definitions, assessment of how eutrophication status is interpreted as regards the Directive objectives of "good quality status", equivalence between this Directive's requirements and those of previous Directives (Urban Waste Water Treatment Directive - UWWT - 1991/271 and Nitrates Directive 1991/676), comparison of eutrophication assessment criteria currently used by Member States and correspondence to WFD .

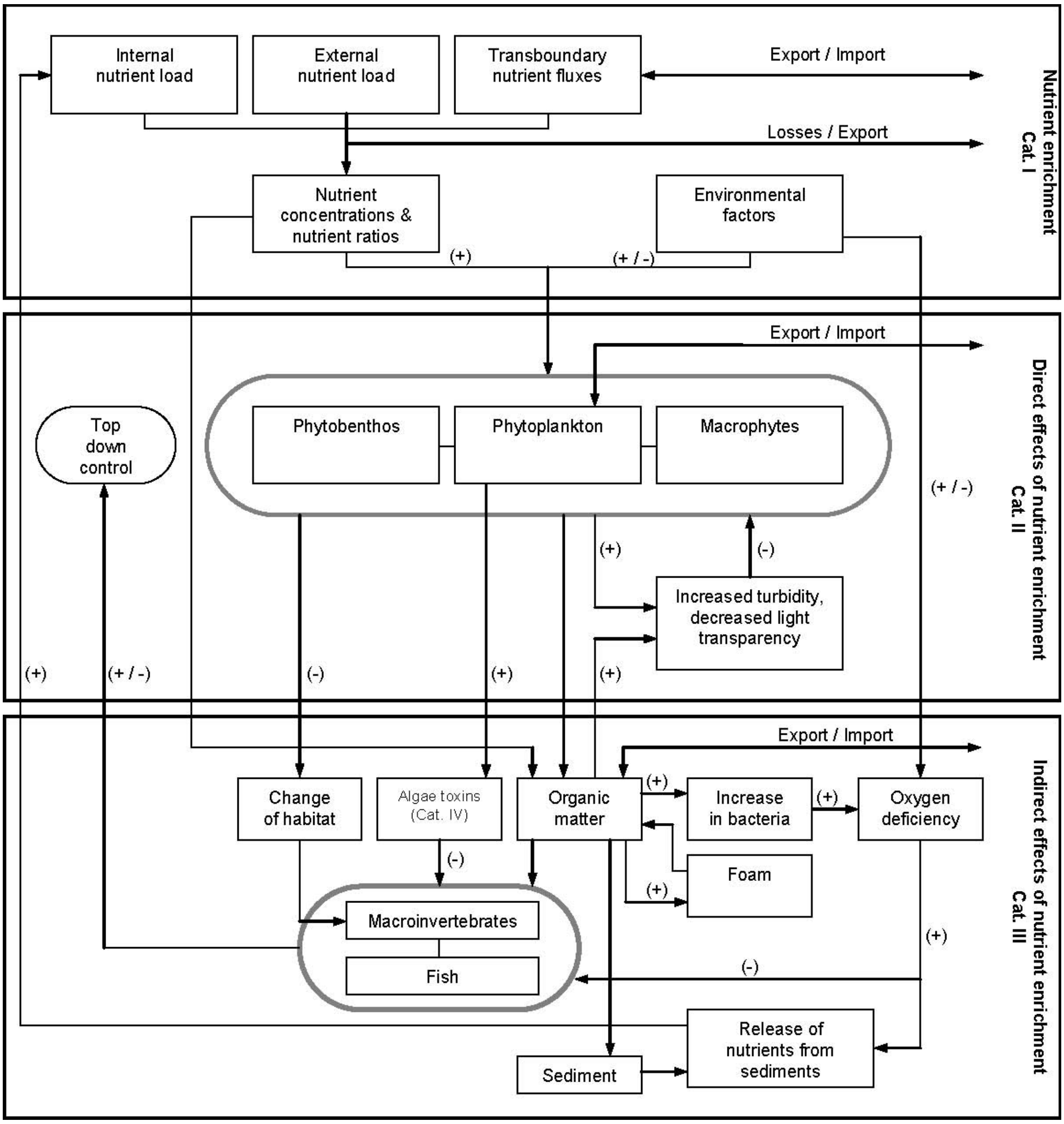
The objective, under the Common Implementation Strategy of the Water Framework Directive and the European Marine Strategy is to provide guidance on:

* the harmonisation of assessment methodologies and criteria for agreed eutrophication elements/ parameters/ indicators for rivers, lakes, transitional, coastal and marine waters;
* the use of type-specific objectives for biological and general physico-chemical elements
* the co-ordination of monitoring and reporting.

The document provides a **conceptual framework for eutrophication** (causes, effects, interactions …), based closely on that of OSPAR, and confirms that the definition of eutrophication given by the UWWT Directive is confirmed as valid and applicable:

"The enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned."

Conceptual framework for understanding eutrophication



General conceptual framework to assess eutrophication in all categories of surface waters.
'+' indicate enhancement, '-' indicate reduction. Round boxes indicate biological quality elements of WFD.

The document further **clarifies the term "eutrophic"** as referring to *"when the natural trophic status (including the biology) is out of balance because of anthropogenic interventions … Water bodies that fail to achieve Good Ecological Status due to these effects of human induced nutrient enrichment can be considered to be eutrophic"*.

Ecosystem assessment

The Water Framework Directive clearly specifies that **eutrophication aspects of "Quality Status" should be assessed on the basis of observed changes in the biological factors in the aquatic ecosystem**: changes or disturbances in ecosystem balance, biological populations, etc, and not simply on the basis of nutrient concentrations.

This document confirms that in order to assess eutrophication, nutrient concentrations and also all other environmental factors/elements that influence eutrophication should be taken into account, in particular light availability/turbidity, hydrodynamic conditions, temperature, etc. Nutrient concentrations alone should not result in "Poor" or "Moderate Quality" status classification, unless assessment of the biological factors indicates either that the nutrient levels are resulting in ecological disturbance, or that they are likely to do so.

Existing Directives and the Water Framework Directive

The correspondence between the requirements of the three Directives (Water Framework UWWT and Nitrates) and OSPAR are specified, as in the table below.

	Classification		Area concerned
Water Framework Directive 2000/60	Water body failing to achieve "Good Quality" status – or risk of deterioration – because of eutrophication related biological quality		River basin
	"Poor Quality" or "Bad Quality" status	"Moderate Quality" status	
	Major or severe change in biological communities	Moderate change in ecosystem: biomass, composition	
Urban Waste Water Treatment Directive 1991/271	Designation as "Sensitive Area" is required		Catchment of sensitive area
	"eutrophic"	"may become eutrophic in the near future"	
Nitrates Directive 1991/676	Polluted Water		Designation as Nitrate "Vulnerable Zone" is required
OSPAR	Problem Area		Not applicable

In particular, this confirms that **any water body failing to achieve "Good Quality" status under the Water Framework Directive, or at risk of deterioration, where this is related to nutrient inputs and eutrophication, should be designated a "Sensitive Area" under the UWWT Directive 1991/271**. See elsewhere in this SCOPE Newsletter for implementation of this in Scotland.

The Guidance Document refers to **European Court of Justice case law regarding the designation of "Sensitive Areas"** (C-208/02 against France, see SCOPE Newsletter n°55), recalling the "*Need to **decouple duty to designate sensitive areas from whether or not agglomerations with more than 10,000 population equivalents exist in the catchment***" and that for designation "*it is not important to define what percentage of pollution goes from urban waste water discharges or from agricultural pollution since both of them may contribute to eutrophication … When urban wastewater discharges involve in combination to* *nitrate flows of agricultural origin, Member States have to designate water body in question as being as a sensitive area in accordance with the directive 91/271/EEC. The significance of a nutrient loading to a water body should be not only importance of the percentage of that nutrient input but also of the absolute amount of nutrient in tonnes. The decision of its importance in the overall nutrient budget has to be taken on case-by-case basis."*

Minimum benchmark

The document indicates that: *"the **interpretation of the European Court of Justice must be used as minimum requirement** for the level of protection in environmental laws of the European Communities. The interpretation of terms and criteria in this and related judgements must be used as benchmarks for any assessment method applied under any EC Directive applicable to eutrophication. In particular, the outcome of the intercalibration exercise and the guidance provided by this document in relation to the WFD classification must meet, at least, the obligations that can be derived from this judgement."*

Significant undesirable disturbance

The Guidance Document clarifies the **definition of ecosystem changes which under the WFD would lead to classification as failing to achieve "Good Quality" status** for reasons of eutrophication. Accelerated algal or aquatic flora growth is considered compatible with "Good Quality" status, so long as no "Significant undesirable disturbances" result.

This Guidance Document will continue to be revised and improved, in particular taking into account conclusions of case studies currently underway.

See under "CIRCA" access via
http://ec.europa.eu/environment/water/water-framework/implementation.html

"Significant undesirable disturbances" which may result from accelerated growth of aquatic flora:
Causes the condition of other elements of aquatic flora in the ecosystem to be moderate or worse (e.g. as a result of decreased light availability due to increased turbidity & shading)
Causes the condition of benthic invertebrate fauna to be moderate or worse (e.g. as a result of increased sedimentation of organic matter; oxygen deficiency; release of hydrogen sulphide; changes in habitat availability)
Causes the condition of fish fauna to be moderate or worse (e.g. as a result of oxygen deficiency; release of hydrogen sulphide; changes in habitat availability)
Compromises the achievement of the objectives of a Protected Area for economically significant species (e.g. as a result of accumulation of toxins in shellfish)
Compromises the achievement of objectives for a Natura 2000 Protected Area
Compromises the achievement of objectives for a Drinking Water Protected Area (e.g. as a result of disturbances to the quality of water)
Compromises the achievement of objectives for other protected areas, e.g. bathing water.
Causes a change that is harmful to human health (e.g. shellfish poisoning; toxins from algal blooms in water bodies used for recreation or drinking water)
Causes a significant impairment of, or interference with, amenities and other legitimate uses of the environment (e.g. impairment of fisheries)
Causes significant damage to material property

France

P-removal in small sewage works

The French Ministry for Agriculture, Food, Fisheries and Rural Affairs has published a short technical guide (50 pages) on phosphorus removal in small sewage works, developed for local technicians and decision makers. This is of relevance in the current context of the EU Water Framework Directive requirements to ensure phosphorus removal in small sewage works discharging into potentially eutrophication sensitive waters.

The report, by CEMAGREF (French State agricultural and rural technology research institute), is based on a 2002 survey which obtained responses from operators of 57 sewage works fitted with phosphorus removal, most of which were < 20,000 pe (range 500 – 77,000 pe).

It is indicated that around one third of phosphates generated in France are in sewage, with two thirds coming from agriculture, industry and natural sources.

The EU Urban Waste Water Treatment Directive 1991/271 requires phosphorus removal from all sewage works serving agglomerations (towns or groups of villages) of more than 10,000 pe (including where this means several smaller sewage works serving a group of villages) discharging into potentially eutrophication sensitive waters. French legislation (1996) further requires "appropriate" treatment for all urban waste water, so that phosphorus removal is often required by local permit regulators for smaller sewage works (2,000 pe) discharging into potentially nutrient sensitive waters.

Combined biological and chemical phosphorus removal

The Technical Guide summaries and explains in simple terms the chemistry of phosphorus and phosphates in waste waters, analysis techniques and the mechanisms of biological and chemical phosphorus removal. The different factors affecting biological phosphorus removal performance are examined: bacteria types, available organic carbon, pH, temperature, ions (calcium, magnesium, potassium), sludge ageing, metals (copper, zinc, heavy metals which can affect phosphorus metabolising bacteria), and oxygen balance (oxygen and nitrate in the anaerobic zone). Iron, aluminium and calcium reagents for chemical phosphorus removal are presented. The dimensioning and management of biological and chemical phosphorus removal installations are examined, including reagent handling and sludge production.

Cost guidance

The Technical Guide concludes that **biological phosphorus removal offers lower costs** (no reagent purchase, little additional sludge production), whereas chemical phosphorus removal will increase sludge production by approximately +20%. However, biological phosphorus removal only poses difficulties to achieve reliable P-removal performance in small sewage works. **The Guide therefore recommends combined biological + chemical P-removal, which enables reduced reagent consumption and sludge production (+10%) and reliable P-removal**, but with the condition that good management is necessary to optimise chemical reagent dosing as a function of the effective biological P-removal being achieved.

The experience of the survey sewage works operators indicates that biological P-removal works were achieving 60 – 70% phosphorus removal (but dropping to 30 - 50% during rainy weather because of rainwater dilution of inflows), and combined biological + chemical P-removal works 90% P-removal (discharge concentration 1.3 mgP/l).

Cost estimates are presented, including investment and operating costs. The Guide concludes that, at a 50% investment subsidy level, the additional upstream anaerobic tank necessary for combined biological-chemical P-removal (compared to chemical treatment only) will offer a 5-year payback for a 5,000 pe wwtp, deteriorating to 7 years for a 2,500 pe wwtp. With a 20% only investment subsidy, the payback time for the anaerobic tank for a 5,000 pe wwtp would increase to 12 years. The choice of P-removal technology must also take into account the requirement for closer process management where biological treatment or combined treatment is installed.

« Traitement du phosphore dans les petites stations d'épuration à boues actives », Ministère de l'Agriculture, de l'Alimentation, de la Pêche et des Affaires rurales, FNDAE n°29, Document Technique, ISBN 2-11-0928565-5, 2002, 50 pages, in French.

G. Deronzier, J-M. Coubert, CEMAGREF, Unité de Recherche QHAN, Parc de Tourvoie, BP44, 92163 Antony Cédex, France. http://www.cemagref.fr/Informations/Produits/Editions/Eau/04-0073.htm

Nutrients and ecosystems

Baltic Sea

Eutrophication phase shift in the Greifswalder Bodden bay

Significant inputs of inorganic nutrients to the Greifswalder Bodden coastal bay in the Southern Baltic in the 1950's – 1980's led to phytoplankton development, and so to a loss of macrophytes. Within 30 years, macrophyte cover of the seabed fell from 90% to 15%. Although nutrient loads have now been considerably reduced (50% decrease in phosphate, 40% for nitrate), there is no sign of ecosystem recovery, and in particular of macrophyte recolonisation.

The Greifswalder Bodden, on the German Baltic coast, is a shallow bay of surface 510 km^2 and average depth 5.8 m. Urban and agricultural nutrient inputs between 1950 and 1980 led to eutrophication, with increased pelagic productivity (water column algae) resulting in increased turbidity, and loss of light for macrophytes. This paper is based on a variety of monitoring data sources. Light penetration of the water column and depth of the growing zone are shown to have decreased markedly, with macrophytes showing to be dependent on clear water.

From the 1990's, nutrient loads, and also concentrations in the bay, were considerably reduced. Consequently, This resulted in lower chlorophyll concentrations (algae), and in particular in reduced summer blooms with chlorophyll concentrations staying nearly constant over the growing period. However, Secchi depths (water transparency) during the summer period did not improve and even deteriorated.

Cyanobacteria

Summer algal development is now dominated by blue-greens (cyanobacteria), probably favoured by the shift in nutrient ratios resulting from the relatively greater reduction in phosphate concentrations compared to nitrates. This cyanobacteria dominance contributes to turbidity.

Another major cause of turbidity is the **resuspension of particulate matter from the sea bed**, now no longer held in place by macrophyte beds, caused by wind, boats and water movements. Macrophytes, when present, reduce turbidity both by holding sediment down with their roots, and by acting as a sediment trap in the water. Macrophytes also limit internal cycling of nutrients from sediments into the water column, by root uptake and retention.

Phase shift

The loss of macrophytes therefore represents a phase shift in the eutrophication status of the bay, comparable to those described for shallow lakes (stable states, see *Scope Newsletter n°29*). In the absence of macrophytes, sediment resuspension leads to turbidity which in turn prevents macrophyte recovery. Without macrophytes, nutrient recycling from the sediments, and the absence of macrophyte competition, enable algal blooms dominated by cyanobacteria.

Ecosystem restoration measures which have proven successful in lakes, such as reducing fish populations (to allow zooplankton grazers of algae to develop), removing sediments or treating sediments to prevent nutrient mobilisation, are not feasible in an open coastal bay : fish movements cannot be limited, marine grazers are less effective than daphnia in freshwater, particularly as regards cycanobacteria, sediment removal or treatment would be difficult over such a large open area.

The author indicates that **further work is necessary** to better understand similarities and differences between phase shifts in brackish and in freshwater ecosystems. Because of the difficulty in restoring marine systems, priority must be accorded to protecting water systems which are as yet in good ecological condition.

"Eutrophication, phase shift, the delay and the potential return in the Greifswalder Bodden, Baltic Sea", Aquatic Sciences 67 (2005), pages 372-381
http://www.eawag.ch/publications/aquatic_sciences/d_index.html

D. Munkes, Leibnitz Institute for Marine Science, Düsterbrooker Weg 20, D-24105 Kiel, Germany
bmunkes@ifm-geomar.de

Arkansas
Nutrients in a waste water affected stream

Columbia Hollow is a 3rd order stream with measured flow rates of 14 – 162 litres/second at the study reach in the Ozark Plateaus of Arkansas. This 3rd order stream receives effluent discharge from a small wastewater treatment plant (wwtp) in Decatur, Arkansas treating waste water (secondary treatment, without nutrient removal) from a community with a population of ca. 1,000 and from a poultry processing factory. The authors used "spiralling methods" to evaluate the transport and net retention of nutrients in the stream, based on comparing downstream declines in nutrient concentrations with estimated dilution calculated using downstream changes in chloride ion concentrations.

Seven sites were sampled monthly for 8 months between June 1999 and February 2000. The effluent discharge represented 17 – 83% of measured stream flow downstream from the discharge point. Chloride ion concentration in the stream increased from 5.8 – 20.3 mg/l immediately upstream of the wwtp discharge to 23.2 – 67.9 mg/l immediately downstream. In the first 2.7 km downstream of the discharge, dilution of the stream water by inflows was estimated as 16 – 41%. Soluble phosphate upstream of the Decatur discharge ranged from 0.06 – 0.17 mg SRP/l, and would be considered moderately enriched with sufficient soluble phosphate concentration to saturate algal growth. Soluble phosphate concentrations were then further increased up to 50x by the wwtp discharge, and the maximum observed concentration downstream from the wwtp discharge was almost 10 mg SRP/l. Nitrate concentrations were often not changed by the wwtp discharge, whereas ammonium concentrations were elevated compared to upstream conditions.

Nutrient retention and release

After correcting for dilution, soluble phosphate concentration decreases were observed at points downstream of the discharge on 6 of the sampling dates, but increases were observed on the other 2 dates (December and January, coinciding with the lowest input levels from the wwtp). On the dates when the stream was retaining phosphate, net nutrient uptake lengths (Snet) were estimated to be 7 – 13 km (approximate stream length downstream of discharge before approximately 63% of soluble phosphate would uptake from the water column). When wwtp inputs were low, the stream reach released previously stored phosphate back into the water column. Nitrogen showed a progressive increase in nitrate concentration downstream of the discharge point, as ammonium in the discharge was converted to nitrate, and overall no net retention or removal of nitrogen (total dissolved N) occurred in the study reach.

The authors conclude that nutrient cycling in the stream varied between conditions characterized by (1) very long nutrient uptake lengths, (2) no net nutrient uptake, or (3) net release of previously retained phosphorus, and thus that the overall nutrient retention capacity of such an effluent-dominated small stream is minimal. They also note that the relatively high point source loading has created unusual nutrient cycling conditions including a phosphorus exchange mechanism which helps maintain high soluble phosphate concentrations and a distorted nitrogen cycle, so that instead of acting as a nutrient sink the stream acts as a short-term phosphorus storage zone and a nitrogen transformer.

"Nutrient retention in a point-source-enriched stream"
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B. Haggard, Biological and Agricultural Engineering Department, University of Arkansas, 203 Engineering Hall, Fayetteville, Arkansas 72701 USA haggard@uark.edu *; E. Stanley, Centre for Limnology, University of Wisconsin, Madison, Wisconsin 53706 USA,* ehstanley@wisc.edu *; D. Storm, Biosystems and Agricultural Engineering Department, Oklahoma State University, Stillwater, Oklahoma 74078 USA,* dstorm@okstate.edu

Phosphorus and nitrogen

Sources of nutrients to European waters

The European Environment Agency (EEA) report n°7 (2005) "Source apportionment of nitrogen and phosphorus inputs into the aquatic environment" presents a 10-year update on available information on what proportion of N and P inputs to surface waters come from agriculture, point sources (sewage discharges), industry and background. Data at the EU level, national levels, selected river basin and seas are presented, as well as time trends. The question of nutrients from diffuse settlements is addressed (households not connected to sewage works).

The report is based on data collected by international organisations and commissions, national and regional studies and scientific research projects (eg. Moneris see SCOPE Newsletters n°58 and n°37 and EuroHARP see SCOPE Newsletter n°53). The report updates the previous EEA report n° 4 (1999) "Nutrients in European Ecosystems" (see Scope Newsletter n°44).

For nitrogen (N), agricultural run-off is the principal source, contributing 50-80% of loads to most surface waters. For phosphorus (P), point sources (municipal sewage works, industry) are often the majority source, but as sewage P-removal has been implemented in the last 15 years, agriculture is now sometimes the most important phosphorus source (for example: in Northern Ireland, Germany, the Baltic, the Elbe river basin …).

Variations

Source apportionment of nutrients varies considerably between regions. The Baltic Sea catchment, for example, shows only 25% of phosphorus from point sources (0.07 kgP/ha), whereas the North Sea shows 54% from point sources (0.5 kgP/ha). An apportionment is not available for the Black Sea, but the Danube basin shows point sources (of which 78% are municipal sewage works, the remainder being industrial and agricultural point sources) as slightly less important than diffuse sources (agriculture + background).

For the 10 large river catchments with apportionment data shown, agriculture and background sources are around half or more of phosphorus sources in 5 out of 10 cases. For smaller river catchments, six small Baltic catchments results are shown, with diffuse sources being considerably more important than point sources of phosphorus in all but one case. Similarly, diffuse sources are considerably more important than point sources of phosphorus in 7 out of 8 small river basins (from 8 EU states) presented from the EuroHarp project. Diffuse sources are also significantly more important than point sources in 5 out of 7 large lake catchments presented, approximately equal in one (Arreso, Denmark) and somewhat lower than point sources in one (Lake Geneva).

Diffuse settlements

The report addresses the issue of scattered dwellings, where households are not connected to sewage works. This source of nitrogen is generally smaller than background sources. For phosphorus, the report concludes that this source is "small, usually of the same order of magnitude as background loss, but in some catchments is not insignificant".

"Source apportionment of nitrogen and phosphorus inputs into the aquatic environment", European Environment Agency (EEA) report no. 7/2005, prepared by NERI Denmark.
http://reports.eea.europa.eu/eea_report_2005_7/en