SCOPE NEWSLETTER

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WATER POLICY

NUTRIENT MANAGEMENT

AQUATIC ECOSYSTEMS

International Conference
'From Nutrient removal to recovery'
Amsterdam, 2 - 4 October 2002

Organised by the International Water Association (IWA) in co-operation with the Netherlands Association on Water Management (NVA) and Aquatech Amsterdam 2002

- Societal and Economical Impacts of Wastewater Nutrient Removal and Recovery.
- Re-use of nutrients and wastewater in agriculture
- Nutrient recovery from concentrated liquid
- Nutrient recovery form diluted wastewater
- Improved/Advanced Biological Nutrient Removal
- Alternative Sanitation and Source Separation
- Nutrient (N,P,S) recovery and re-use technologies
- Centralised and decentralised techniques
- Hygienic aspects of re-use of nutrients
- Public perception of nutrient re-use
- Quantification and evaluation of sustainability aspects of nutrient recovery
- Modelling tools to implement nutrient recovery and re-use technologies
- Life cycle analysis of nutrient recovery technologies
- Novel biological, physical or chemical techniques for nutrient removal

http://www.nva.net/agenda/conference200210_2-4.htm
and http://www.iawq.org.uk/template.cfm?name=nutrient_removal

The SCOPE Newsletter is produced by the CENTRE EUROPEEN D'ETUDES DES POLYPHOSPHATES, the phosphate industry's reserach 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 reader are invited on all subjects concerning phosphates, detergents, sewage treatment and the environment. You are invited to submit scientific papers for review.

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WATER POLICY

EUROPEAN UNION

Member States under attack for failure to implement EU water policy

Both the Commission and the EU Parliament seem determined to accelerate effective implementation of existing water quality directives. The Commission has published an assessment of implementation of the Urban Waste Water Treatment Directive 91/271, criticising many Member States for failure to adequately designate "sensitive areas" and for failure to implement adequate sewage treatment. The Commission has also initiated European Court procedures against a number of Member States for failure to implement adequately this Directive and/or the Nitrates Directive 91/676, the Bathing Water Directive 1976/160, the Shellfish Water Directive 1979/923/68 and the Drinking Water Directive 1998/83, the relevant obligations of all of which are implicitly maintained in the Water Framework Directive. Meanwhile, the EU Parliament has reacted by announcing a draft resolution criticising delays in implementation of the EU Waste Water Treatment Directive.

The Commission launched an active communications campaign addressing implementation of the Urban Waste Water Treatment Directive 91/271 with a press seminar presented as "Name and Shame" in March 2001. The accompanying press release stated that *"the vast majority of Member States show major delays and shortcomings in implementation. 37 large cities are still discharging untreated waste water into the environment, and many others are discharging large quantities of effluent after inadequate treatment"*.

Sewage "name and shame"

In a reply to a European Parliamentary question concerning non-compliance with the Urban Waste Water Treatment Directive, in July 2001, Environment Commissioner Mrs Wallström confirmed that ***"the Commission will not hesitate to take all the necessary steps … to ensure full compliance"***, and by the end of 2001 the Commission had sent "Reasoned Opinions" to seven Member States concerning failure to implement this Directive. This is the Commission's last formal step before a European Court of Justice procedure.

Concerning the Directive's requirements for nutrient removal from sewage, the Commission states that **Member States have designated Sensitive Areas in a *"restrictive fashion"***, not taking account of the sensitivity of waters downstream from the immediate discharge point. **London, Paris, Athens and Dublin** are cited as amongst major cities where incomplete designation of Sensitive Areas has resulted in nutrient removal not being planned where it is in fact required. This is coherent with the European Environment Agency report on marine eutrophication (see Scope Newsletter n°44) which identifies the **Seine** as a major contributor of phosphorus and nitrogen to the Channel sea area.

Nutrient removal

The Commission's documents show that 67% of the 1017 agglomerations of more than 10,000 inhabitants discharging into Sensitive Areas in the 11 Member States which provided data were not providing adequate nutrient removal. Only Austria and Denmark were close to compliance with the December 1998 deadline for implementing nutrient removal. France and Germany had not provided any information whatsoever with regard to the treatment of their urban waste water at 31 December 1998, a situation described by environment Commissioner Margot Wallström as *"unconstructive … a barrier to transparency and proper information to the public"*.

The **EU Parliament has also reacted to the delays in implementation of the EU Waste Water Treatment Directive, with a resolution voted on 13th March 2002 to underline the legally binding nature of the timetable of implementation deadlines in the Directive** and the responsibility of Member States to enact these.

The motion voted emphasises that *"are major shortcomings in the implementation of the urban waste water Directive due to the failure of Member States to enforce the more than ten year-old Directive, whereas the urban waste water Directive is a cornerstone of European water legislation. ... underlines the importance of the legally binding timetable of the urban waste water Directive and stresses the importance of ensuring that the, in some cases, already considerable delay of the Member States in implementing the Directive is not further added to"*

Inadequate definition of "sensitive areas"

Commission criticism covers nearly all Member States. Germany has not classified most of its **Danube basin** area as sensitive, which is inconsistent with reducing nutrient loads to this river and to the Black Sea, as agreed by the Danube Commission. In **Spain,** the Commission estimates that there are 44 areas which have not at present been designated as Sensitive, but which should be so.

For **France**, also, the Commission identifies a number of areas which have not been designated as sensitive but should be so, in particular the Seine river basin in which Paris and other large cities are situated, rivers and coastal waters in Brittany, areas of the Vendée, the Mediterranean coastal lagoon of Thau … France has also failed to provide information concerning conformity of its sewage works.

The **Wallonia region of Belgium** is criticised for not only failing to have installed adequate, or in some cases any, sewage treatment (since late 2000, one third of Brussel's sewage receives secondary treatment, but the sewage works to treat the remainder is still only at the planning stage!), but also for failing to identify as Sensitive Areas rivers which flow into the Flanders area (which is designated as Sensitive).

Italy has failed to designate as Sensitive the **Po river tributaries** (despite the Po being historically concerned by problematic eutrophication, in particular as a result of agricultural loadings), meaning that the cities of Milan and Turin should be equipped with nutrient removal. Indeed, in December 2001, the Commission initiated a European Court action against Italy for inadequate treatment of Milan's sewage, because discharge is into the Po river which flows, 300 km downstream, into the (designated) nutrient Sensitive Area of the Po Estuary.

The **UK** designated 36 sensitive areas in 1994 and a further 40 in 1998. However, even after this second "wave" of designations, many estuaries and coastal waters which the Commission considers as Sensitive are not designated, including major estuaries such as the **Thames** and Humber, as well as certain loughs and estuaries in Northern Ireland including Lough Foyle, Carlingford and Belfast Loughs and the Bann Estuary.

This is consistent with the report published by WWF concerning eutrophication of UK estuaries, see this Newsletter. Of the 207 conurbations in already designated sensitive areas in the UK, only 19 were had nutrient removal installed in their sewage works in compliance with the Urban Waste Water Treatment Directive by 1998. On top of this backlog will be agglomerations in the areas which the Commission considers should be designated sensitive but have not been to date, which includes cities such as London, Leeds, Hull and Southampton.

In **Austria**, which considered that none of its territory was Sensitive, the Commission identifies 3 rivers as requiring designation, as well as several areas which are in the Rhine, Elbe or German lake catchment areas – but in this case nearly all the agglomerations concerned already have nutrient removal installed.

This criticism for inadequate designation of Sensitive Areas is reiterated by the EU Parliament motion (see above) which *"Underlines that several Member States have been restrictive and unhurried in their designation of sensitive areas" and "Urges the Commission to initiate infringement procedures in cases where criteria for designating sensitive areas have not been respected or ignored"*

European Court condemns Member States

The Commission is also acting to enforce implementation of the Urban Waste Water Treatment Directive and other water protection Directives (Nitrates Directive, Bathing Water Directive, Shellfish Water Directive, Drinking Water Directive …) through European Court actions against Member States.

On 7 December 2000 the European Court of Justice (case C 1999/069) judged that **the UK had not adequately implemented the EU Nitrates Directive 91/676**, by failing to identify adequately nitrate polluted waters and to designate nitrate "Vulnerable Zones".

The UK had in fact omitted from consideration all surface and ground waters not being used for the extraction of drinking water, thus inappropriately limiting the areas. Since the decision, designation processes have been re-launched in England, Scotland and Wales. This could lead to around 80% of England being designated.

In October 2001, the Commission followed up the Court decision by a "Letter of Formal Notice" reminding the UK of its obligation to complete the identification of all nitrate polluted waters. The Commission's press release recalls that the Commission has power to act against a Member State which does not comply with a European Court judgement, including the possibility to impose financial penalties.

On 8 November 2001, the European Court of Justice again condemned a Member State for failure to implement the Nitrates Directive 91/676 – this time Italy (case C-127/1999). This follows a 1999 judgement that Italy had failed to designate nitrate Vulnerable Zones. The 2001 judgement states that Italy has failed to establish the action programmes for the protection of waters against agricultural nitrate pollution required by the Directive, failed to carry out fully the required monitoring, and failed to provide adequate reporting to the Commission. The judgement however also criticised the lack of case-specific evidence and information supplied by the Commission.

Actions have also been launched against **Finland, Portugal and Luxembourg** for non-respect of the Nitrates Directive.

On 8th March 2001, **the European Court ruled against France for failure to comply with the 50 mg/l nitrates limit in drinking water** in Brittany. Early 2002, the Commission followed this up with a Letter for Forma Notice (a first written warning) for not complying with this judgement, considering that no effective measures have been taken to reduce this nitrate pollution problem.

On 13 November 2001, the European Court also condemned the UK for failing to meet minimum water quality standards at over 10% of designated bathing beaches in 1996 and 1997 **(Quality of Bathing Water Directive 76/160)**. The UK acknowledged the breach, and indicated that compliance has been better since 1998.

On 24th July, the Commission also began actions, by sending formal warning letters (Reasoned Opinion) against **France** and **Spain** for **breaches of standards set by the Drinking Water Directive (1980/778)** and against a number of countries for failing to transpose into national legislation by the 25/12/2000 deadline the updating of this Directive (1998/83)

The same day, the Commission announced action against **France, Belgium and Greece for non-respect of the Urban Waste Water Treatment Directive.** France is targeted for having failed to designate as "Sensitive Areas" various nutrient effected bodies of water, and for failing to adequately treat sewage discharging into them. Belgium is late in designating "Sensitive Areas" and in installing sewage treatment, including for Brussels. Greece is faced by three actions, for failure to equip Athens' new sewage treatment plant with nutrient removal despite the nutrient affected state of the Gulf of Sarinokos, for failure to install nutrient removal in the Elefsina area, and for failure to designate the Thermaikos Gulf as a sensitive area.

On 22nd February 2002, the Commission issued a press release emphasising the various procedures launched against Member States for failure to comply with the Urban Waste Water Treatment Directive and other water quality Directives. As well as the actions indicated above, this announced referral to the European Court of **Belgium, France, Germany, Ireland, Luxembourg, Spain and the UK**. Belgium is stated to have not finalised transposition into legislation in Flanders or Wallonia of the updated 1998 Drinking Water Directive; France is pinpointed for not providing bathing water monitoring results for 1999, for polluting freshwater hydroelectric plant discharges into the Etang de Berre in contradiction to the Mediterranean Sea protection protocol and for failure to transpose the Drinking Water Directive; Germany's federal legislation, according to the Commission, fails to provide adequately for wastewater treatment monitoring; Ireland has failed to implement a pollution reduction programme to respect the Shellfish Water Directive; Luxembourg has failed to transpose Drinking Water Directive; Spain and the UK have also not finalised transposition of the Drinking Water Directive.

Portugal, on the other hand, has obtained the first ever sewage treatment derogation to be accorded under the Urban Waste Water Treatment Directive 91/271. This Directive states that the water treatment standards defined may be "relaxed" in specific cases where Member States designate waters as "less sensitive" to eutrophication and microbiological pollution. Portugal applied for a derogation from the Commission for the Estoril conurbation (720,000 population equivalent) on the Atlantic coast. The Commission's decision (2001/720/EC) allows discharge to be subject to primary treatment only, plus disinfection during the bathing season. The Commission decision indicates that the emission point is situated a long way from the bathing waters, and that this coastal zone offers "exceptional" marine conditions "some of the most favourable of European coastal waters for the dilution and dispersion of pollutants". ENDS Daily (12/10/01) indicates that two other requests for derogations re currently being examined by the Commission, both concerning small conurbations.

Accession States

Concerning **Accession Countries**, the Commission estimates that implementation of the Waste Water Treatment Directive will cost in total around €30 billion but that good progress has been made in preparing the financial strategies to achieve this. As regards nutrient emissions, implementation in the Accession countries is expected to reduce these by 40-50% overall from current levels.

To date, transitional arrangements regarding implementation of this Directive have been negotiated and agreed with the following countries (in brackets, the deadline accorded for Directive implementation): Cyprus (2012), Czech Republic (2010), Estonia (2010), Hungary (2015), Latvia (2015), Lithuania (2009), Poland (2015), Slovenia (2015).

EU sewage treatment "name and shame" press release
http://europa.eu.int/comm/environment/nsf/index.htm

EU water pollution fact sheets page
http://europa.eu.int/scadplus/leg/en/s15005.htm

EU DG Environment press releases
http://europa.eu.int/comm/environment/press/index.htm

Information about implementation of EU environmental Directives in Accession States
http://europa.eu.int/comm/environment/enlarg/home.htm

EU Parliament Resolution:
http://www.europarl.eu.int/plenary/default_en.htm
then go to "Texts adopted by Parliament" -> "By date" -> March 13th 2002

MARINE EUTROPHICATION

Nitrogen discharges remain problematic

Both the EEA (European Environment Agency) and HELCOM (the Baltic Marine Environment Protection Commission) have published recently overview reports assessing progress on addressing marine eutrophication. These reports indicate that objectives for phosphorus emission reductions have been widely achieved (up to 50% reductions) through improved sewage treatment (installation of P-removal). Diffuse nitrogen emissions, on the other hand, have not been successfully reduced or have

even increased. Diffuse agricultural phosphorus releases from agriculture in West European Baltic countries have also increased, despite reductions in phosphate fertiliser applications.

The EEA report emphasises that inadequate data was available for the Mediterranean, the Bay of Biscay and the Iberian Atlantic Coast. In fact, effective monitoring data is indicated as available for the North Sea, Skagerrak, Kattegat, Belt Sea, Baltic open sea, Gulf of Riga, Gulf of Finland and Gulf of Bothnia areas ; partial data are available for the Channel, North Atlantic, Iceland coast, Celtic Sea and Baltic coastal areas ; but " almost no measurements on eutrophication variables " are available for the Bay of Biscay, Iberian coast and Mediterranean Sea. **This confirms previous reports that marine eutrophication science and policy in Europe is centred on the North Sea areas and is not necessarily relevant to other marine ecosystems** (see eg. Vidal, Duarte and Sanchez “Coastal eutrophication research in Europe: progress and inbalances”, Marine Pollution Bulletin 1999).

The report indicates that eutrophication in the Mediterranean is limited to certain specific coastal areas, and discharge of untreated sewage, in addition to agricultural run-off and fish farming are the main nutrient sources. **Only 72% of the 290 major towns on the Mediterranean coast have secondary sewage treatment to date, and even fewer operate nutrient removal.**

In the North Sea, there has been a significant reduction in phosphorus loadings since the 1980’s, but **no reduction in nitrogen loadings, primarily because of agricultural releases**. The drop in phosphorus loadings has continued with a 20% fall over the 1990-1996 period, resulting from improved sewage treatment.

Ecosystem effects

The report indicates that there are **no symptoms of eutrophication for the marine areas of the Irish coast, the North Atlantic coasts of the Shetland Isles and Norway**. In the remaining areas of the Channel, North Sea and Skagerrak, nutrient levels are closely related to the localisation of river inflows, and nutrient enrichment appears mainly in coastal areas near river outlets and in estuaries. Nitrogen and phosphate levels in the Baltic appear to vary considerably with aquatic biological denitrification processes and with phosphorus adsorbtion into/release from sediments (depending on the oxygenation or not of the sea bottom).

Chlorophyll-*a* concentrations, an indicator of algal development, showed a slight correlation with winter concentrations in the marine waters, even in the low range of 0 – 50 µMN. **Chlorophyll levels were not correlated with phosphorus concentrations or with any other variable**. Sea bottom oxygen concentrations were not correlated to nutrient or chlorophyll levels, but only to the vertical stratification of the water column (degree of mixing), and possibly to the related sedimentation rates.

The report concludes that ***“The main source of nitrogen is run-off from agricultural land brought to the sea via rivers”*** and emphasises the need for more thorough data collection.

Nitrogen challenge in Baltic

In the Baltic Sea, nitrogen loads have dropped very slightly, as a result of reductions of agricultural intensity in Eastern European countries. Phosphorus loads have been very significantly reduced, on the other hand. **The HELCOM target objective of a 50% reduction has been achieved for phosphorus from point sources, in particular through installation of sewage treatment with P-removal**, so that diffuse sources and in particular agriculture are now the main cause of concern. According to HELCOM’s 2001 report " Most of the nitrogen discharges are coming from agriculture. The challenge is to gain control over diffuse sources within the agricultural sector ".

HELCOM indicate that the 50% reduction for phosphorus from all sources has been achieved by almost all Baltic Sea countries, but that most did not achieve this for nitrogen. Reductions in the 1990’s were lower for Finland, Western Germany, Sweden and Denmark, because they had already achieved point source reductions through nutrient-removal in sewage works in the 70’s and 80’s.

Sweden and Finland are estimated to be now achieving an overall 90% removal of phosphates from municipal wastewater, and had by 1995 the lowest per inhabitant load of phosphorus from municipal sources at <0.2 kgP/inhabitant/year after sewage treatment.

Agricultural phosphorus losses did not fall in Sweden, Germany and Finland, despite lower fertiliser application rates, probably because of high soil P levels. Agricultural nitrogen losses have been reduced in all of the Transition Countries except Poland, but this is linked to 30-40% drop in agricultural production.

A HELCOM press release in March 2002 confirmed that pollution from the agricultural sector is ***"considered to be the main reason for eutrophication".***

"Eutrophication in Europe's coastal waters" European Environment Agency Topic Report 7/2001, Copenhagen, 2001.
European Environment Agency
http://www.eea.eu.int eea@eea.eu.int

" Working Document on Evaluation of the Implementation of the 1988 Ministerial Declaration regarding Nutrient Load Reductions ", Helsinki Commission, Katajanokanlaituri 6 B, FIN-00160 Helsinki, Finland, August 2001 helcom@helcom.fi

HELCOM press release, 7th March 2002 " The 2002 Helsinki Commission Meeting "
http://www.helcom.fi/helcom/pressroom/pressreleases/07032002.html

EUROPEAN UNION

Developments in EU water policy and implementation

EU water policy is currently in a phase of rapid development, with the definition of a Recommendation concerning coastal zone management and the start of the implementation process of the Water Framework Directive 2000/60. The latter involves a considerable body of consultative and scientific work to define the practical meaning and application of the Directive's obligation for Member States to achieve "good ecological quality" in all surface waters (except for specific exceptions) by 2015: how should this ecological status be defined and measured in the field ?

The **Water Framework Directive** provides extensive annexes outlining the criteria for assessing whether water bodies have achieved the required "good ecological quality". The Directive requires that objectives and action plans for achieving this quality status should be defined in the field on a catchment basin basis. However, these annexes specify the different criteria to be assessed, but do not generally give limit values or numerical objectives to be achieved. **Good ecological quality is defined as water quality such that the ecosystem functioning (eg. species variety and balance, compatibility with water usages …) do not differ significantly from the natural state.**

The Commission published in May 2001 **a strategic guidance document *"Common Strategy on the Implementation of the Water Framework Directive"***, with the aim of achieving a coherent and harmonious implementation across Europe, in particular where river basins cross national boundaries. This is the first time that an EU Directive has been accompanied by such an implementation guide. The Common Strategy establishes a series of expert and working groups to take forward various aspects of the Directive. The expert groups assist the European Commission in developing policies in areas that are not yet (or are inadequately) addressed in the text of the Directive, such as priority substances, groundwaters and reporting. The ten working groups each address specific technical issues, ranging from the typology of waters and defining 'heavily modified waters', to monitoring and the use of GIS. The working groups each have two lead institutions, at least one of which is a Member State, to take forward the initiative. The Common Strategy recognises that while there is significant expertise and experience of 'best practice' in the Member States, the Water Framework Directive requires extensive innovation in many areas (eg in defining "ecological status"). The objective is, therefore, to draw on experience to assist in this innovation, not necessarily to achieve standardisation across the EU, but to avoid duplication and promote integration.

Other important components of the Common Strategy include an **emphasis on capacity building, involvement of stakeholders and public awareness and the need to integrate implementation of the Directive with other legislation and policy areas.** The latter issue includes transitional arrangements (eg on reporting) for those Directives that are repealed by the framework Directive and integration with the remaining EU water Directives and policies - such as integrated product policy.

Coastal management and soil directive

In October 2001, the European Council adopted a Recommendation concerning **Integrated Coastal Zone Management (ICZM)**. At the time of going to print, this was pending final (2nd reading) approval by the European Parliament. This gives Member States five years to develop national strategies for coastal management, integrating land use and marine water protection, including international cooperation for regional waters, and information systems for monitoring and dissemination.

Also in October, the EU Commission (DG Environment) issued a **"Soil Protection Communication"**, intended as a consultation document to lay the foundations for a future "soil framework directive".

EU document "Common strategy on the implementation of the Water Framework Directive" download (WWF site)
http://www.panda.org/europe/freshwater/pdf/WFD-CSImpl.pdf

EU Commission's "Soil Protection Communication"
http://europa.eu.int/comm/environment/agriculture/pdf/soilpaper2.pdf

Common Position (Council-Commission, 13th December 2001) on Integrated Coastal Zone Management (ICZM), COM2000(547)final
http://europa.eu.int/eur-lex/en/com/cnc/2000/com2000_0547en01.pdf

UK

WWF calls for action to reverse coastal eutrophication

"Current policy is threatening and reducing biological diversity" in the UK's estuaries according to WWF UK. Nutrient levels in some UK tidal rivers and estuaries are up to 100x higher than levels officially recognised as problematic, posing a threat to marine habitats and species, including eelgrass meadows, seahorses, and different commercial fish species. Of Britain's 155 estuaries, only 20 still possess eelgrass beds of one hectare or more (a decline in 85% of estuaries since the 1920's). Important international conservation areas are threatened by loss of biodiversity. WWF suggests that the UK's eutrophication strategy has concentrated on fresh waters, ignoring estuaries and coastal waters, but that this is inconsistent with international commitments such as OSPAR. The particular threats of fish farming are also emphasised.

The WWF report indicates that phosphorus and nitrogen are the two key nutrients which can contribute to problems such as algal development, leading to turbidity and changes in biodiversity. Nitrogen is usually the critical "limiting" nutrient and there is some evidence that disproportionately reducing phosphorus inputs may increase the competitive advantage of some "undesirable" species. **Many estuary ecosystems may be sensitive to relatively small increases in nutrient levels.**

Symptoms of increased nutrient levels emphasised by WWF include growth of annual seaweeds, which can form thick mats of weed, and smother perennial plants such as kelp and eelgrasses. Floating algae (phytoplankton) and small surface algae (epiphytes on the surface of larger plants) can also develop, causing the water to become turbid, and preventing light from reaching depths where perennial plants grow. This rapid development of different plant forms can provide food, for example for sea snails which then are eaten by brent geese, but can also cause a change towards smaller phytoplankton species, which provide lower food value for fish.

Submerged eelgrass meadows are a very important ecosystem, in particular the subtidal species Sostera marina, providing shelter for species such as seahorses, pipefish, cuttlefish, and fish nursery areas for commercially valuable species such as bass. Eelgrass has declined massively in UK estuaries, and there is significant evidence that this is related to increased nutrient levels.
Many UK estuaries, which are nature conservation areas of international status (SACs and SPAs), are currently being deteriorated by eutrophication.

OSPAR commitments

In 1987, under OSPAR, the North Sea countries committed themselves to reduce nitrogen and phosphorus inputs to the sea "by the order of 50%". The UK has not implemented this commitment. In 1998, the "OSPAR Strategy to Combat Eutrophication" committed all parties including the UK to not only meet this 50% reduction target, but also to take further measures to ensure that by 2010 a healthy marine environment is achieved "where eutrophication does not occur".

WWF recommends that the UK now urgently address these commitments, which will inevitably have to be met in time, since the EU is a signatory of OSPAR and will ensure enforcement. WWF also suggests that **many estuaries should be designated as nutrient "sensitive areas" under the EU Urban Waste Water Treatment Directive 91/271 provisions**, which would then require 75% nutrient removal in sewage works. Many should also be designated as "nitrate vulnerable zones" under the EU nitrates directive 91/676.
WWF identifies as the actions required nutrient removal in sewage works, addressing agricultural nutrient pollution (reducing nitrogen loads to fields, restoring vegetation buffer zones alongside rivers), and rewilding of the land around lower estuary areas.

Specific action is also called for to limit nutrient releases from fish farming. Fish farming on the West and North coasts of Scotland are estimated to release the same levels of phosphorus as raw sewage from 9.4 million people, in an area where the ecosystem is particularly diverse and sensitive to nutrients.
The report emphasises that there are reasons for hope given the experience from Denmark which shows that when nutrient inputs to estuaries are reduced then important species, such as eelgrasses, and biodiversity in general slowly recover.

"Out of sight – out of mind – Marine eutrophication in the UK". Malcolm MacGarvin/ ModusVivendi for WWF UK, August 2001.
Report :
http://www.wwf-uk.org/filelibrary/pdf/nutrientoverview.pdf

List and map of affected estuaries :
http://www.wwf-uk.org/filelibrary/pdf/nutrientmap.pdf

NUTRIENT MANAGEMENT

FRANCE, UK, GERMANY

Nitrate emissions too high and increasing

The French Environment Institute (IFEN) has published a summary of analysis of ten year's figures for nutrient loads carried by France's rivers (the full data will also be available shortly). This estimates that the country's rivers carry each year some 646,000 tonnes of nitrogen (N), mainly as nitrate, into surrounding seas, along with 43,800 tonnes of phosphorus (P) and nearly ten million tonnes of sediment (averages for the last ten years). Trends are compared to the commitment made by OSPAR states, which include France, to reduce nutrient inputs to the North Sea by 50% from 1985 – 1995.

Figures over the last 10 years were analysed from 90 French rivers discharging either into the sea or into the transboundary Rhine river. River nutrient loads were calculated by comparing monitored concentrations with data for river flows. The authors note that this may induce considerable inaccuracies for the Mediterranean rivers such as the Rhône, in particular, where large loads of nutrients are carried in sediments related to short flood/high flow events.

Even in the Seine, which carries 85% of France's phosphate emissions to the Channel sea area, only 44% of this is soluble, showing **the importance of sediment phosphorus fixing mechanisms.**

The Institute's study shows a complete difference between trends for nitrates, and those for phosphorus. **Phosphorus emissions have been significantly reduced, as have ammonium emissions (in both cases, probably as a result of improved waste water treatment installation), whereas nitrate emissions have note fallen.**

Phosphorus emissions have fallen significantly, for example by around 50% 1990-2000 for the heavily populated Seine and Rhône rivers, although emissions have remained stable in the Loire (predominately agricultural). Total phosphorus emissions in 1999 at 375,000 tP/year were nonetheless considerably higher than the OSPAR target, of around 200,000 tP/y.

Nitrate emissions from the two main catchments flowing into the North Sea, the Seine and the Loire, are actually still increasing, leading the authors to state that *"an imaginable deadline for achieving the OSPAR objective cannot be given"*.

The nutrient emissions from North Brittany and Normandy are relatively high, reaching 33 KgN-NO_3/hectare/year and 2.5gP/inhabitant/day for Brittany, indicating the contribution from agriculture. The study results also show that **smaller rivers make a contribution which is signific ant** overall, and can be locally determining, to coastal marine eutrophication.

Nitrates also the problem in UK rivers

A similar situation to that in France is reported by the UK Environment Agency. **Rising nitrate concentrations** stand out as the black spot in the "best ever" results for river quality reported in the UK Agency's five yearly survey for the year 2000. 94% of rivers achieved "fair or good" chemical quality in 2000, leading the Agency to state that rivers are now "probably cleaner than they have ever been since the industrial revolution".

Nutrient data show an improvement in phosphate levels, with a halving of the percentage of rivers classed as having "excessively high" levels. On the other hand, nitrate levels have increased with 31.7% of river sections having "high" concentrations in 2000, whereas only 30.3% did so in 1995.

EU Court action on nitrates

Germany, meanwhile, has been condemned by the

European Court of Justice for allowing farmers to spread too much manure on land, in contradiction with the EU's 1991 Nitrates Directive 91/676. According to the judgement, member states must precisely apply EU limits defined for farms' nitrate application in "nitrate vulnerable zones", including where the nitrates are spread in manures. This will also affect The Netherlands and Italy, who face similar enforcement actions from the EU Commission.

France: "Les données de l'environnement – numéro 72". IFEN – Institut Français de l'Environnement, 61 bd. Alexandre Martin, 45058 Orléans Cédex 1, France. Available at: http://www.ifen.fr Available spring 2002: "10 ans de flux de nutriments des fleuves de la France" (text and CD)

UK: Environment Agency National maps and summary tables of river quality classification http://www.environment-agency.gov.uk/yourenv/eff/water/213902/river_qual/

Germany: se European Court by entering C-161/00 in "Case number" at http://www.curia.eu.int/jurisp/cgi-bin/form.pl?lang=en

VERMONT USA

Effectiveness of river bank restoration and protection

Some 71% of the annual phosphorus loads to Lake Champlain, the US's sixth largest freshwater lake, come from non-point sources, and most of this is from agricultural land. The Lake is undergoing eutrophication, and the management strategy calls for reductions in the phosphorus loadings.

This study looks at rivers in the Missiquoi river drainage sub-catchment of Lake Champlain, in Vermont, in the North East of the USA. The area has annual temperature ranges from –34°C to 33.2°C (average max and min), annual precipitation of just over 1,000 mm and annual snowfall of around 290 cm. This is the most intensively agricultural region of the Lake's catchment, contributing **the greatest non-point phosphorus load of any of the Lake's tributaries (around 82 tonnesP/year) for the second largest volume of water.** The rivers in the area are typically deteriorated by nutrients, bacteria and organic matter originating from animal wastes from dairy farms, crop production and livestock activities near the rivers.

Mainly dairy grassland farming

The study compares two watersheds, the Godin Brook (1422 hectares), in which a river bank restoration programme was launched, and the Berry Brook (954 ha) control (no management actions). These catchments range from 150 – 400 m altitude, and are similar in terms of land use, with **around 60% coverage by mixed woodland, very little urbanisation, and around one third agricultural land. This agricultural land is primarily grass production for livestock, either grazing pasture or hay growing.** The numbers of farm animals reported in the two catchments (larger farms only reported) were respectively 1,656 and 333 "animal units" (that is, equivalents to around 450 kg of animal), predominately dairy cattle.

Restoration work

The river bank restoration work in the Godin Brook catchment involved 11 landowners. Action carried out included protecting both sides of 2300m of stream and wetland with fences to keep livestock out, bank stabilisation including planting willow trees, a 300m stabilised livestock track and bridge. The fence-protected riverbank areas varied from 2 to 8m in width, and grass and shrubs were allowed to re-grow naturally on these areas.

The paired watershed method involves monitoring both watersheds before the management actions to allow comparative regression factors to be defined ("calibration"), then comparing differences in evolution of the monitored parameters following the implementation of management actions on one of the watersheds but not in the other. **The paired monitoring enables changes to be better attributed to the actions taken,** as effects of external factors (climate, precipitation, …) should affect both watersheds similarly. In this case, the two watersheds were "calibrated" by monitoring over 3 years (Spring 1994 – Spring 1997), then monitored in 1998 (following management work in the Godin Brook catchment in 1997). Post-treatment monitoring was expected to continue for an additional two years.

The first year of post-action monitoring showed significant decreases in river total phosphorus concentrations (-25%), river bacteria counts (-46% to –52%) and in total phosphorus export out of the watershed (-42%). All these figures are considerably higher than the margin of possible error indicated by the calibration period results (20%).

The author concludes that livestock exclusion and riparian restoration can be "an effective tool for reducing nonpoint source pollutant concentrations and loads from livestock grazing in agricultural watersheds".

"Water quality response to riparian restoration in an agricultural watershed in Vermont, USA". Water Science and Technology, vol. 43, n° 5, pages 175-182, 2001.
http://www.iwaponline.com/wst/04305/wst043050175.htm

D. Meals, New England Interstate Water Pollution Control Commission/ Vermont Dept. Environmental Conservation, 103 S. Main Street, Waterbury, Vermont 05671 USA. dmeals@wcvt.com

SYSTEMS APPROACH

Imbalance of nitrogen cycle

Although nitrogen is present in the air, rocks and sediments in huge amounts, these N-minerals are mostly too inert to be accessible to biological systems, so that organically available nitrogen has been and continues to be the main limiting factor for global biomass production. Natural biological nitrogen fixing and denitrification mechanisms are approximately balanced, but man has massively altered this situation with the development of mineral nitrogen fertiliser synthesis, in particular with a tenfold increase since the 1960's. Mineral fertiliser synthesis now fixes around 90 million tonnes of N per year, compared to biological nitrogen fixation estimated at 240 million tonnes N worldwide. There are few other elements for which human impact has been so dramatic.

The doubling of the world population between 1960 and 2000 would probably not have been possible without the increase in agricultural production enabled by nitrogen fertiliser use, but at the same time the industrial fixation of nitrogen in fertilisers increased by a factor of 10.

Global warming

The considerable increase in biologically available nitrogen in ecosystems has a number of negative impacts. The authors cite the development of blue-green algae, which can be toxic and problematic for water supplies, the oxidation of ammonia in surface waters which can lead to low aquatic oxygen levels, overproduction of plant and algal biomass in surface waters, and the loss of biodiversity.

Lower water oxygen levels can lead to incomplete denitrification, resulting in the production of NO and the greenhouse gas N_2O, and the decomposition of overproduced biomass in aquatic sediments can generate another greenhouse gas methane. These contributions to global warming gas increases are little understood and have received little attention to date. They add to the impact of the energy consumption necessary for nitrogen fertiliser synthesis.

The average retention time of organic nitrogen in the biosphere is around 7000 years. Industrial fixation of nitrogen in fertilisers is making a considerable contribution to total nitrogen fixation and is not balanced by natural denitrification, thus leading to an ongoing accumulation of available nitrogen in the biosphere, the long-term effects of which are not known.

Systems approach

Only 10-15% of nitrogen fertiliser applied to land actually ends up in food protein, the rest feeds into the environment. Further, only 1-2% of organic nitrogen in food is actually used by the human body, the rest going to sewage. The result of these inefficiencies is mirrored in the economic value of different products containing organic nitrogen (US$/kgN) :

* mineral fertiliser	0.5
* wheat protein	9
* pork protein	55
* milk protein	90

Less than 5% of the world's sewage receives tertiary treatment involving nitrogen removal, and even if this were massively increased, this is a very inefficient 'solution' as it involves investing in expensive capital equipment and running costs to break down organic nitrogen which has been synthesised using energy input. The authors estimate this "negative value" of sewage nitrogen at 3 US$/kgN.

The authors suggest that it is therefore necessary to develop a systems approach to nitrogen fixation and re-use in agriculture and aquaculture. The aim should be to move away from the current inbalance and accumulation of organic nitrogen in the biosphere, towards nitrogen recycling and towards a much more efficient use of nitrogen in crop and food production.

"The nitrogen cycle out of balance", Water 21 (IWA – International Water Association), August 2001, pages 38-40.

H. Gijzen, IHE Delft and A. Mulder, Amecon Environmental Consultancy, The Netherlands arnoldmulder@amecon.nl

AQUATIC ECOSYSTEMS

CANADA

Alternative states in a eutrophied lake

L227 is a 5 hectare, 10m max. depth headwater lake situated at the Experimental Lakes Area of North-West Ontario, Canada. It is usually strongly thermally stratified. The lake had been experimentally eutrophied since the early 1970's in a classic study reported elsewhere. From 1990 onwards, nitrogen was no longer inlcuded in the lake fertilisation regime, so that it was receiving an input of 0.56 gP/m²/year and no other nutrient addition. Before 1993, the fish population was made up only of small fish (cyprinid minnows, dace …) with no piscivorous fish. Densities of these small fish were thought to be comparable to that in other eutrophied lakes in the area, at around 100 kg/ha. In the springs of 1993 and 1994 a total of 160 piscivorous fish (pike, total weight 143 kg) taken from nearby lakes were added.

From 1992-1996 the lake was monitored every 7 or 10 days from May – September for algae, zooplankton, water nutrient chemistry and other parameters. Small fish abundance was assessed monthly using fish traps. The addition of the pike decimated the small fish population within 2 years and by 1996 had apparently been exterminated, so that by that year zooplankton effectively no longer had vertebrate predators in the lake.

Larger zooplankton

Summer average zooplankton size changed little through to 1995, but increased fourfold in 1996. This corresponded to a slight appearance of smaller *Daphnia* species in 1993-1995, and a dramatic increase in the larger *Daphnia pulicaria* in 1996 (98% of zooplankton biomass in July 1996). At the same time, the N:P ratio of zooplankton biomass declined, down to a lowest level of 17:1 in 1996.

In the summer of 1996, zooplankton biomass included more than 32% of epilimnetic phosphorus, compared to less than 1% in previous years. The zooplankton thus effectively acted as a "sink" for available phosphorus, leaving less available to produce algal biomass. This was accompanied by a fall in the seston (mostly algae, some bacteria, but not including zooplankton) biomass C:P ratio.

Sedimentation rates of phosphorus were greatest in 1996, presumably because of the effect of the large zooplankton to "pack" phosphorus into relatively large, rapidly sinking particles (fecal pellets, zooplankton decay remnants …). Also C:N and C:P ratios in sedimented material were significantly lower in 1995 and 1996 than in previous years.

However, the dense Daphnia population in 1996 did not last, and crashed from 375 µg/l on 24 July to 2.1 µg/l Daphnia biomass. This was associated with high densities of invertebrate predators such as diving beetles and notonectids. Total zooplankton biomass also declined with this Daphnia population crash, but nonetheless remained higher than in previous years, being dominated by the omnivorous calanoid copepod Epishura lacustris.

In 1996, during the large Daphnia population development, dissolved phosphorus (TDP) and nitrogen (TIN) concentrations in the lake water were both significantly higher they had been in the Springs of 1992-1995. However, the dissolved nitrogen increased over 4x whereas dissolved phosphorus only around twice, so that the TIN:TDP ratio also doubled in Spring 1996. After the Daphnia population crash in the Summer of 1996, TIN concentrations declined.

Blue-green algae

The proportion of nitrogen-fixing cyanobacteria ("blue-greens") in the lake algal population had begun to increase from 1990, when nitrogen had been removed from the normal experimental fertilization regime. This trend continued in 1992-1995.

However, in 1996, with the Daphnia population development, phytoplankton (algal) biomass plummeted, and cyanobacteria were almost absent. The result was a phytoplankton population assemblage (mix of different species) similar to that present in the lake 25 years earlier, before high external nitrogen and phosphorus inputs occurred.

Alternate states

In 1997 and 1998, despite continuing near absence of small fish, zooplankton remained low and the Daphnia population did not develop as it had in 1996. Dense cyanobacterial algal blooms thus returned.

This is consistent with stoichiometric models of grazer – algae interactions, which predict that highly eutrophied lakes can have two different stable states, one with high grazer populations and low algal development, the other with few grazers and algal blooms. The non-linear response of the zooplankton – phytoplankton system thus strongly limits the feasibility of predicting lake ecosystem reactions to nutrient inputs and food web alterations.

"Pelagic C:N:P stoichiometry in a eutrophied lake:responses to a whole-lake food-web manipulation". Ecosystems (2000)-3 pages 293-307.

J. Elser[1], R. Sterner[2], A. Galford[2], T. Chrzanowski[3], D. Finlay[4], K. Mills[4], M. Paterson[4], M. Stainton[4], D. Schindler[5].
(1) Dept. Biology, Arizona State University, Tempe, Arizona 85287 USA j.elser@asu.edu
(2) University of Minnesota, Saint Paul, Minnesota 55108, USA
(3) Dept. Biology, University of Texas, Arlington, Texas 76019, USA
(4) Freshwater Institute, Dept. Fisheries and Oceans, Winnipeg, Manitoba R3T 2N6, Canada
(5) Dept. Biology, University of Alberta, Edmonton, Alberta, T6G 2E9, Canada.

USA FLORIDA LAKES

Algal polyphosphates provide P-sink to sediment

The authors report studies of sediment cores from the widely-studied hypereutrophic Lake Apopka, near Orlando, Florida, USA. This is a shallow, subtropical lake, situated at 28°4' North and 81°4' West, with an average depth of 1.7 metres. The lake was macrophyte dominated with clear water before the 1920's, when eutrophication began with sewage and citrus-fruit processing discharges.

In the 1940's, the lake area was reduced from 210 to 125 km^2, as "muck farms" were created on drained lake and marsh land. The lake then became dominated by large growths of phytoplankton (algae) and turbid water. By the 1990's, pumping of nutrient-rich farm drainage water provided 85% of the phosphorus loading to the lake (0.42 gP/m^2/year from this source). Because of the high P-loading, phytoplankton growth in the lake is nitrogen limited.

Organic sediment phosphorus

As is the case for other Florida lakes, the shallowness of the lake and frequent resuspension mean that the sediments are exposed to aerobic conditions before permanent deposition. Consequently, the sedimented organic material is mainly "refractory", that is not readily biodegradable. Primary production by phytoplankton is sufficient to account for sedimentation rates and TC:TN [total carbon : total nitrogen] ratios suggest that most of the sedimented material is indeed of phytoplankton origin. **The sediment in Lake Apopka has a relatively high organic content (~65%), and the phosphorus present is not bound to cations (Fe, Al, Mn) so that P release is not redox potential dependent.**

Six sediment cores were taken from the lake and the different forms of phosphorus present were analysed chemically (total P, water soluble P, 0.1M NaOH available P, 0.1M NTA pH7 available P, polyphosphates) and with bioassays (the latter using cultures of Scenedesmus quadricauda). Polyphosphates were measured using heat extraction that has been shown to liberate cellular polyphosphates stored by algae (Fitzgerald and Nelson 1966 methodology). Core samples were aged using estimates based on temporal patterns of sedimentation rates and ^{210}Pb dating work carried out previously to develop core sediment chronologies in the lake (Schelske 1997).

Cellular polyphosphates

The bioassay available P surprisingly represented only a small proportion of the NaOH and total P. NTA-P and water available P were correlated with bioassay P; whereas NaOH-P and cellular polyphosphates were correlated with total P. Among the P fractions measured, **cellular polyphosphate levels in the sediments were the most sensitive indicator of the lake's phosphorus enrichment history.**

Whether samples were freeze-dried significantly affected the results of these analyses. For example, water soluble P was greater in freeze-dried samples from recent periods when sedimentation was dominated by phytoplankton, but not in older samples (macrophyte sedimentation). Cellular polyphosphates were not measurable chemically in the freeze-dried samples, and were higher in phytoplankton than in macrophyte sediments that were analysed wet. Similarly to polyphosphates, NaOH-P was higher in wet samples, and like water soluble P, bioassay-P was higher in freeze-dried samples.

The authors conclude that the freeze drying of samples causes cellular polyphosphates to be released, becoming available for uptake in bioassays. This corresponds to other work showing that phytoplankton cells can remain intact, and indeed viable, in sediments for decades, and that cellular polyphosphates were a significant fraction of phosphorus even in sediments over 100 years old (Newnans Lake, Florida).

Implications for understanding eutrophication

The comparisons of different sediment samples show that as phosphorus loading to the lake has increased in the past, so phosphorus has been accumulated by phytoplankton as internal polyphosphate "reserves", with this uptake probably becoming the dominant mechanism for removal of P from the water. Under experimental conditions, phytoplankton populations from Lake Apopka converted 83% of added soluble phosphate into cellular polyphosphates in less than 2 hours (Newman *et al.* 1994).

The authors conclude that the sinking and burial in sediment of intact phytoplankton cells is a significant factor of P sedimentation in Lake Apopka, thus storing phosphates in a non geochemically available form, and effectively removing P from the aquatic ecosystem. The mass of phosphorus sedimented annually in Lake Apopka equals the total phosphorus present in the water column and is at least 65% of the annual P loading to the Lake. This is probably a significant P-removal process in many eutrophic systems with excessive supplies of P for phytoplankton growth.

Conclusions

The authors draw three main conclusions from this work : 1) that cellular polyphosphate concentrations are the most sensitive indicator in sediments of historical P-enrichment of lake waters; 2) that the different forms of P present in sediments must be measured on fresh wet-kept samples as freeze-drying causes the disintegration of cell structures in the sediment and thus the release of non-geochemically available phosphorus (cellular polyphosphates); 3) that phytoplankton uptake of soluble phosphate from water (beyond cellular needs), storage as polyphosphates, and then sedimentation, can be an important process for the removal of P from eutrophic aquatic ecosystems towards a non-available sediment "sink".

"Changes in polyphosphate sedimentation: a response to excessive phosphorus enrichment in a hypereutrophic lake", Can. J. Fish Aquat Sci 58, pages 879-887, 2001. W. Kenney[1], C. Schelske[2], A. Chapman[3].

1 & 2: Land Use and Environmental Change Institute, Dept. Geological Sciences, University of Florida, PO Box 112120, Gainesville, FL 32611 USA kenney@ufl.edu

3: CyanoLab/BCI Engineers and Scientists, Inc. 205 Zeagler Dr., Suite 302 Palatka, FL 32177 USA

NORTH CAROLINA

Effects of nutrients on phytoplankton and bacteria in dark-watered rivers

Nutrients were added to water samples from two "blackwater" rivers, as different forms and combinations of nitrogen (N) and phosphorus (P), in order to asses the reaction of the ecological system to nutrient enrichment.

"Blackwater" river systems are typical of the coastal plains of the US Gulf Coast, from Virginia to Florida, and are characterised by **low topography, sand sediments, extensive flood plains and high concentrations of organic matter**. Phytoplankton is often low, as a result both of low nutrient levels (due to soil type and retention in flood plains) and light limitation (due to water coloration).

A major nutrient source to these coastal plain areas is industrial pig and poultry production, which is widespread from the Delaware Bay to North Carolina. Traditional agriculture, and industrial and municipal point sources also input nutrients to certain "blackwater" rivers.

The bioassay experiments used triplicated 3-litre samples of river water collected together from the Black River and from the Northeast Cape Fear River, both in south-eastern North Carolina. The rivers are respectively 40 and 50m wide and 4 and 9m deep at the sampling points.

Nutrient addition

The following **combinations of nutrients** were added to the samples in 1 mg/l concentrations:
- no added nutrients (control)
- inorganic phosphate only
- ammonium only
- inorganic phosphate and ammonium (both at 1 mg/l)
- urea only
- soluble organic phosphate (glycerophosphate) only

The experiments were run for 6 days in July, August, October and November 1996 and in January, March, April, May and June 1997. Furthermore, in February and July 1997, experiments using higher nutrient additions (10 mg/l) were carried out. The samples were held in floating cubitainers at ambient river temperature, and subjected to light irradiation comparable to those at a depth of around 0.25m in the Northeast Cape Fear River (by appropriate screen shading).

Samples were analysed after 1, 3 and 6 days for chlorophyll-*a* and for ATP concentrations. **Chlorophyll-*a* is considered to be a good indicator of phytoplankton (algal) development**, as it is the pigment present in all green algae and used for photosynthesis. ATP is a useful indicator of microbial biomass (development of all micro-organisms, including algae, zooplankton, and heterotrophic microbes), because it is present in all living matter and the ratio of ATP:organic carbon is relatively uniform across all such organisms. Where chlorophyll-*a* levels were high, samples of phytoplankton were also analysed for taxonomic data (identification of distribution between main species).

The river water samples showed **low turbidity** (low levels of light-inhibiting suspended matter), but light penetration was reduced by the water coloration. Dissolved oxygen levels were low in summer. Inorganic nutrient concentrations were also generally low, with total nitrogen around 1,000 – 1,200 µg/l (of which 76% organic in summer) and total phosphorus around 75 – 95 µg/l (of which 65% organic in summer).

Nitrogen inputs and algal blooms

The bioassay results showed that both inorganic or organic nitrogen inputs, alone, stimulated phytoplankton development in most cases, but phosphorus inputs alone generally did not. The authors conclude that both inorganic or organic nitrogen loadings to theses rivers could potentially generate algal blooms. The indications are that the phytoplankton physiologically had a higher requirement for N than for P.

The authors conclude that phytoplankton development in these rivers appears to be generally nitrogen, not phosphorus, limited.

Phosphate inputs alone, particularly organic phosphorus, did result in increased ATP concentrations in many cases (especially in summer). In other cases, ATP concentrations increased in response to nitrogen addition only. The authors conclude that these ATP responses are probably the **result mainly of stimulated development of heterotrophic bacteria.** Such development could pose environmental problems by increasing oxygen demand, either by the activity of the bacteria, or by their decomposition on death, depending on water mixing and other factors.

"Effect of nitrogen and phosphorus loading on plankton in coastal plain blackwater rivers". Journal of Freshwater Ecology, vol. 6, n°3, September 2001.

M. Mallin, L. Cahoon, D. Parsons, S. Ensign, Center for Marine Science, University of North Carolina, Wilmington, NC28409, USA. mallinm@uncwil.edu

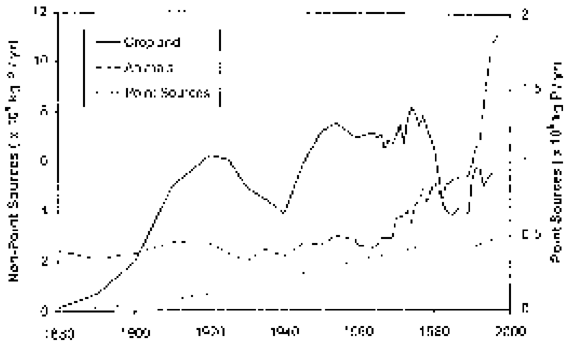
NORTH CAROLINA

Muted river response to nutrient input reductions

The Neuse River estuary in North Carolina, has shown significant and problematic symptoms of eutrophication over recent years (mid 1990's). This is despite significant reductions to river phosphorus inputs. The river and estuary P concentrations have fallen, in line with these reductions, but river and estuary nitrogen concentrations have not reflected changes in inputs – raising the question of what effect can be hoped for from planned reductions in nitrogen loads of 30%.

The Neuse river is 320km long with a 16,100 km² watershed, made up mainly of farmed land (35%) and forest (34%).

Cropland phosphorus application in fertilisers began to increase around 1900, and rose irregularly through to the 1970's (to over 8,000 tonnesP/year), when it fell significantly in the 1980's, before recovering slightly in the 1990's. Animal phosphorus sources were low steady until the 1970's, when they began to increase, tripling to 12,000 tonnesP/year by today. **Point sources rose steadily from the late 19th century through to the late 1980's, when they fell by 20-25% as a consequence of a detergent phosphate ban and improvements to sewage P-removal.**



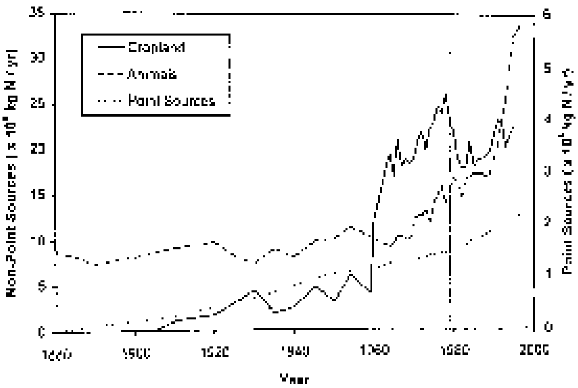
Estimates of annual anthropogenic Phosphorus loadings within the watershed from cropland, animals and point sources. The vertical line corresponds to the first year for which loading estimates were calculated.

River phosphorus concentrations have responded to changes in inputs, both upstream and downstream. They dropped significantly following the construction of a 35 km² dam in 1983, then again following the detergent phosphate ban and improved sewage treatment in the late 1980's.

Nitrogen inputs

Cropland nitrate inputs increased rapidly and by a factor of around 4 in the 1960's, remaining high if irregular since then. Point source nitrogen inputs have increased steadily since around 1900 (with population increases). **Animal nitrogen inputs, like animal phosphate inputs, have increased rapidly since 1960, and particularly since 1990, with an overall near quadrupling from 1960 to today.**

Like phosphorus, river nitrogen concentrations fell upstream with the construction of the dam, but unlike phosphorus, **no consistent patterns in river nitrogen levels are visible further downstream,** although there does appear to have been an increase over the period approximately 1985-1995, followed by a recent decrease at monitoring stations downstream from the major point sources.



Estimates of annual anthropogenic Nitrogen loadings within the watershed from cropland, animals and point sources. The vertical line corresponds to the first year for which loading estimates were calculated.

Muted response

The authors note that the absence of a clear increase in river nitrogen loads (amounts carried by the river water) is surprising, given the ongoing increases in watershed inputs, and in particular the recent large increase in animal manure inputs. For phosphorus also, loads carried by the river, do not appear to have responded to the recent increases in inputs within the watershed.

The authors estimate that in fact only around 10% of the inputs of nitrogen and phosphorus into the river in the watershed are in fact carried out by the river into the sea, probably because of storage in groundwater, riparian zones and losses during river and stream transport (denitrification, transfer to sediments).

They conclude that even if the proposed objective of a 30% nitrogen input reduction is achieved, several years may be necessary before any detectable change will result in river concentrations or in loads carried to the estuary (at least four years, even if the reduction were made as a single step). Also, it would appear that the watershed was already receiving excess nutrients in the 1970's and earlier, so that resolving the problem in a short time-scale may be difficult. Indeed, the release of sediment-stored nutrients could mean that **reductions in inputs may not lead to improvements in the river and estuary ecosystems, even after a "substantial" number of years.**

"Long-term changes in watershed nutrient inputs and riverine exports in the Neuse river, North Carolina". Wat. Res. vol. 35 n°6 pages1489-1499, 2001.

C. Stow[1], M. Borsuk[1], D. Stanley[2].
(1) Nicholas School of the Environment, Duke University, PO Box 90328, Durham, NC27708, USA cstow@duke.edu
(2) Institute for Coastal and Marine Resources and Dept. Biology, East Carolina University, Greenville, NC, USA.

LOWLAND ENGLAND

Seasonal phosphorus retention in a river system

Inputs of total phosphorus to the upper River Cherwell, Oxfordshire (in England's Midlands) were estimated from populations connected to sewage works and from export coefficients related to land-use coverages. These estimations were then compared with the loads of phosphorus being carried out of the catchment in the river water, according to monitoring data. The results suggested that the input estimates were reasonably accurate (within 15%) and that there was a significant seasonal retention phenomenon in the river, with phosphorus being stored in the system in spring and summer, then released downstream in autumn – winter.

The upper River Cherwell catchment studied covers just over 17,500 ha upstream of Banbury i Oxfordshire, GB, with mainly clay soils, so that the river is fed mainly by surface rather than underground water flows. **Water quality on this 34km section of river is classified as "good"** by the UK Environment

Agency, with a variety of fish present including roach, dace, chub, grayling and trout. The catchment includes a number of smaller tributaries, with five up to 17 km long but most less than 3 km long.

Much of the catchment is tilled (ploughed) farmland (48.9%), with a further 31% meadows and grassland. Only 1.6% is forested and 8.9% is urbanised. Annual total phosphorus losses for each land cover type were estimated using the export coefficient method (Johnes, 1996), in particular using values of 0.65 kgTP/ha/year for the tilled land and 0.3 kgTP/ha/y for the meados/grassland.

This method suggested a **total annual phosphorus run-off from land of 8,759 kgTP/y, of which 64% from tilled land**, 19% from meadows/grassland, and 15% from urbanised areas.

40% of river phosphorus from sewage

Annual total phosphorus discharges from the 12 significant sewage works discharging into the studied catchment (with population equivalents ranging from 150pe to 3,500pe) were estimated by calculating 0.73 kg/pe/year, in the absence of monitoring data. This gave a **total estimated output of 6,900 kgTP/y from the sewage works, that is 40% of the total catchment phosphorus inputs to the river system.**

The total load of phosphorus being carried downstream out of the catchment by the river was estimated from daily river flow data and total phosphorus concentrations measured every four days. This gave a total outflow load of 13,425 kgTP/y for the study year (March 1998 – February 1999), lower than but **within 15% of the estimated total inputs to the river** (15,700 kgTP/y).

However, the phosphorus load being carried downstream out of the catchment by the river showed strong seasonal variation. A number of authors have shown that high river flow events can carry significant proportions of catchment phosphorus outflow. However, in this case, despite spring storms in April and high monthly water flows at this period (55% of annual water flow in the Spring), **the seasonal total phosphorus load carried by the river was much higher in winter** (56% of TP load for only 37% of the year's water flow in winter, compared to 20% of TP load for spring). Autumn TP load was significant (19%) despite low water flows (6%), and in summer both the TP load (4%) and the water flow (3%) were very low.

The authors conclude by emphasising the significance of this seasonal variation in river phosphorus loads, resulting from an apparent retention in spring and summer. **Total phosphorus has little impact on river ecology during high flows (which occurred in autumn and winter), and during the period of the year when algae are not susceptible to develop (again, autumn and winter)**. On the other hand, in the spring and summer when phosphorus may contribute to algal development, it appears to be retained in the river system and be suppressed in the river load by seasonal variations.

"Seasonal export of phosphorus from a lowland catchment: upper River Cherwell in Oxfordshire, England". Science of the Total Environment 269, pages 117-130, 2001.

L. May, Centre for Ecology and Hydrology – Edinburgh, Bush Estate, Penicuik, Midlothian, EH26 0QB, Scotland.

W. A. House, M. Bowes, Centre for Ecology and Hydrology – Dorset, Winfrith Technology Centre, Dorchester, Dorset DT2 8Z, England.

J. McEvoy, Environment Agency, Kings Meadow House, Kings Meadow Road, Reading, RG1 8DQ, England. wah@ceh.ac.uk

Response of Lake Balaton to sewage nutrient removal

Lake Balaton is a 596 km² shallow (3.2 m deep), calcareous lake in Hungary, around 80 km long by 10-15 km wide, and separated into four basins by narrower stretches of water. Increases in nutrient loa-

ding in the 1970's led to eutrophic conditions in the upper basins of the lake. Outflow rates in the lake's exit canal from basin 4 can be up to 40 m3/s in late winter, but are generally zero from spring to autumn.

Significant actions were undertaken to reduce nutrient loading, targeting the Zala river which flows into the upper end of the lake (basin 1) and which carried over 90% of nutrient inputs, in particular **opening of two retention reservoirs on this river in 1985 and in 1993, and the introduction of phosphorus removal at the Zalaergerszeg municipal sewage works** (65,000 inhabitants) in 1991. Nutrient loads to the other lake basins were also considerably reduced in the 1980's, mainly by sewage diversion from the shoreline settlements of basins 3 and 4 and by installation of P-removal in sewage works in the catchment. Overall, these measures reduced the lake phosphorus load from 0.5 to 0.3 mg/m^2/year.

The authors examine the changes in a number of monitored factors over this period, both in the lake and in this main tributary river, the Zala. These include total phosphorus, calcium, suspended solids, chlorophyll, algal blooms as well as loading ratios between particulate (organic) and dissolved phosphorus and lake phosphorus sedimentation rates.

Carbonate makes up some 50-60% of Lake Balaton's sediments (dry weight). Unlike in many calcareous lakes, the main process for phosphorus sedimentation in the lake, however, is not carbonate precipitation but sorption and mineralisation of detrital and organic phosphorus in the sediments. **The construction of the pre-reservoirs significantly changed the dissolved:particulate phosphorus ratios** in the inflowing river (from around 1.4 to 0.7 for the hypertrophic upper reservoir in 1985, then to around 2.5 with the opening of the reed-bed lower reservoir in 1993). This is thought to have considerably modified phosphorus sedimentation rates. The introduction of phosphorus removal in the sewage works, on the other hand, did not significantly change this ratio.

Rapid recovery of the upper lake basin

The upper lake (basins 1 and 2) responded rapidly and positively to the nutrient management actions undertaken, with both total aquatic algal biomass (measured by chlorophyll concentrations) coming down to pre-1970's levels by 1995-1997, and also nuisance algal blooms effectively being eliminated by this same date.

The authors note that the type of management measures taken probably had significant impacts on the rate of phosphorus sedimentation in the lake, because of induced changes in factors such as the dissolved:particulate phosphorus ratio, inflowing suspended solids and calcium. This seems to have resulted in rapid immobilisation of phosphorus in the sediments, leading to ecological recovery of the lake's upper basins, but is certainly "not a universal phenomenon" and would be hard to predict in other lake systems.

Furthermore, and surprisingly given the interconnectivity, **at the same time as this described recovery of the two upper basins of the lake, the two lower basins (basins 3 and 4) actually showed definite eutrophication and an accentuation of blue-green algal blooms.** A first analysis of monitoring data suggested that this might be the result of increased hydraulic residence times in the lower lake, resulting both from climatic factors (draught years with low precipitation) and from the cessation of pumping of karstic water into the lake (closure of a bauxite mining operation).

However, the hydraulic residence time of Lake Balaton is relatively long, so that the lake is not subject to flows high enough to "flush out" algal development. Although the increase in residence time was thus significant (from around 2 to 4-7 years), it was considered that this could not account for the increased algal development in the lower basins.

Blue-green algae

As phosphorus inputs were reduced, basins 3 and 4 of the lake showed increasing nuisance blooms of the blue-green cyanobacterium *Cyclindrospermopsis rasiborskii*. This is a subtropical species which appeared in the lake in the 1980's, and may have been able to develop because of the eutrophied state of the lake combined with unusually warm late summers.

The authors suggest that the blooms of this cyanobacterium, occurring despite falling external phosphorus loads, may result from its ability to mobilise internal (sediment) stored phosphorus sources. *C. rasiborskii* may be efficient in doing this because of its **high shade tolerance and high affinity for phosphorus and ammonium uptake**, allowing it to reach very high biomass concentrations, thus producing a powerful "drain" for mobile phosphorus from sediments. Calculations based on estimated phosphorus requirements of the observed algal biomass levels were coherent with this hypothesis.

The development of the blue-green algae can be considered surprising given **the changes in P:N loading ratios resulting from the improvements in sewage treatment** (ratio increased from 16 to 27 by weight). Indeed, field data suggest that during the algal blooms only around 10% of C. *rasiborskii's* nitrogen needs were being supplied by fixation of atmospheric nitrogen.

The authors conclude that specific morphological features of the lake, and not nutrient loadings, may have led to the blue-green algal dominance. The completely different response of the lower and the upper basins of Lake Balaton to external nutrient loading reductions show the **difficulty in predicting lake recovery and lake response to eutrophication management policies.**

"Factors influencing lake recovery from eutrophication – the case of Basin 1 of Lake Balaton". Water Research vol.35 n°3 pages 729-735, 2001. See also:
http://phytoonline.ocean.org.il/Lakes/L__Balaton/body_1__balaton.html

V. Istvanovics, L. Somloyody, Dept. Civil Engineering, Budapest University of Technology and Economics, H-1111 Budapest, Hungary.
istvera@goliat.eik.bme.hu

"Cyanobacteria-mediated internal eutrophication after load reduction in shallow Lake Balaton". Water Research, in press. Above authors plus A. Clement.