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Over 400 data sets were analysed to compare response to nutrients in temperate and subtropical lakes, with and without large zooplankton grazers of phytoplankton

USA, Japan, China

Three shallow lakes: challenges for nutrient-chlorophyll modelling

Data from three large shallow lakes in the USA, Japan and China were used to assess the ability of published empirical models to predict nutrient and chlorophyll concentrations.

British Columbia

N and P co-deficiency in lake plankton

Different nutrient ratio analyses and bioassay methods applied to 10 lakes show the complexity of nutrient limitation and deficiency for different phytoplankton groups.

Spring Lake

Testing alum dosing to reduce internal P loading

Sediment/water cores collected from four sites in Spring Lake were tested for phosphorus release over one month in aerobic and anaerobic conditions, with and without aluminium sulphate dosing.

Book review

IWA Publication

"Phosphorus in Environmental Technologies – Principles and Applications"

New 650 page reference work provides up to date and complete overviews on environmental management of phosphorus and phosphate recovery for recycling, including technical, industrial and economic aspects.

CEEP
Centre Européen d'Etudes des Polyphosphates

cefic

Regulatory

EEA report

Cost effectiveness of waste water treatment

The European Environment Agency has compared levels of sewage treatment and costs in six countries to examine how compliance with EU urban waste water treatment legislation (Directive 91/271) can be achieved at a lower cost. Because sewage treatment plant construction costs are a key obstacle, this should accelerate implementation.

The report compares the situation in two EU member states which have achieved near complete implementation of the Directive (The Netherlands, Denmark), two which are significantly behind deadlines and are not achieving adequate waste water treatment today (France, Spain), and two new member states (Estonia, Poland).

Institutional organisation is identified as a key obstacle to progress in both France and Spain, in particular the fact that provision of sewage collection and treatment is the responsibility of local authorities, leading to local political reluctance to spend the necessary investment costs and overlaps of responsibilities with national authorities and basin authorities, which have both regulatory powers and financing capacities.

Polluter payer

The key area for improving cost effectiveness appears in fees for industrial wastewater discharges. Combined treatment of industrial and domestic waste waters leads to difficulties in efficiently defining capacity needs and investments plans. Low industrial discharge fees, resulting in industries not installing their own treatment or reducing discharges by changing processes, leads to high needs for sewage treatment capacity, and so high investment costs. The Netherlands is shown to have achieved EU-Directive compliant sewage treatment at a lower cost than Denmark, because levels of discharge fees for industry have been significantly higher, resulting in lower discharges and savings on capacity installed at public sewage treatment plants. Investment costs per capacity installed in The Netherlands appear as 1.64 € (per inhabitant connected) compared to 2.71 € for Denmark.

Failure to implement UWWT Directive

France and Spain are both failing markedly to implement minimal sewage treatment as defined by the EU Urban Waste Water Treatment Directive 91/271. In France, 58% of plants in eutrophication Sensitive Areas (as currently designated by France) and 37% of plants outside these areas, do not meet requirements (EU 2004 report). Furthermore, France was condemned by the European Court of Justice for inadequate designation of Sensitive Areas (see *Scope Newsletter n°59*), so that areas not presently designated will have to be, thus further increasing the number of non compliant sewage works.

Spain is also failing to implement EU sewage treatment requirements. 45% of households are not connected to sewage treatment, and 60% of sewage does not receive secondary treatment. This is despite considerable EU subsidies since Spain joined the EU in 1986 (85% EU subsidies).

Estonia already today (on accession to the EU in 2004) shows levels of sewage collection and treatment similar to France (but with a much higher proportion of tertiary treatment = nutrient removal) and very significantly better than Spain. Poland shows levels of connection comparable to Spain, but a higher proportion of tertiary treatment.

The report suggests that both Estonia and Poland will need EU structural fund support to achieve compliance with the UWWT Directive, but that new methods of distributing these funds should be investigated. In Spain, structural fund subsidies were made directly to sewage works construction, thus enabling all households and industries of cities such as Barcelona to benefit from considerably reduced waste water treatment costs (85% subsidy), running into the future as the subsidy reduces or avoids loans. This reduces incitement to reduce pollution loads, whilst failing to target aid to needy households.

The report emphasises that water pollution control costs account for some 0.8% of some member states' GDP and have taken up over 50% of all environmental investment in recent decades, and concludes that the use of the polluter-payer principle to give incentives to reduce discharges can reduce overall costs to society and so facilitate implementation.

"Effectiveness of urban wastewater treatment policies in selected countries: an EEA pilot study", European Environment Agency (EEA) report n° 2/2005. 51 pages. ISBN 92-9167-763-9. Available for download free (pdf) at www.eea.eu.int *direct link* http://reports.eea.europa.eu/eea_report_2005_2

USA

Regional stream nutrient criteria

This paper was funded by the US Environment Protection Agency (EPA) and formed the basis for a discussion process. It looks at how a statistical distribution of "natural" phosphorus and nitrogen concentrations in streams can be derived by examining selected data (sites filtered to avoid those with significant, identified, point or agricultural nutrient sources), sorted by "ecoregion".

The paper uses 14 "ecoregions", resulting from agglomeration of comparable US EPA Level III EcoRegions (there are 84 of these covering the USA). The approach therefore differs slightly from the 17 EcoRegions used by the EPA in publication of "ecoregional nutrient criteria" in 2001 (see SCOPE Newsletter *n°44*).

The 14 aggregated ecoregions in this paper are made of geographical areas showing similar natural and human (land use) characteristics. The 17 EPA 2001 ecoregions were defined around water body types: 8 types of stream/river, 8 of lakes/reservoirs, one for wetlands (see: *http://www.epa.gov/ost/standards/nutrient.html*).

The 14 ecoregions used in this paper are:

* Willamette and central valleys
* Xeric West
* Great plains and shrublands
* Central cultivated Great Plains
* Corn belt and Northern Great Plains
* Mostly glaciated dairy region
* Nutrient poor, largely glaciated upper Midwest and Northeast
* Southeastern temperate forested plains and hills
* Texas-Louisiana coastal and Mississippi alluvial plains
* Central and Eastern uplands
* Southern coastal plain
* Southern Florida coastal plain
* Eastern coastal plain

Monitoring data

The main source of data for this paper was the National Eutrophication Survey (NES), where lakes with eutrophication or potential eutrophication issues (in particular, those where sewage treatment installations were present in the watershed) were identified and monitored. This paper used sampling data from streams draining into or near these lakes, collected within this survey. This meant that the data sites were significantly concentrated in the two "glaciated" ecoregions above (many natural lakes), but with sites also in other regions particularly around reservoirs.

Data from 928 stream sites were used in this paper, selected from the 5,000 such sites in the NES by rejecting all sites which contained identified point source nutrient inputs and also by selecting sites considered typical or representative of the given ecoregion's watersheds.

The average watershed area of the 928 streams was 42 km^2.

Regional patterns

Regional patterns of total phosphorus were found to be somewhat different from those of total nitrogen. Total phosphorus and soluble phosphorus were generally higher in the West of the USA, and nitrogen in the East. Total nitrogen was particularly related to agriculture, but also inorganic nitrogen to atmospheric deposition in the North East.

Stream phosphorus concentrations, on the other hand, were in places more closely related to natural phenomena such as soil pH.

Case study example

The authors examined data from a subset area of one ecoregion as a case study: small streams in the Mid-Atlantic highlands, within the Central and eastern forested uplands ecoregion. The NES (EMAP *http://www.epa.gov/emap/*) data set for this sub-area included 235 streams (that is, in the total of 5,000 NES sites). However, only 17 of these sites corresponded to the filtering criteria applied (that is, in the 938 selected sites), so a further 5 sites were selected manually (selected to avoid sites with significant identified human nutrient inputs). The filtering criteria excluded streams with: >5% catchment land surface agriculture, >1% urban, identified point nutrient source in catchment, riparian livestock grazing, elevated sedimentation rates, mine drainage, acidification problems.

These two resulting sets of 235 and 22 sites, were used to derive statistical distributions of total phosphorus and total nitrogen concentrations.

The authors suggest setting as "nutrient criteria" for the ecoregion's streams, the 75% percentile levels of nutrient concentrations for the selected (filtered) subset of streams (that is, a nutrient level respected by 75% of the stream sites selected as having no significant anthropogenic nutrient enrichment). This would suggest levels of 375 µg/l for total nitrogen, and 13 µg/l for total phosphorus.

The authors estimate that around 57-58% of stream length for all streams in the studied sub-area would exceed these levels.

The authors indicate that the same method could be used to derive ecoregional criteria for other parameters such as dissolved oxygen or chlorophyll, subject to availability of suitable data sets.

It is to be noted that the "criteria" proposed by the authors address, in effect, nutrient concentrations, but not the actual effects of nutrients in terms of ecosystem modification, such as species balance changes, algal blooms or depletion of oxygen.

"Regional characteristics of nutrient concentrations in streams and their application to nutrient criteria development", Journal of the American Water Resources Association (JAWRA), vol.38, n°1, February 2002, pages 213-239 http://awra.org/jawra/ *Purchase full article, paper n° 01007* http://awra.org/jawra/papers/J01007.html

Abstract available at: http://www.epa.gov/wed/pages/publications/abstracts/current/rohm02.htm

C. Rohm, A. Woods, Dynamac Corporation, 200 SW 35th Street, Corvallis, Oregon 97333, USA and J. Omernik, J. Stoddard, US EPA, National Health and Environmental Effects Laboratory, Western Ecology Division, same postal address. stoddard.john@epa.gov

Switzerland

Agricultural soil phosphorus

A 179-page document published by the Swiss Federal Agency for Environment, Forests and Landscape analyses the status of phosphorus in Swiss soils and its implications for fertiliser and manure management. The document assesses the phosphorus status in long term fertiliser trials and in agricultural soil samples from different areas of Switzerland, and then analyses the transfer of information between research and agricultural practices.

The report first provides a comprehensive overview of current understanding regarding phosphorus dynamics in soils, in particular the relationship between "plant available" and "non available" phosphorus and the performances of different methods of soil phosphorus extraction. Agricultural soil contains 1-3 tonnes of phosphorus per hectare in the top 20 cm of soil. The availability of this phosphorus for plant uptake (and thus for crops) depends on the form in which the phosphorus is present, on soil biology and soil chemistry which causes phosphorus to be modified from one form to another, on the plant (crop) biology, and on endomycorhiza (fungus living within the plant root and which facilitate mineral uptake).

The report summarises different techniques for assessing the "available" phosphorus in soil, based mainly on dissolution in different media (water, $CaCl_2$, Olsen agent, Cottenie agent as used as a reference in Switzerland, ammonium oxalate

DSPox, anionic resins, amorphous iron oxide impregnated filter paper …), as well as on radio-isotope soil-solution phosphorus exchange measurements.

Losses to surface waters

Until recently, it was assumed that phosphorus was retained in soils. It is now recognised however that significant losses of phosphorus occur from soils, depending on modes of cultivation, soils characteristics and hydrography. In particular, phosphorus is carried off soils and into surface waters by erosion during winter rains and high flow periods in water courses.

Field studies

The report summarises the conclusions of 7 field fertiliser trials (lasting 15 – 25 years), soil studies using radio-isotope methods and other extraction methods, as well as monitoring of a network of farms.

The 7 field studies, started in 1971 and 1989 showed that phosphorus initially present in soils was adequate for crops, in the "control" fields without phosphate fertiliser addition, for at least ten years.

Radio-isotope analysis of soils from 250 sites in the Fribourg region (cultivated land, permanent pasture, alpine pastures) showed that 66% of samples exhibited high phosphorus saturation.

A second study of 53 sites on 11 farms in the Lake Baldegg catchment (Lucerne region) also showed excessive phosphorus enrichment of soils, with over 90% of the sites (both pasture and cropland) showing phosphorus levels higher than those necessary for crops and higher degrees of phosphorus saturation.

A study of 1023 samples of agricultural soil from the Geneva region, compared phosphorus extraction methods using water and ammonium acetate + EDTA (AAEDTA). These results were compared with field crop growth studies using soils with different AAEDTA phosphorus levels. This suggests that the region's soils contain adequate phosphorus reserves for winter wheat and that the official interpretation guideline for fertiliser application to this crop should be modified .

Observations from the Suisse Romande and Tessin network of integrated farming system (ecological constraints) indicate that in many cases the level of "available" phosphorus in soils has decreased, often to levels classified as "inadequate" using current official recommendations, but that crop production was not yet affected. This again suggests that phosphorus application can be reduced without losing productivity, and that a new definition of the "adequate" soil phosphorus content is necessary.

The report provides detailed guidance for farmers and authorities for moving towards better phosphorus management (reduced fertiliser application without loss of crop production), for different types of soils and crops.

"Le phosphore dans les sols - Etat de la situation en Suisse" Cahier de l'Environnement n° SRU 136 – Sol – Phosphorus in soils, the situation in Switzerland, 2004. Abstract in English. Available in French and German. 24 Swiss Francs.

Office Fédéral de l'Environnement, des Forêts et du Paysage OFEFP, CH 3003 Berne. jean-auguste.neyroud@rac.admin.ch *or* www.buwalshop.ch

Michigan
Key role of lake floor algae in primary production

Fertilisation experiments in four Michigan lakes enabled the response of two groups of floor-growing (benthic) algae to be measured: epixylon (growing on wood as substratum) and epipelon (growing on sediment). Benthic algae showed to contribute up to 80% of total lake primary production in unfertilised lakes, and 10-40% of total lake primary production response to fertilisation. Because benthic algae are likely to have lower productivity in fertilised (eutrophic) lakes, this means that the total lake primary production response to fertilisation may be significantly overestimated by traditional assessments which take into account only floating (pelagic) phytoplankton.

Paul, Peter East and Peter West, and Long Lakes are situated within 1km of each other in the Upper Peninsula of Michigan, USA (89°32' W, 46°13' N).

Long Lake was divided into three basins in 1991. The East and West Long Lake basins and Peter Lake were fertilised daily throughout the algal growth season (May – September) during 1993, 1994 and 1995, with phosphorus addition of 0.3 – 2.0 $mgP/m^3/day$ and N:P ratio >25. Paul Lake was not fertilised (control). This study work is documented in previous papers (Carpenter and Kitchell 1993, Carpenter *et al.* 1995, 1996, Christensen *et al.* 1996, Cottingham *et al.* 1998).

Three groups of primary producers were monitored: pelagic phytoplankton (floating algae), epixylon (benthic algae fixed on wood substrate), epipelon (benthic algae on sediments). Benthic algae were sampled by scuba diving over the whole lake floor for each lake (random selection of sampling sites) and primary production estimated by measuring chlorophyll and counting cell numbers in collected samples from given surface areas. In situ C^{14} fixation was also assessed. Similar measurements were made to assess floating phytoplankton primary production.

Benthic algae in primary production

Before lake fertilisation, benthic algae accounted for up to 80% of total lake primary production, but this fell to 10-40% in the fertilised lakes.

Epixylon primary production showed a positive reaction to lake fertilisation, but not epipelon. The authors consider that this is because epipelon, growing on sediments on the lake floor, are not limited by nutrient concentrations in the water column, because of nutrients available in the sediments/sediment pore water (nutrient concentrations in the sediment pore water showed to be 10x higher than those in the water column).

Fertilisation, on the other hand, is very likely to significantly reduce benthic algal primary production, because of the development of phytoplankton in the water column reducing light penetration.

Whole lake primary production

The authors note that sediment-growing benthic algae (epipelon) are 5-10 more productive (per unit area) than those growing on wood (epixyon) and that they cover a much greater proportion of the lake floor, including down to relatively deep areas (down to 1% light penetration). Consequently, although fertilisation may reduce epixylon productivity, the overall effect on benthic algal productivity is largely negative.

Thus, the increase in primary productivity resulting from fertilisation will be significantly lower than that predicted by traditional assessments, which take into account only floating phytoplankton productivity, for example 25% lower for Lake Peter.

The authors also note that a shift between benthic and floating phytoplankton as the main driver of primary production can be considered indicative of lake ecology modifications resulting from fertilisation (eutrophication).

"Whole-lake fertilization effects on distribution of primary production between benthic and pelagic habitats", Ecology, vol. 82, n°4, pages 1065-1077, 2001. www.esajournals.org

Y. Vadeboncoeur, D. Lodge, Dept. Biological Sciences, University of Notre Dame, PO Box 369, Notre Dame, Indiana 46556 USA, S. Carpenter, Center for Limnology, University of Wisconsin, 680 N. Park Street, Madison, Wisconsin 53706, USA. Y. Vadeboncoeur present address: Dept. Biology, McGill University, Montreal, Quebec yvonne.vadeboncoeur@wright.edu

Lake ecology

Nutrients, grazers and algal response

Two multi-lake data sets were analysed: one of 361 lake years from temperate lakes in North America and Europe (Mazumder 1994) and one of 59 subtropical lakes in Florida (Bachmann *et al.* 1996; Mazumder and Havens 1998). Four variables, available for most of the data sets, were used: total phosphorus (TP), total nitrogen (TN), chlorophyll, Secchi depth (transparency).

The temperate lakes were separated into those dominated by significant populations of large crustacean herbivores, grazers of phytoplankton (large bodied *Daphnia* taxa) = "LH" lakes, and those without such large grazers = "SH" lakes (dominated by small grazers such as rotifers, copepods and bosminids). The Florida subtropical lakes were assumed to be all "SH" on the basis of information available from literature on grazer populations in such lakes.

Statistical methods were used to analyse the four relations: TP-chlorophyll, TN-chlorophyll, TP-Secchi depth, chlorophyll-Secchi depth.

Large grazers and algae

The total phosphorus – chlorophyll relationships showed significantly lower chlorophyll yields (algal density) in “LH” (large grazer dominated) lakes than in either temperate or subtropical “SH” lakes, but similar yields between temperate and subtropical “SH” lakes. Also, both the temperate and subtropical “SH” lakes showed similar sinusoidal response curves to (log)TP whereas the “LH” lakes showed a reduced, near (log) linear response.

Nitrogen and algae

Fewer data sets included lake water TN (total nitrogen) levels. On the data available, the TN-chlorophyll relationship did not appear to be significantly different between “LH” and “SH” lakes, nor between temperate and subtropical lakes, although chlorophyll yield was generally somewhat lower in the subtropical lakes.

Multivariate TN-TP-chlorophyll analysis however showed significantly better correlation than TN-chlorophyll or TP-chlorophyll only, indicating that algae in both subtropical and in temperate lakes respond significantly to total nitrogen as a secondary independent variable.

Transparency

Temperate “SH” lakes showed greater transparency (deeper Secchi depth) for given chlorophyll levels than did subtropical (“SH”) lakes, while temperate “LH” lakes showing even greater transparency. This may be related to a larger mean size of phytoplankton in temperate lakes, but may also be the result of suspended clay particles or organic matter in subtropical lakes.

The authors conclude that their results point to a potentially important role of zooplankton grazers in determining algal development (chlorophyll) and water transparency, in both temperate and subtropical lakes. Mazumder (1994) concluded that among a large number of temperate lakes, shallow lakes with small grazers are the most susceptible lakes to algal blooms in response to increasing nutrient concentrations.

“Phosphorus-chlorophyll relationships under contrasting hervibory and thermal stratification – predictions and patterns” Canadian Journal of Fisheries and Aquatic Science, 51, 1994, pages 390-400. http://pubs.nrc-cnrc.gc.ca/cgi-bin/rp/rp2_vols_e?cjfas

“Nutrient-chlorophyll-Secchi relationships under contrasting grazer communities of temperate versus subtropical lakes”. Canadian Journal of Fisheries and Aquatic Science, 55, 1998, pages 1652-1662. http://pubs.nrc-cnrc.gc.ca/cgi-bin/rp/rp2_vols_e?cjfas

A. Mazumder, Biological Sciences, University of Montreal, CP6128, Succursale Centre Ville, Montreal QC, H3C 3J7, Canada (Current address: Water and Watershed Research Program, University of Victoria, Victoria, BC V8W 3N5 Canada). K. Havens, Ecosystem Restoration Dept., South Florida Water Management District, West Palm Beach, FL33416-4680, USA (Current address: University of Florida, Gainsville, Florida, USA). mazumder@uvic.ca

USA, Japan, China

Three shallow lakes: Challenges for nutrient-chlorophyll modelling

Data from three large shallow lakes in the USA, Japan and China were used to assess the ability of published empirical models to predict nutrient and chlorophyll concentrations.

Three large (>30 km^2), shallow (<4m mean depth) and eutrophic lakes were used to test seven different models of the relationships between nutrient loading, water nutrient concentration, and chlorophyll (algal biomass): Lake Kaumigaura (Japan, 50 km North East of Tokyo), Lake Donghu (China, near Wuhan City, Hubei Province), Lake Okeechobee (USA, 100 km North West of Miami).

Nitrogen and phosphorus budgets were calculated for each lake

Phosphorus		Lake Kaumigaura	Lake Donghu	Lake Okeechobee
Annual load	tonnes P	220	95	426
Lake retention of P		65%	80%	65%
Total P in water	µgP/l	75	400	100
Nitrogen				
Annual load	tonnes N	3890	3890	5554
Annual net loss*		69%	60%	46%
Total N in water	µgN/l	1095	3083	1504

Seven published models relating nutrient loads to in-lake nutrient and chlorophyll concentrations were tested, comparing model predictions with actual lake data:

Vollenweider 1975 and 1976
Dillon and Rigler 1974-I and 1974-II
Canfield 1983
Mazumder 1994 (SH-mix) and 1994 (LH-mix)

None of the models accurately predicted phosphorus or chlorophyll in all three lakes. The authors note that these models were developed with data from deeper temperate lakes. Extreme shallow lakes display properties not taken into account in these models, including nitrogen fixation, light limitation, and human impacts such as stocking of algae-grazing fish.

Shallow eutrophic lakes may have greater differences and specificities, with general models being less applicable than in temperate stratified lakes. Shallow lake models may need to consider especially the impacts of fish grazing on nutrient – chlorophyll relationships.

"Nutrient dynamics and the eutrophication of shallow lakes Kasumigaura (Japan), Dnghu (PR China) and Okeechobee (USA)". Environmental Pollution 11, 2001, pages 263-272.
http://www.sciencedirect.com/science/journal/02697491

K. Havens, R. James, South Florida Water Management District, PO Box 24680, West Palm Beach, FL 33416-4680, USA. T. Fukushima, Dept. Civil and Envt. Engineering, Hiroshima University, Hiroshima 739, Japan.P. Xie, Donghu Experimental Station of Lake Ecosystems, Chinese Academy of Sciences, Wuhan 430072, People's Republic of China. T. Iwakuma, Graduate School of Earth Envt. Science, Hokkaido University, Sapporo 060, Japan. N. Takamua, Regional Envt. Division, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba 305, Japan. T. Hanazato, Suwa Hydrobiological Station, Shinshu University, 5-2-4 Kogandori, Suwa, Nagano 392, Japan. T. Yamamoto, Ibaraki Prefecture, Tsuchiura, Japan.
khavens@ifas.ufl.edu

"Nutrient-chlorophyll-Secchi relationships under contrasting grazer communities of temperate versus subtropical lakes". Canadian Journal of Fisheries and Aquatic Science, 55, 1998, pages 1652-1662.
http://pubs.nrc-cnrc.gc.ca/cgi-bin/rp/rp2_vols_e?cjfas

A. Mazumder, Biological Sciences, University of Montreal, CP6128, Succursale Centre Ville, Montreal QC, H3C 3J7, Canada (Current address: Water and Watershed Research Program, University of Victoria, Victoria, BC V8W 3N5 Canada). K. Havens, Ecosystem Restoration Dept., South Florida Water Management District, West Palm Beach, FL33416-4680, USA (Current address: University of Florida, Gainsville, Florida, USA).
mazumder@uvic.ca

British Columbia
N and P co-deficiency in lake plankton

Three different nutrient ratio comparisons and three different bioassay methods were used to asses long term nutrient limitation and "immediate" nutrient deficiency in samples collected over 2 years from 12 sites in ten lakes in British Columbia, Canada (6 coastal region lakes, 4 inland lakes).

The lakes are situated approx. 48°N with surface areas ranging from 5 to 605 ha and mean depths of 3

- 23 m. Summer temperatures reach 20-25°C in the lakes. The coastal lakes show rare or no icing in winter (monomictic) whereas the inland lakes can be considered as dimictic.

The following ratios were assessed:
* PC:PN (particulate carbon : particulate nitrogen) -> indicator of N limitation
* PC:PP (particulate carbon : particulate phosphorus) -> indicator of P limitation
* TN:TP and PN:PP -> indicators or P limitation
* P debt bioassays
* N debt bioassays
* N debt AER bioassay

The AER bioassay is based on the uptake of radioactive labelled carbon after nitrogen spiking (NH_4).

Further, comparison was made between N and P deficiency results for the <3 µm phytoplankton (after filtration) and for the > 3 µm fraction. The < 3µm fraction of phytoplankton (bacteria, picoplankton) accounted for a significant proportion of biological activity (mean 62% of total darkness carbon fixation).

Different sensitivities

AER was apparently more sensitive in identifying phytoplankton nitrogen deficiency. Of 58 samples, for the > 3 µm fraction, subject to both AER and N debt bioassays, 38 showed no nitrogen deficiency with the N-debt bioassay, but only 7 with AER.

Analysis based simply on the nutrient ratios (compared to the Redfield ratio) suggested – from this data only - that when the lakes were nutrient limited, phosphorus was likely to be limiting. Particulate PN:PP ratios were however lower than total TN:TP ratios, with PN:PP ratios sometimes falling below the Redfield ratio.

PC: PN ratios further suggested that phytoplankton were nitrogen limited in some periods, and bioassays of P-debt, N-debt and AER confirmed that the phytoplankton communities were both P- and N-deficient. As would be expected, nutrient debt was greater when concentrations of dissolved nutrients present in the lake waters were low, with nutrient deficiency appearing when dissolved phosphorus was below around 0.27 µmol/l and dissolved nitrogen (NO_3^-) below around 7.1 µmol/l.

Methods

The authors note that severe P deficiency and N deficiency occurred simultaneously in many samples, although total phosphorus may be ultimately limiting over long time scales. Nutrient co-deficiency appeared as a common occurrence, rather than an exception. P-deficiency was dominated by the contribution of the < 3µm fraction of phytoplankton, whereas this fraction (bacteria and picoplankton) very rarely showed nitrogen limitation.

Particulate nutrient levels and bioassays may be more reflective of varying phytoplankton community composition and which species is more competitive. The paradigm of N-limitation in oceans and P-limitation in lakes may be due in part to differences in techniques.

Larger phytoplankton are at a disadvantage in contexts of low dissolved nutrient concentrations, because of their lower surface/volume ratio, and so proportionally smaller contact with scarce nutrients. One response to this may be to absorb P-rich bacteria. This may explain why phytoplankton show nitrogen limitation despite high TN:TP ratios. Another possible explanation is that dissolved organic nitrogen is less readily available than dissolved organic phosphorus.

The authors emphasise the need to apply several different methods for measuring nutrient deficiency and limitation to obtain a picture of the situation in any given lake, and the need to separate the <3µm fraction because of the important role of bacteria in nutrient cycling and uptake.

"Temporal changes in nitrogen and phosphorus codeficiency of plankton in lakes of coastal and interior British Columbia", Canadian Journal of Fisheries and Aquatic Science 61, pages 1538-1551 (2004).
http://pubs.nrc-cnrc.gc.ca/cgi-bin/rp/rp2_desc_e?cjfas

J-M. Davies, W. Nowlin, A. Muzumder, NSERC/IRC Environmental Management of Drinking Water, Dept. of Biology, University of Victoria, PO Cox 3020, Stn. CSC, Victoria, BC V8N 3N5, Canada jmdavies@uvic.ca *and* mazumder@uvic.ca

Spring Lake

Testing alum dosing to reduce internal P loading

Spring Lake, draining into the Grand River, Michigan, covers just over 5 km^2 with an average depth of 6m and residence time of 5 months (winter) – 11 months (summer). The catchment (134 km^2) includes around one fifth urbanisation, one fifth agricultural land, and most of the remainder forest or undeveloped land. The lake is considered eutrophic, with summer water column total phosphorus concentrations (measured in this study) ranging from 0.04 – 0.11 mg/l and Secchi depth 0.75 – 1.25m.

Sediment/water core samples were collected from four different sites (depths ranging from 5 – 10m) in June 2003, giving a 7cm diameter core samples consisting of approx 20cm sediment plus 25cm of water from above the lake bottom. 12 samples were collected from each of the four sites. They were then maintained at approximately lake water temperature and transported to the laboratory.

In the laboratory, the samples were subjected to light and temperature regimes similar to in-lake conditions, and for each site subjected to four different conditions (each in triplicate): aerobic (aeration using air) or anaerobic (aeration with nitrogen + CO_2), with or without addition of aluminium sulphate (25 mg Al/l). Water samples were taken from the columns (replacing with lake water) at 2, 4, 8, 16 hours then 1, 2, 4, 12, 16, 20, 28 days. Further data were obtained by measuring total and reactive phosphorus, chlorophyll, Secchi depth and other parameters at each sampling site on the sampling date, and by analysis of the sediment samples.

Phosphorus release

Rates of phosphorus release from the sediment were calculated from total phosphorus concentrations in the overlying water column after different times, with different time periods being used to calculate maximum, average and minimum release rates.

Existing data on time series for dissolved oxygen (DO) concentration from a deep site (frequency of anoxia) were used to estimate the proportion of time during which phosphorus release was susceptible to occur in the lake itself: DO< 1 mg/l occurring 4-25% of the time. These estimates, the authors note, may be high relative to the rest of the lake because the site in question was particularly deep.

The phosphorus release rates indicated by the laboratory experiments are in the same range as those previously calculated in literature in eutrophic systems, and indeed approach some of the highest rates previously recorded at 60-80 mgP/m^2/ day.

When compared to the estimated proportion of time for which the lake is anoxic, and to literature estimates of external phosphorus loadings for Spring Lake, this suggested that the internal loading (release from sediments) accounts for between one half and two thirds of total phosphorus loads to the lake.

Alum control of loadings

For all four sites, the lowest levels of sediment phosphorus release shown by the laboratory experiments occurred with alum dosing (with or without aeration), with anaerobic + no alum consistently giving the highest rates of phosphorus release.

Aluminium sulphate is known to reduce or prevent phosphorus release from sediments through two simultaneous mechanisms: precipitation of soluble inorganic phosphorus to insoluble aluminium compounds, and the formation of amorphous aluminium hydroxide flocs which remove both soluble and particulate phosphorus by adsorption and also settle onto the sediment surface forming a phosphorus-adsorbing layer.

The authors note that other work has shown that alum treatment of lakes may vary in its effectiveness depending on water mixing and other factors, and that a longevity of the effects of such treatments of 4-20 years can be expected.

"The reduction of internal phosphorus loading using alum in Spring Lake, Michigan", Journal of Environmental Quality, n°33, 2004, pages 2040-2048
http://jeq.scijournals.org/

A. Steinman, R. Rediske, Annis Water Resources Institute, Grand Valley State University, 740 West Shoreline Drive, Muskegon, MI 49441, USA. K. R. Reddy, Institute of Food and Agricultural Science, 106 Newell Hall, PO Box 110510, Gainesville, Florida 32611-0510, USA. Email steinmaa@gvsu.edu

Book Review

"Phosphorus in Environmental Technologies – Principles and Applications"

The new 656 page book "Phosphorus in Environmental Technologies – Principles and Applications" is the 5th in the *IWA* (International Water Association) Integrated Environmental Technology series. The book presents an overview and update on latest knowledge covering phosphorus (P) chemistry, P in the environment, P removal from wastewaters, P-recovery for recycling, and relevant novel biotechnologies. It is edited by Dr. E. Valsami Jones, of the London Natural History Museum's mineralogy department, coordinator of the phosphate recycling website

http://www.nhm.ac.uk/research-curation/departments/mineralogy/research-groups/phosphate-recovery/

The introduction section provides summaries of the chemistry, mineralogy and biology of phosphorus and of the more than 100,000 phosphorus compounds known today.

The environment section looks at the sources of phosphorus to surface waters and the related risks of eutrophication. Haygarth, Evans and Burke (*et al.*) present current understanding of mechanisms and management of phosphorus run-off from land, and relations to management of agriculture. Haygarth *et al.* explain the different stages controlling phosphorus loss: sources to soils and their relation to soil P contents, mobilisation of phosphorus in soils (thus making it potentially available for transport towards surface waters) by either solubilisation or detatchment of soil particles containing P, and transport (with water movements). The importance of "incidental transfers" (when applications of phosphorus in fertilisers or manures correspond to water discharges) is emphasised, as is the distinction between percolation (diffuse transport) and preferential flow (run-off streams along channels or drains). Burke *et al.* emphasise the importance of "VSA" (Variable Source Area), that is dynamic areas of hillside (expanding and contracting as a function of hydraulic conditions) where convergent subsurface flows meet, thus generating accelerated surface or subsurface flows (preferential flows).

Farmer presents a global overview of phosphate pollution, noting that eutrophication is a significant environmental issue worldwide with 28% of lakes and reservoirs showing problems in Africa, 41% in South America, 48% in North America, 53% in Europe and 54% in Asia. Phosphate concentrations in surface waters across Europe are generally decreasing since the 1990s. Farmer notes however the problems of inadequate implementation of EU sewage treatment legislation (Directive 91/271) and the importance and difficulty in all areas of reducing non-point (diffuse) phosphorus loads related to agriculture and land use.

15 papers address phosphorus precipitation chemistry and rector design as applicable to P-recovery, phosphorus removal from wastewaters and phosphorus recovery for recycling, including updates of full scale phosphate recycling plants operational in the UK, The Netherlands, Italy and Japan. These reports show that phosphorus recovery from municipal wastewaters is technically and industrially feasible, and that the recovered product has value as an agricultural or horticultural fertiliser. Kohler provides an overall economic analysis of phosphate recycling, and an assessment of the obstacles and issues (including an update on recent process cost estimates), and Klapwijk and Temmink summarise scenarios for implementation in The Netherlands (proposing further investigation of recovery as aluminium phosphate from P-rich streams in sewage works operating biological nutrient removal).

Kohler emphasises that "the pricing of waste water treatment has been determined by public health and regulatory considerations. This has resulted in economically inefficient pricing regimes". He concludes that, in the context of increasing implementation of EU regulations requiring nutrient removal in sewage works which drive up costs, and of pressures on sewage sludge disposal, "recycling opportunities should be identified allowing for local conditions and where economically and environmentally beneficial, should be exploited in order to keep the increase in costs down" through a systems approach.

The book features an all-encompassing approach in an inter-disciplinary text : fundamental science of phosphorus, key aspects of its environmental behaviour and mobility, industrial applications and the principles behind them, and socio-economic issues which often influence implementation and the ultimate success of any new technology. A detailed subject index is included.

"Phosphorus in Environmental Technologies – Principles and Applications", 2004. Editor: Dr. E. Valsami Jones. ISBN: 1-84339-001-9 IWA *(International Water Association) Integrated Environmental Technology series. IWA Members Price: €110.25, Non Members €147.00*
http://www.iwapublishing.com/template.cfm?name=isbn1843390019

Book

Phosphorus in Environmental Technology: *Principles and Applications*

IWA Integrated Environmental Technology Series

Provides a definitive and detailed presentation of state-of-the-art knowledge on the environmental behaviour of phosphorus and its applications to the treatment of waters and soils. Special attention is given to phosphorus removal for recovery technologies, a concept that has emerged over the past 5-6 years: the fundamental science of phosphorus (chemistry, geochemistry, mineralogy, biology), key aspects of its environmental behaviour and mobility, industrial applications (treatment, removal, recovery) and the principles behind such applications, novel biotechnologies and, importantly, it also addresses socio-economic issues which often influence implementation and the ultimate success of any new technology.

State-of-the-art knowledge on the behaviour of phosphorus and its applications to environmental science and technology. Covers all aspects of phosphorus in the environment, engineered and biological systems; an interdisciplinary text.

IWA Integrated Environmental Technology Series - ISBN: 1843390019 - June 2004 - 656 pages - http://www.iwapublishing.com/template.cfm?name=isbn1843390019

Conference

Recovery of Phosphorus from Wastewater and Sludge

12-13 December, Darmstadt, Germany http://www.iwar.bauing.tu-darmstadt.de/seminar/abwasser.html

in German

Two day conference looking at current research, experience and development in recovery of phosphorus from wastewaters and sludges, uses and applications of recovered phoshorus.

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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