SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - European Union

Application of directive 91/271: sewage treatment, and in particular P removal.

A recently published Special Report by the EC Court of Auditors looks at the implementation of EU policy and action as regards water pollution. The report looks in particular at application of the Urban Waste Water Treatment (91/271), Nitrates (91/676) and Sludge (86/278) Directives.

Concerning the Urban Waste Water Treatment Directive 91/271, dated 21st May 1991, the Auditors indicate that the Directive has still not been transposed into national legislation in Germany, Greece and Italy. This Directive also poses particular problems for reporting : seven Member States had not yet produced the required information regarding implementation (Art. 17 of the Directive) as of September 1996.

======== Deadlines for P removal ========

The Directive requires that all conurbations ("agglomerations") must be provided with "appropriate" sewage treatment by 2005 and conurbations of more than 15,000 person equivalents by 2000.

The Directive also requires (Art. 5) that P removal be installed, by 31st December 1998, for sewage plants serving conurbations of more than 10,000 person equivalents and discharging into potentially nutrient sensitive waters.

The Auditors indicate that "most of the Member States were finding it difficult to achieve... within the specified time frame" the Directive's objectives regarding installation of sewage treatment and of secondary or tertiary treatment (nutrient removal) in sensitive areas. In all the audited Member States "the authorities confirmed the possibility of their being unable to fulfil their statutory obligations... within the specified time frame."

The report indicates that currently more than 40,000 sewage works are in operation across the EU. Of those built before 1992, some 30% will need upgrading. **Overall, around 40,000 sewage works will need building or upgrading by 2005.**

Despite these problems, the EC Commission has confirmed its intention to ensure application of the

Urban Waste Water Treatment Directive within the defined time frame.

======== The Commission confirms the objectives and time scales set in the Directive ========

In the Commission's answers published with the Auditors' report, the Commission underlines that the widely differing levels of sewage treatment connection and quality across the EU should not be seen as an implementation problem, but as one of the main reasons for the existence of the Directive. **The Commission states that it "considers the deadlines for achieving the objectives... sufficient, and does not consider at present proposing any changes to the deadlines."** The Commission emphsises that not one Member State has requested changes to these deadlines and indicates that non-compliance with the Directive will result in infringement procedures.

======== Agricultural policy ========

The Auditors' report also indicates considerable problems with the application of the other Directives examined, the Nitrates and the Sludge Directive. Nitrates, in particular, pose a problem with certain populations exposed to levels in drinking water higher that the 50 mg/l limit set by the Directive. There are major contradictions between the objectives of this Directive and current EC agricultural policy: large CAP subsidies for maize for silage but little or no support for nitrogen fixing crops or nutrient retaining cover vegetation.

"Special Report no. 3/98 concerning the implementation by the Commission of EU policy and action as regards water pollution (Court of Auditors) accompanied by the replies of the Commission" Official Journal of the European Communities C191/2 18.6.98.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - USA
New Ion Exchangers for P removal

A fixed bed of a new polymeric ligand exchanger (PLE) has been tested for phosphate removal from treated urban waste waters at Bethlehem sewage treatment plant, Pennsylvania, USA, by Liegh University.

The PLE is based on the chelating resin DOW3N, containing only nitrogen donor atoms, as a parent polymer, loaded with copper II (Cu2+) for which it has a high affinity. This combination was chosen because the immobilised Cu2+ has a high affinity for phosphates (Lewis acid - Lewis base attraction). Using minicolumn experiments and PLE as 0.3 - 0.8 mm spheres, it was demonstrated that this PLE **was effective in phosphate uptake with relatively low competition from sulphates or organic compounds** present in waste water. For example: phosphate uptake rates for phosphate concentrations of 5 - 20 mgP/l were virtually unchanged with sulphate concentrations doubled from 200 to 400mg/l. The phosphate/sulphate separation factor is over an order of magnitude higher than for other sorbents previously studied. The very low levels of copper bleeding were completely stopped by adding a small amount of virgin chelating resin at the bed exit.

======== P removal and P recovery ========

The ion exchanger bed remained efficient up to around 1000 bed volumes of through flow, despite the concentrations of competing anions (eg. chloride, sulphate, nitrate and bicarbonate 10-20 x higher than those of phosphate).
The bed was applied to the effluent of the Bethlehem sewage works which had a concentration of around 4mgP/l. **Bed outflows with near zero concentrations of phosphorus (<0,1mgP/l) were achieved.**

========Struvite recovery ========

6% salt solution (brine) at pH 4.5 was found to be an efficient PLE regenerant. 90% of phosphate was recovered from the bed in less than eight bed volumes. The regenerant solution was treated with magneisum chloride or potassium chloride, resulting in the precipitation of struvite (magnesium ammonium phosphate) or potassium struvite (potassium ammonium phosphate) and replenishing the chloride ions in the brine. **The precipitated struvite was 99% pure and would be adapted for recovery for recycling in the phosphate industry or for use as a fertiliser.** The whole system demonstrated its reliability, running for over three years using secondary treatment waste water outflow from the Bethlehem sewage works (more than 100 regeneration cycles) without significant loss of efficiency or physical deterioration. No bacterial growth was observed in the bed, despite the presence of organic matter. This was probably due to the acid brine regeneration and the presence of copper. Operating costs, for a reduction from 4 mgP/l to less than 0,5 mgP/l, ranged from 25 to 35 $US per 1000 US gallons.

"Ultimate removal of phosphate from wastewater using a new class of polymeric ion exchangers" Wat. Res. vol. 32 no. 5 1998.
D. Zhao and A. K. Sengupta, Dept. Civil & Environmental Engineering, Leigh University, Bethlehem, PA 18015, USA.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Holland
Simultaneous bio P and N removal and possible Phosphorus recovery

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Both biological P removal and N removal can be achieved in the same reactor if P-stripped activated sludge is fed to appropriate zones.

A pilot plant with an influent flow rate of 35l/h was constructed to simulate conditions at the Bennekom sewage works, Holland. After preliminary sludge removal by settling, influent was passed through a Modified Renphosytem reactor consisting of **four zones:**

- in the initial **anaerobic zone** bio P bacteria use internal phosphates as an energy source to take up fatty acids, releasing phosphates into the supernatant. **The bio P bacteria are thus "activated" by P depletion.**

-in the **first aerobic zone** these activated bio P bacteria respond to aeration by using oxygen to take up phosphates from the supernatant. At the same time, ammonium is oxidised to nitrates

- **in the anoxic zone t**he bio P bacteria continue to accumulate P, but now use nitrates as an oxygen source and thus denitrify the supernatant. When all the nitrates have been removed, P will begin to be released back into the supernatant.

- **the final aerobic zone** allows optimal P uptake by the bacteria in order to remove any P released in the anoxic zone and to minimise outflow P levels.

The recycling of sludge ensures the effectiveness of bio P removal. The P rich final sludge is removed and sent to an anaerobic P stripper, where it is fed with fatty acids or acetate : the bio P bacteria thus become once more P deficient and "activated" (by the same mechanism as above) and P is released into the stripper supernatant as a sidestream.

The specificity of the Modified Renphosystem is that this activated sludge, generated by the P stripper, is fed back to both the first aerobic and the anoxic zone in order to ensure P removal and denitrification in these areas.

========= Possibility for P recovery =========

The system described included a DHV Crystalactor¨ **to recover phosphates (as calcium phosphate pellets)** from the P rich sidestream generated by the stripper (20-50 mg ortho-P/l). The authors indicate that the Crystalactor recovered 70 - 80% of the phosphates in this stream (reactor pH 8-8.6, recirculation ratio 2-3)

The configuration described resulted in total P and N concentrations in unfiltered effluent of 0.4 mgP/l and 2 mgN/l respectively.

"The Modified Renphosystem: a high biological nutrient removal system". Wat. Sci. Tech. vol. 35 no. 10 1997.
J. H. rensink, J. van der Ven, G. van Pamelen, F. Fedder and E. Majoor. Dept. Environmental technology, Wageningen Agricultural University, PO Box 8129, 6700 EV Wageningen, Holland.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Denmark
Sludge Hyrolysis improves Biological Nutrient Removal

Biological hydrolysis of sludges produces organic substances such as fatty acids which are excellent carbon sources for biological P and N removal processes. Theses substances can be used to improve reaction rates, plant capacity and nutrient removal reliability.

The process was demonstrated full scale at three Danish sewage works : Lundtofte 115,000 pe (chemical P removal and bio N removal), Viby 100,000 pe and Frederikssund 33,000 pe (both biological P and N removal). Raw or activated sludges were hydrolysed using anaerobic reactors at temperatures ranging from 8 - 20ûC.

No description is given in the paper of the equipment and process used for hydrolysis and there are no details concerning the chemicals used.
The net hydrolysis yields were 7 and 12 % with the raw sewage sludge and 2.5% with activated sludge.

========= Improvements to bio P removal efficiency =========

The use of the hydrolysis products significantly improved bio P at the two sewage works using this process (enabling outflow levels to be met without adding other carbon sources) but was not shown to improve N removal.

The hydrolysis process proved effective at temperatures of 17-18ûC with a long retention time of 5 days. At this temperature, the energy used to heat the sludge is to a large extent recovered through the sludge thickening obtained, reducing the energy needed to heat sludge digesters. Furthermore, treatment plants with anaerobic digesters will usually have low quality energy available suitable for heating to this sort of temperature. **The process thus appeared to be cost - benefit competitive at all three plants studied.**

"Reduction of nutrient emission by sludge hydrolysis", Wat. Sci. Tech vol. 35 no. 10 1997.
K. Andreasen, G. Petersen, H. Thomsen, R. Strube : KrŸger A/S, Gladsaxevej 363, 2860 Soeborg, Denmark.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Australia
Detergent phosphates don't reach sewage works as STPP

Specific resin ion exchanger chromatography was used to separate and quantify concentrations of orthophosphates and polyphosphates (tripolyphosphate, pyrophosphate) in sewage samples from the Lower Molongo Sewage Works, Canberra, Australia..

Phosphate species were separated using Dowex 1-X8 (Cl-) ion exchange chromatography and different KCl/acetate buffers for elution. Specific recovery rates of at least 85% for phosphate species added to the raw sewage demonstrated the reliability of the analysis. The analysis method is considered relatively simple and reproducible.

Of the 4.1 - 4.9 mgP/l total phosphorus contained in the sewage, around 86% was found to be dissolved orthophosphate (lowest quantifiable levels 1 µg/l). **No polyphosphates were detected**.
This conclusion confirms previous work by Halliwell et al. Analyst no. 121, 1996).

======== Polyphosphates hydrolised to orthophosphates ========

The absence of detectable polyphosphates in the sewage arriving at the treatment works is suggested to be due to hyrolysis, which converts detergent sodium tripolyphosphate (STPP) and other polyphosphates to orthophosphates. **Hydrolysis is facilitated by high temperatures and pH** (the conditions found in washing machines), but also by the presence of **multivalent cations** (Ca^{2+}, Fe^{2+}, Mg^{2+}) present in waste waters. **Bacteria in sewers** also probably play a significant role.

"Rapid method for separating and quantifying orthophosphate and polyphosphates : application to sewage samples". Wat. Res. vol. 32, no. 3.
D. Jolley, W. Maher, P. Cullen. Cooperative Research Centre for Freshwater Ecology, University of Canberra, PO Box 1, Belconnen ACT 2616 Australia.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Finland
Assessing The real Impact of Sewage Phosphates

An average of only 36% of total P present in effluent from 5 Finnish sewage works equipped with P stripping was available for algal growth in bioassays lasting several weeks. The study concludes that total P is not an adequate criterion for use in eutrophication control.

Finland has significantly improved waste water treatment and **P loading from urban waste waters is now only around 12% of early 1970's levels.** Most waste water is treated with simultaneous P precipitation which removes more than 90% of phosphorus from sewage. National targets suggest P loadings should be further reduced by setting limits for total P concentrations in outflow of 0.2 - 0.6 mgP/l, depending on sewage works size.

In order to test what proportion of total P is bioavailable, bioassay experiments using the green alga Selenastrum capricornutum were carried out on 20 one-day composite samples from 5 Finnish sewage works outflows. All five works were equipped with simultaneous P stripping using FeSO4 ; 2 were also equipped with post-precipitation and 3 with permanent or intermittent denitrification. The outflow samples contained 0.088 - 0.61 mg total P/l with an average of 24% dissolved P (range 8 - 58%). The carbon content of the outflow was low (<21 mgC/Kg of suspended solids in all samples) suggesting that the particulate matter present was essentially inorganic.

Bioavailability of phosphorus was evaluated by measuring uptake by the algae over 2 - 4 weeks in a system where P starved algae were separated from the wastewater by a membrane which allowed diffusion of dissolved substances but not of particles. The authors justify that direct contact between the algae and particles would not increase P mobilisation.

======== Only a third of total P bioavailable ========

An average of only 36% of total phosphates present in the sewage works outflows (range 0 - 67%) proved to be bioavailable. The proportion was higher in the denitrfying plants (50%) than in the post-precipitation plants (20%). In addition, the proportion of bioavailable P appeared to increase in situations where the sewage works operating capacities were exceeded. **Dissolved reactive phosphorus (DRP) was totally bioavailable, whereas only 22% (0 - 74%) of dissolved unreactive P and 25% (0 - 54%)**

of particulate P were bioavailable.

Although the amount of P becoming bioavailable at the end of the bioassays was very small, 2-4 weeks is a very short time scale compared to P cycling in natural systems. As a consequence, the assessment of long term bioavailability cannot be considered certain. The low bioavailability ratio may also be related to the efficiency of the purification processes at these five sewage works (total P removal of 87 - 98%): the bioavailable P is likely to be the fraction most easily removed in sewage treatment.

The authors conclude that **total P, alone, is not a satisfactory criterion for defining and evaluating eutrophication control measures** related to municipal waste water P loading.

"Bioavailablility of phosphorus in purified municipal waste waters". Wat. Res. vol. 32 no. 2.
P. Ekholm, Finnish Environment Institute, PO Box 140, FIN 00251 Helsinki and K. Krogerus, HŠme Regional Environment Agency, PO Box 297, FIN33101 Tampere, Finland.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Lake Windermere, UK
Tertiary sewage treatment Key to Restoration

Lake Windermere is England's largest natural lake and one of the most well known natural assets and leisure attractions of the Lake District. Major eutrophication problems started in the 1960's but a restoration programme is proving successful. This success is mainly due to P removal at the sewage works.

Studies of sediment cores from the lake offer an understanding of its geographical history. The lake appeared 14,000 years ago in the wake of the last glaciation. Initially, tundra-type vegetation released clay and fine debris, rendering the lake fairly fertile. From around 10,000 - 3,000 years ago, the lake was oligotrophic and unproductive as nutrients were retained by dense forests (birch, pine, hazel). Nutrient release to the lake has gradually increased since then as a result of human modification of the landscape. This has accelerated over the last four centuries with timber harvesting and sheep rearing. The lake's fauna and fauna changed aver the 18th and 19th centuries to a steady mesotrophic state.

In the 1960's however, the lake rapidly moved to a eutrophic state. Dissolved phosphorus concentrations rose rapidly. It gradually became clear that this was not simply a natural cycle of variation but a real and continuing problem. Blue-green algal blooms appeared. The deep water oxygen deficit began to affect the breeding success of the arctic charr, a fish species originating from the glacial period, valued by fisherman.

========= Sewage treatment ... causes pollution problems =========

Phosphorus budgets showed that the rapid increase in concentrations could not be accounted for simply by the increased fertiliser use or increasing populations of catchment area villages. **The main cause of the problems was in fact the increase and improvement in sewage treatment!** Septic tanks and soak-aways, in particular, were proving inadequate and were being replaced by mains drains. The sewage and nutrients were thus being transported to the sewage works which discharged into the rivers feeding the lake. Furthermore, the sewage works were breaking down organic material and producing soluble available phosphates.

70% of the lake's total phosphorus load was coming through the Ambleside and Tower Wood

sewage works, and this made up 93% of soluble phosphates reaching the lake.

North West Water therefore took the courageous decision to introduce **tertiary P-stripping** to these two works, in 1992, well before any legal requirement to do so.

The lake's quality began to improve almost at once. Reductions in phosphorus concentrations and algal growth and improvements in deep water oxygen concentrations were noted as early as 1993. Arctic charr breeding has now begun to recover.

The lake's phosphorus load is still higher than pre-1960 levels but further reductions should be possible by continuing to implement improvements in sewage treatment.

"Back from the brink: reversing the deterioration of Windermere" Cumbrian Wildlife no.50 1998.
C. Reynolds, Windermere Laboratory, Institute of Freshwater Ecology, UK

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - North West Midlands, UK
Lake ecosystems show no Response to Phosphorus levels

Three small lakes on the glacial outwash plain of the UK North West Midlands were studied to assess response to changes in nutrient loading resulting from the diversion of sewage inflow.

Mere Mere (15.8 ha, max. depth 8.1m) feeds via a stream into Little Mere (2.5 ha, max. depth 2.6m) which then feeds Rostherne Mere (31ha, max. depth 31m). Since the 1930's and until June 1991, sewage effluent was discharged into Little Mere.

======== Significant P inputs ========

Quantities were significant : making up an average of 40% of lake inflow (2-10% in winter and over 90% in summer) and contained high organic levels, due to sewage works overloading and inefficient operation. Nutrient loading also comes from the catchment area which is made up of agricultural land, small villages and a golf course. Farming methods have significantly intensified over the last 50 years.

Little Mere has responded to the reduction in nutrient loading resulting from the introduction of sewage diversion. **Total P concentrations have fallen from around 2 mg/l to around 60µg/l;** oxygen concentrations have increased permitting fish recolonisation (particularly perch) ; but nitrate concentrations have not changed significantly. **The lake's general ecosystem has not, however, changed significantly**. Before the sewage diversion, the lake was plant dominated and the water remained clear with algal growth controlled by *Daphnia magna*. After this diversion, submerged plant growth was accentuated and the zooplankton population evolved. The lake remained in a plant dominated state. It is not yet clear whether algal growth is limited by grazing by plant associated *Cladocera* or by nitrogen limitation.

Rostherne Mere, on the other hand, showed little or no change three years after sewage diversion. **Total P levels have remained high despite the major reduction in external loading. This is thought to be because of very efficient P recycling within the lake and its sediments and a very low level of P washout.**

========= P recycling between water and sediments =========

P is released from the sediments in Spring and Summer, when it is necessary for plant and algal growth, but when outflow is low.

In winter, when lake outflow is higher, P descends back into the sediments and the bottom water, and is retained in the lake. A low P loading from the catchment area may have been effectively concentrated by the lake's ecosytem over time : data from the 1970's suggest that P has been abundant in Rostherne Mere for many years and that nitrogen is probably the limiting nutrient.

During the same period, **Mere Mere**, which was located upstream of the sewage inflow has shown various fluctuations, offering a useful point of comparison for the other two lakes.

These examples show the capacity of lakes to achieve **stable plant dominated states which are resilient to changes in external loading**. They also show that natural P recycling can lead nitrogen to become the limiting nutrient, mitigated by the production of nitrogen fixing cyanophytes.

"Vertically challenged limnology; contrasts between deep and shallow lakes". Hydrobiologia 342/343 1997.
B. Moss, M. Beklioglu, L. Carvalho, S. Kilinc, S. McGowan, D. Stephen, Dept. Environmental and Evolutionary Biology, University of Liverpool L69 3BX, UK

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Germany
Reducing lake water Phosphorus by Calcite Precipitation

Experiments were carried out to assess the affect on phosphate concentrations of calcite precipitation (calcium carbonate CaCO3) induced by injection of CaO and aeration of the deepest water layers of the eutrophic hard water lake Dagowsee in Germany.

This lake has a surface area of 0.24 km2 and phosphorus concentrations in early Spring of around 0.005 mgP/l orthophosphate and 0.067 mgP/l total P. Four 10m diameter enclosures in the deepest part of the lake (9m) were used. These were open to the bottom sediment and embedded in it. The volume of each enclosure was 700m3.

Around 700g/enclosure of CaO was injected on five dates in the late Spring. This was followed each time by aeration for 24 hours.

========= Effective P removal =========

Compared to the control enclosure, these CaO injections were calculated to have ensured **96% removal of orthophosphates and 73% removal of total phosphates.** Levels stayed much lower through into the following winter, whereas in the control enclosure they rose during the summer and were significantly higher during the following winter. From one winter to the next, orthophosphate levels decreased from 30 to 2µg/l in the treated enclosure, and total phosphate from 80 to 60µg/l.

The phosphorus removal was thus significantly better than that obtained by surface application of lime Ca(OH)2.

The phosphorus content of precipitated calcite was calculated as around 0.1% by weight. The coprecipitation efficiency was thus comparable to values given in laboratory experiments and with natural waters (eg. A. House).

"A balance analysis of phosphorus elimination by articicial calcite precipitation in a stratified hard water lake" Wat. Res. vol. 31 no. 2 1997.
M. Dittrich, R.Koschel, Institute of Freshwater Ecology, Dept. of Stratified Lakes, Alte FischerhŸtte 2,

D16775 Neuglobsow, Germany. T. Dittrich, Physics Dept. E16, Technical University Munich D85747 Garching, Germany. I. Sieber, Hahn-Meitner Institute, Rudower Chaussee 5, D12489 Berlin, Germany.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Germany
Calcite precipitation in natural waters

The precipitation of calcium carbonate CaCO3 as calcite in natural waters is influenced by many factors, of which the most important are calcium concentrations and food web activity (uptake or release of CO2). Inorganic phosphate also has a significant influence by inhibiting calcite crystal growth as phosphates are incorporated into the surface.

This paper provides an overview of different studies on calcite precipitation and provides information on the variability of calcite crystal formation.

Calcite precipitation is a natural cleaning mechanism for lakes. **Coprecipitation removes phosphates from water: the P content of calcite ranges from 0.01 to 1% by weight.** Other minerals and organic material are also removed to sediment due to flocculation caused by the calcite crystals. Calcite precipitation has been observed to increase sedimentation rates and the transport of phosphorus, particulate matter and algal cells to the sediments.

"Structure and function of pelagic calcite precipitation in lake ecosystems" Verh. Internat. Verein. Limnol. 26 1997.
R.Koschel, Institute of Freshwater Ecology, Dept. of Stratified Lakes, Alte FischerhŸtte 2, D16775 Neuglobsow, Germany.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Canada & North America
N and P fertilisers added to lakes permit Salmon recovery

Lake enrichment programmes in Canada are proving successful in restoring commercial salmon fisheries whilst maintaining the ecosystem.

Three papers present the experience of a number of years' treatment of lakes in British Columbia, Canada. P and N fertilisers are added to restore the nutrient levels necessary for salmon breeding.

======== Kokanee Salmon in the Kootenay lake========

Kootenay Lake (395 km2) has suffered various perturbations resulting, in the 1980's, in the collapse of Kokanee Salmon stocks. These ecosystem changes included the upstream construction of reservoirs, which held back nutrients, and the introduction of an exotic shrimp species which competes with young fish for zooplankton food sources.

A five year 1992-1996 programme of nutrient addition was launched to permit salmon population recovery. 47 tonnes/year of P and 206 tonnes/year of N were added to the 174 km2 North Arm of the lake.

Fertilisation resulted in increased zooplankton densities. Kokanee Salmon escapement increased and in 1994 reached the highest levels since 1986, comparable to 1970's levels. Spawner size and fecundity also increased.

======== Pacific Anadromous Sockeye Salmon========

The Canadian Lake Enrichment Programme has now been running for 20 years involving 20 lakes. The aim is to restore Anadromous Sockeye Salmon fisheries. This species, the most valuable Pacific coast commercial salmon, had fallen into a declining cycle : habitat destruction and overfishing had reduced populations and escapements, thus reducing nutrient input to nursery lakes (fewer decomposing adult carcasses bringing in imported nutrients).

The addition of liquid fertilisers to lakes has led to increased bacteria, phyto- and zooplankton abundance, and a doubling of primary biomass production. The results are increased growth and survival of juvenile salmon (smolt weight has increased by 60%) and **larger fishery takings worth 10 - 20 million $ Can./year.**

======== Demonstration in lake enclosures ========

Fertilisation experiments in large lake enclosures in America have also demonstrated the effectiveness of the technique and the capacity to maintain water quality.

Juvenile Kokanee salmon were used for experiments in enclosures in Redfish Lake, Idaho. The objective was to assess the potential of lake nutrient enhancement for the declining and protected Snake River sockeye salmon.

Fertilisation of the metalimnion in the large enclosures substantially increased primary production (+250%), zooplankton levels (+200%) and enabled a measurable increase in fish growth (+12%) compared to control enclosures. At the same time, water transparency declined only to a limited extent (<15% change) and community compositions of phyto- and zooplanktons changed little.

The authors concluded that **whole lake fertilisation would aid the recovery of Snake River sockeye salmon without deteriorating the aesthetic value of the lake.**

"Restoration of an interior lake ecosystem : the Kootenay Lake fertilisation experiment". Watere Qual. Res. J. Canada vol. 32 no. 2 1997.
K. Ashley, D. Sebastian, Fisheries Branch, British Columbia Ministry of Environment. L. Thompson, Fisheries Centre, University of British Columbia, Vancouver V6T 1Z4 British Columbia. D. Lasenby, L McEachern, K. Smokorowski, Dept. Biology, Trent University, Peterborogh, K9J 7B8 Ontario, Canada.

"British Columbia lake enrichment programme : two decades of habitat enhancement for Sockeye Salmon" Regulated Rivers Research and Management vol. 12 1996.
J. Stockner, E. MacIsaac, Dept. of Fisheries and Oceans, West Vancouver Laboratory, 4160 Marine Drive, West Vancouver V7V 1N6 British Columbia, Canada.

"Adding nutrients to enhance the growth of endangered sockeye salmon: trophic transfer in an oligotrophic lake" Transactions of the American Fisheries Society 127 1998.
P. Budy, C. Luecke, W. Wurtsbaugh, Dept. of Fisheries and Wildlife Ecology Center, Utah State University, Logan, Utah 84322 - 5255, USA.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Holland
Reduced grazing of nutrient Limited algae

Experiments looking at grazing efficiency of 2 species of Daphnia on 2 species of green algae showed that P and N limited algae were less effectively digested. This was shown to be due to cell wall morphology adaptations.

The experiments used the zooplankton grazer Daphnia pulex and Daphnia magna and the green algae *Chlamydomonas renhardrii* and *Selenastrum capricornatum.*

The nutrient limited algae mostly passed intact and viable through the zooplanktons' gut, thus being spared from grazing pressure. As a consequence, the Daphnia in this situation showed reduced growth. This lower zooplankton productivity is then passed on up the food chain.

It was further shown that the **nutrient limited algae developed thicker cell walls, probably due to stocks of proteins, carbohydrates and lipids** being lain down within the cell wall. The improved survival against grazers may thus simply be a side effect of storage of different molecules within the cell because of retarded cell division. Other algae in nutrient limited conditions are known to produce extracellular mucous, which may also protect against grazers' digestive systems.

A control was carried out using wall deficient mutant algae. No reduction of grazing efficiency was noted when these mutant algae were nutrient limited, suggesting that the grazing effect was indeed due to cell wall morphology changes and not to other factors.

"Altered cell wall morphology in nutrient deficient phytoplankton and its impact on grazers". Limnol. Oceanogr. 42 (2) 1997.
E. van Donk, M. LŸrling, Dept. Water Quality Management and Aquatic Ecology, Agricultural University, Wageningen PO Box 8080, 6700 DD Wageningen, Holland. D. Hessen, Dept. biology, University of Oslo, PO Box 1207 Blindern, 0316 Oslo, Norway G. Lokhorst, University of Leiden, Research Inst. Rijksherbarium, PO Box 9514, 2300 RA Leiden, Holland.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Australia / Darling River
Factors causing Blue-Green algal blooms

A three year field study of factors controlling algal growth in the Darling River looked at the environmental conditions initiating cyanobacteria growth, nutrient supplies and phosphorus sources.

The study was carried out for the Murray Darling Basin Commission and centred around the Bourke township weir pool. Two significant cyanobacterial blooms occurred during the three year study, with smaller populations appearing intermittently and providing more complete data.

The study confirmed **the importance of flow rates in limiting algal growth**. Cyanobacterial biomass only became excessive when the flow rate in the weir pool fell below 500 ML/day and did not occur in free flowing stretches of the river (without dams or weirs). The two blooms were also associated with periods when low flow rates were also accompanied by intense thermal stratification.

Cyanobacterial growth was stimulated by decreased turbidity. This occurred in particular **at periods of low flow rate which permitted saline ground water intrusions**. These raised Mg2+ and Ca2+ concentrations and caused particles to coagulate and settle, thereby reducing turbidity and letting light penetrate the water to stimulate algal growth.

The Darling River has high P/N ratios and the cyanobacterial blooms occurring are dominated by nitrogen fixing species. However, **total P level was found to be a poor predictor of nutrient limitation because much of the P is bound to particles and is not bioavailable**. The cycle of P release from sediments into water is thus a key factor in determining nutrient availability for algal growth. Nutrient management strategies must take this into account.

==== Natural sources may account for all sediment phosphorus ====

The study suggests that natural soil sources could alone account for the sediment P present in the Darling River. Anthropogenic sources may have had no detectable effect on these levels. **Nutrient input limitation strategies should therefore target reducing bioavailable nutrient releases into**

particularly sensitive river reaches rather than relating to overall nutrient input.

The study's conclusions indicate that flow management is the key tool for regulating algal blooms and that the potential for effective nutrient management actions is unclear.

"Cyanobacterial blooms in the Darling River". Water May-June 1998.
R. Oliver, C. Rees - MDFRC Albury. M. Grace, B Hart - Water Studies Centre, Monash University. G. Caitcheon, J. Olley - CSIRO Land and Water, Canberra, Australia.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - Germany
Mechanisms of Phosphorus release from Sediments

The extent of P release from sediment and its effect on bottom water soluble reactive phosphate (SRP) concentrations were studied in 20 stratified lakes in North East Germany.

SRP concentrations in interstitial water amongst lake sediment particles are considerably higher than lake water concentrations, even bottom water concentrations, in stratified lakes. The concentration gradient was found to be highest at the end of the summer (water stagnation period), meaning that SRP diffusion rates were then at their highest.

The pH in the upper layers of the sediment decreased at this period, sulphate concentrations fell and concentrations of NH4+ increased. The concentrations of SRP and NH4+ were closely correlated.

========= Mineralisation =========

It was concluded from the NH4+ correlation that SRP release from the sediment was mainly a result of mineralisation of organic matter.

Chemically induced P release, resulting from lower pH and/or lower redox potential, may have a higher influence on P release towards the end of the summer than it does earlier in the year.

"Variations of phosphorus release from sediments in stratified lakes" Water, Air and Soil Poll. 99 1997. T. Gonsiorczyk, P. Casper, R. Koschel, Institute of Freshwater Ecology, Dept. of Stratified Lakes, Alte FischerhŸtte 2, D16775 Neuglobsow, Germany.

SCOPE NEWSLETTER

SCOPE N°27 - 09/1998 - USA
Non point source pollution

Point sources of nutrients and pollutants are relatively easy to identify and control, and have in many cases been significantly reduced over recent years. Non point sources, on the other hand, can be intermittent, may be spread over large areas and are difficult to manage.

The report underlines the role of non point sources particularly P and N, in eutrophication problems. Even if point sources were reduced to zero, 72 - 82% of eutrophic lakes would require control of non point P inputs to meet water quality standards. **Non point sources are also dominant contributors of P and N to most US rivers**. In one study of 86 rivers, non point sources of P made up more than 90% of input in a third of cases. **Non point sources are also 9x higher than inputs from waste water plants to the North Atlantic coastline**.

========= Importance of landscape management =========

The main non point sources are related to agricultural run off rom fertiliser and manure.

Urban run off is however significant and is the third most important cause of lake eutrophication in the US, affecting 28% of lake area. Urban run off results from soil erosion at construction sites (the biggest cause), lawn fertilisers, pet wastes, septic systems...

Actions to reduce non point sources are presented and include rational fertiliser use, animal waste management and landscape restoration. In particular, both vegetation buffers along waterways and wetland restoration can significantly reduce nutrient input to surface waters.

"Non point pollution of surfce waters with phosphorus and nitrogen" - Issues in Ecology report no. 3 1998.
Ecological Society of America, 2010 Massachusetts Avenue NW, Suite 400, Washington DC 20036.
