SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Holland

Environmental P standards revisited

Data from several Dutch waterboards (60 environmental variables, >4,000 samples from streams and >1,000 samples from ditches) were used to establish quality levels for 12 different inland aquatic ecosystems for 8 variables: conductivity, chloride orthophosphate, total phosphate, nitrite + nitrate, ammonium, potassium and chlorophyll-a.

The sampled sites were classified into 12 different ecosystem types : 6 stream ecosystem types (hill streams upper, middle and lower reaches; lowland streams upper. middle and lower reaches) and 6 ditch ecosystem types (sandy, clayish and peaty, bottomed ditches ; acid, brackish and slightly brackish ditches).

========= Biodiversity =========

For each ecosystem type, data were available covering a range of states from pristine undisturbed through to strongly impacted sites.

The quality classification for each type were was defined as a function of the presence and abundance of different species of macroinvertebrates (for running waters) and of macrophytes, macroinvertebrates and epiphytic diatoms (for ditches). Critical species of these groups are very sensitive to environmental impact. Common species occur over a wide range of environmental states whilst certain tolerant species are abundant only in heavily impacted sites. This work enabled the environmental quality level of the aquatic ecosystems to be classified from 1 to 5. The detailed methodology is described in 5 reports of the Dutch Association for Applied Water Research (1992 - 1995).

========= Quality levels =========

Statistical analysis was then used on the classified ecosystem data to calculate the level of the different parameters corresponding :

- for "general environmental quality (GEQ)"
  75% of sites achieving at least middle quality (3/5)

- for "specific environmental quality (SEQ)"
  50% of sites achieving highest quality (5/5) or nearly highest (4/5) where data was limited

This method enabled field data derived environmental quality levels to he calculated and proposed for the variables studied. The levels for total phosphorus and nitrite+nitrate are set out below:

Proposed environmental quality levels

mg/1	**total P**		**nitrite+nitrate**	
	GEQ	**SEQ**	**SEQ**	**SEQ**
hill stream upper reaches	0.38	0.24	11.00	4.95
hill stream middle reaches	1.03	0.72	8.10	4.24
hill stream lower reaches	1.35	1.00	5.00	4.65
lowland stream upper reaches	0.40	0.15	9.54	2.40
lowland stream middle reaches	0.76	0.18	6.51	5.64
lowland stream lower reaches	0.76	0.36	6.10	5.00
sandy bottomed ditch	0.32	0.08	2.12	0.34
clayish bottomed ditch	0.66	0.17	2.20	0.89
peaty bottomed ditch	0.28	0.14	6.51	5.64
acid ditch	0.05	-	0.14	-
brackish ditch	0.42	-	2.3	-
slightly brackish ditch	1.9	-	1.28	-

======== Current standards revisited ========

The current Netherlands environmental standard for total phosphorus is 0.15 mg/l, based on summer average values from shallow, stagnant eutrophication sensitive waters. **The proposed quality levels for total phosphate (table above), based on the field data are higher, and generally considerably higher, for all of the studied ecosystems except acid ditches.**

Concerning nitrogen, the proposed **nitrite+nitrate** quality levels are 2 - 5 times higher than the current Netherlands standard for total nitrogen.

On the other hand, the quality levels for **chlorophyll-a** proposed in the study, on the basis of the field data are significantly lower than the general environmental quality standard of 100 mg/l.

The authors conclude that environmental quality levels for nutrients need to be specific and water type dependent. Existing overall standards for phosphorus and nitrogen, extrapolated from certain particular situations, are not defendable as general overall standards for streams and ditches.

"Ecologically based standards for nutrients in streams and in the Netherlands" Water Science technology vol 37, no. 3, 1998

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SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Temperate streams

Variations in phosphorus - chlorophyll relationships

Literature data for total phosphorus and chlorophyll levels were assembled for 115 Northern Hemisphere and one Southern Hemisphere temperate streams and rivers. The P-chl relationship was examined and compared with data on catchment areas.

From these rivers and streams, a total of 292 data points were established, each corresponding to the mean of at least 5 samples. Total phosphorus concentrations at these averaged data points varied from 5 to 1030 µg/1, with a mean of 192 µg/l. Chlorophyll levels varied from 0.4 - 170 µg/1, with a mean of 27 µg/l.

Statistical methods were used to compare log-log scales (log total P µg/l against log chl µg/l). **Graphs of direct linear comparisons are not given, presumably because these would show excessive scattering.**

A best statistical relation between log TP and log chl is established as being curvilinear (not linear)

An optimal equation of :

$$\log chl = - 1.65 + 1.99 x \log TP - 0.28 x (\log TP)^2$$

gave a curve where a **majority of data points fell within 65% confidence limits.**

======== Effect of catchment area ========

Catchment areas for the 116 streams and rivers studied varied from 1 to 541.000 km² with most catchments in the range 450 -66.000 km².

Catchment area was found to be weakly but significantly correlated to total phosphorus (r=0.44, $p < 10^4$ when log values were compared) and somewhat more strongly correlated to chlorophyll (r=0.54). That is : **larger catchments tend to have higher phosphorus and chlorophyll concentrations.**

Catchment area modifies statistical log(chl):log(TP) ratio

The best fit equation relating log chlorophyll to log total phosphorus was found to be:

$\log chl = -1.92 + 1.96 \times \log TP - 0.3 \times (\log TP)^2 + 0.121og\ A_C$
(A_C = catchment area in km^2).

Increasing the catchment area thus appears to lead to an increase in the log(chl):log(TP) ratio (ie. higher chlorophyll levels are found for a given phosphorus concentration).

The introduction of the catchment area (A_C) into the equation accounted for 18% of the variation in chlorophyll not accounted for by the curvilinear log chl - log TP model above.

The authors indicate that the correlation between catchment area and chlorophyll levels may result from different physical factors which are known to vary with catchment area and to affect chlorophyll levels. One factor, in particular, would be the mean flushing rate.

This would confirm previous studies (Burkholder-Crecco and Bachmann 1979, Jones et al. 1984, Soballe and Kimmel 1987) which suggest that statistical average algae concentrations are lower, for given total phosphorus levels, in streams compared to lakes, due to flushing rates. On the other hand, algal levels in lakes are often limited by low nitrogen/phosphorus ratios, low euphotic depth:mean depth ratios or high levels of suspended solids.

The authors conclude that the chlorophyll: phosphorus ratio in a river draining a 100,000 km^2 catchment can be to be approximately half that of a lake, and the ratio in small stream, to be to he roughly, half that again.

"Phosphorous chlorophyll relationship in temperate streams and its variation with stream catchment area" Can. J. Fish Aquatic Science no. 53, 1996.

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SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - UK

Eutrophication of nature conservation sites

A site by site study was carried out on 102 UK nature conservation areas previously identified by conservation agency staff as apparently deteriorated by eutrophication.

The sites studied are all inland aquatic "SSSI's"- (areas of nature conservation value classified Sites, of Special Scientific Interest), obtained by classifying into individual water bodies 120 SSSI's (some contained 2 distinct water bodies, one water body was covered by 2 SSSI's): The sites included 90 lakes, ponds and reservoirs, 17 wetland and ditch systems, three narrow boat canals and 16 rivers. Coastal sites were not studied, but contacts with conservation bodies (English Nature) indicated that there are significant concerns regarding eutrophication of coastal grazing marshes and estuarine sites, as well as inland non-aquatic sites such as peat bogs or ditches.

======== Inadequate monitoring ========

The 102 sites studied had previously been indicated as apparently deteriorated by eutrophication but **objective data was often missing.** The UK National Rivers Authority, except for a few, sites, does not routinely monitor total phosphorus. Where soluble reactive phosphorus is measured, the methods used give a lower detection limit of 50 µg/l - this is adapted for sewage or industrial waste waters, but not for lake and river monitoring, where lower detection limits of 5 µg/1 are essential and readily obtainable.

Available data concerning the effects of eutrophication, where available, were generally limited to record notes indicating increases in phytoplankton or, occasionally, declining macrophytes.

Existing data was therefore completed from scientific literature and from original analyses.

Of the 102 sites studied, phosphorus levels at 65 sites were hypotrophic (UK Dept. of the Environment definition : total P>100 mg/l) and 13 eutrophic (>50 mg/l). 84% of sites showed symptoms of eutrophication (i.e: stratification of dissolved oxygen, effects on fauna, macro- and microflora).

======== Causes of eutrophication : predominance of sewage

sources ========

The primary causes of eutrophication related changes were evaluated for the 79 sites identified.

In certainly 44% of these sites and most probably in 50%, the primary cause of eutrophication related change was identified as mains sewerage effluent. Nutrient control, including either sewage phosphorus removal or sewage diversion, is already being introduced at a small number of these sites.

The second most widespread cause of change in sites was **imbalances in the fish communities.** This was caused, in particular, by overstocking of common carp *(Cyprinus carpio)* which churn up bottom sediments releasing nutrients, and bream *(Abramis brama)* as well as reducing zooplankton populations (and thus affecting algal grazing). Fish communities were identified as the primary cause in 19 - 27% of sites.

Other primary causes identified included farm animal wastes (9 - 18%) and septic tanks (4 - 5%)

======== Application of the Urban Waste Water Treatment Directive ========

The EC Urban Waste Water Treatment Directive (91/271) requires the installation of phosphorus removal in sewage works serving conurbations of more than 10,000 pe. and discharging into "eutrophication sensitive" surface waters.

Some 2/3 of the sites, where mains sewage is identified as the primary cause of eutrophication problems, receive effluent from sewage works of less than 10,000 pe. **To ensure protection of these sites, it is therefore necessary to go beyond the specifications of the EC Directive.**

The authors, also underline that this Directive is not, at present, adequately applied in the UK. Generally, only polluted river systems have been designated as eutrophication "sensitive areas", whereas pristine ecosystems can be affected by nutrient loadings which are small in absolute terms but represent a significant relative change. Also, areas not receiving discharge from sewage works of >10,000 pe. are not classified as thereby preventing adequate monitoring.

"The current status of a sample of English Sites of Special Scientific Interest subject to eutrophication" - Aquatic Conversation : Marine and Freshwater Ecosystems, vol. 5 1995.

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SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Mesocosm eutrophication

Polluted sediment releases algal growth

2m^3 outdoor mesocosms filled with natural surface water were studied over three years and then used for a closely monitored eutrophication ecoassay from January - March 1997. Polluted sediment resulted in significantly increased algal growth at comparable nutrient levels, probably because of a reduced and modified algae -grazing zooplankton population.

The effects of **"naturally polluted" sediment (collected from Ketelmeer at the mouth of the river Ijssel, a branch of the Rhine)** were composed with relatively "unpolluted" sediment from lake Oostvaardersplassen. In order to ensure temperature variations comparable to natural waters, two 2m^3 mesocosms (0.8m deep, 2m diameter inert plastic tanks) filled with "unpolluted" natural surface water from Markemeer, were installed outdoors embedded in the ground 50 cm apart.

Both mesocosms initially contained Markemeer water and a 30cm layer of polluted or unpolluted sediment. They were then used for a variety of observations and small experiments from 1993 - 1996. In December 1997, both mesocosms were drained and refilled with fresh Markemeer water in order to ensure comparable starting conditions for an ecoassay involving intensive observation of plankton and zooplankton development.

========= Differing zoocommunities =========

The initial 1993 - 1996 period enabled a number of observations. Mysid shrimps *(Neomysis integer)* added to both mesocosms produced nearly 3 times as many juveniles in the "unpolluted" mesocosm. The microlepidoteran *Cataclysta lemnata* was regularly observed in the "unpolluted" mesocosm but was absent in the polluted one. Amoebae densities were much higher in the "polluted" mesocosm with some species present in large numbers being absent in the other one. In addition, the biting midges *Culex sp.* were present in abundance in the "polluted" mesocosm and absent in the other one.

It was also noted that the "unpolluted" mesocosm had consistently substantially lower algal densities than the "polluted" one, except when duckweed growth on both mesocosms limited light penetration.

======== Algal growth not related to nutrient levels ========

At the beginning of the 1997 ecoassay, water conditions in both mesocosms were measured and found to be very similar. Higher silicate and inorganic nitrogen levels appeared in the "unpolluted" mesocosm but disappeared by mid February. **Soluble phosphate levels in the water in the two mesocosms never differed significantly,** increasing, in both from around 1 µmol/l in January up to around 6 µmol/l in March.

Plankton development however was very different between the two mesocosms. Initially, chlorophyll-a levels were twice as high in the "unpolluted" mesocosm (under 50 µg/l) but algal growth in the "polluted" mesocosm showed exponential development in early February reaching 230 µg/l. This was nearly twice the level of 120 µg/l reached in the "unpolluted" mesocosm at the same time. After this peak, algal density fell in both mesocosms, but remained twice as high in the "polluted" one, stabilising at around 100 and 50 µg/l respectively.

The species composition of the algae in the two microcosms remained similar, with domination by *Microcystis aeruginosa* and flagellates, the latter being s1ightly more abundant in the "unpolluted" microcosm".

======== Modified zooplankton populations ========

The microcosms were covered with ice during January, filling. and after the ice had melted zooplankton densities were extremely low.

The cladoceran population first began to develop in the "unpolluted" mesocosm at the start of February. Development began only two weeks later and more slowly in the "polluted" system. *Daphnia longispina* was the most abundant cladoceran in the "unpolluted" mesocosim, whilst virtually the only cladoceran present in the "polluted" system was *Bosmina longirostris.*

The most abundant group in both mesocosms was copepods (mainly *Cyclops sp.*), present in comparable numbers in both systems. Rotifers were nearly absent.

======== Daphnia and reduced algal grazing ========

The authors suggest that the **increased algal growth in the "polluted" mesocosm may be the result of slower and different Cladoceran population development, resulting in lower algae-grazing efficiency.** The sensitivity of *Daphnia sp.* to low levels of toxicants has been demonstrated elsewhere (eg. Hanazato 1991), and this was confirmed by experiments using D. magna in the sediment mesocosms : their survival after one week was 50% lower in the "polluted" system.

The toxicants in the "polluted" sediment may be preventing *Daphnia longispina* from developing. *Bosmina longirostris*, which appears in the "polluted" mesocosm as the dominant Caloceran species has a lower maximum rate of population increase. Its reproduction cycle is different from *Daphnia sp.* which may render it less capable of responding to algal growth. *B. longirostris* is also smaller than *D. longispina* which probably also makes it less efficient at grazing fast-growing algae.

The authors conclude that the low levels of different chemicals seeping out of **"naturally" polluted sediments collected from the lower Rhine river area can indirectly cause algal blooms,** by reducing Cladoceran algae-grazing. This can occur in situations with nutrient levels comparable to an "unpolluted" area where no algal bloom may appear.

"Mesocosm observations on the response of an aquatic community to sediment contamination" Water Science technology vol. 36, no. 6-7, 1997.

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SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - **River Swale, Yorkshire, UK**

Soluble phosphorus reductions in river water

Three sampling campaigns in October 1995 (after a dry autumn), February and April 1996 monitored water chemistry and flow, at upstream and downstream sites 55 km apart and at the confluence of the 3 major and 15 significant tributaries along this reach.

Dissolved silicon, calcium, soluble phosphorus, total phosphorus, nitrate, nitrite and ammonium concentrations were measured. Nutrient point sources and catchment land use were also assessed in order to compare calculated nutrient movements with predictions.

======== Silicon equilibrium ========

Water mass balance results were found to be very coherent : the sum ofwater inflows measured differed by only 2.4 - 7.6% from the outflow downstream.

Dissolved silicon concentrations were somewhat higher in February with relatively limited variations along the reach of river. **The silicon mass balance corresponded closely to water mass movements** (difference <0.3%) indicating that riverine interactions, such as the dissolution of mineral silica or uptake by diatoms, are not significant. This is probably because of the slow kinetics of silicon reactions.

======== Water hardness and calcium ========

The calcium mass balance is strongly influenced by the harder water inflows of the downstream tributaries. **Comparison of calcium movements with the water mass balance indicates significant losses in April.** This is probably a result of calcium carbonate deposition induced by biofilm photosynthesis whereby reductions in dissolved CO_2 lead to increases in pH. This agrees with lower CO_2 concentrations and higher calcite supersaturation measured in the April sampling.

======== Reductions in dissolved phosphorus ========

Losses from the water of soluble reactive phosphorus (SRP) are very significant for all three

monitoring campaigns: 63%, 37% and 26% of outflow mass balances in October, February, and April respectively.

These losses are probably the result of uptake by sediments, macrophytes and benthic algae. This was indicated by measurements of the equilibrium phosphorus concentration (EPC) in samples of sieved bed sediment. EPC averaged 0.84 µmol/l, with no discernible downstream trend, compared with an average concentration in the overlying water of 6 µmol/1 at low flow.

Fluvarium experiments further confirmed that collected sediments showed a net soluble phosphorus, uptake when the overlying water's concentration exceeded around 2.5 µmol/1.

Unlike soluble reactive phosphorus (SRP), total phosphorus (TDP) was nearly constant along the river reach in April. This is consistent with in-strearn conversion of SRP to organophosphorus or polyphosphate compounds in the spring period.

On the other hand, mass balances for particulate phosphorus show a net loss in October (when low flow conditions prevailed after an early autumn with little rain), but large gains in February and April. This may be the result of **uptake of soluble reactive phosphorus (SRP) onto suspended matter** during periods of high flow. This occurs when bank erosion and surface run-off bring soil particles and other matter into the river water with subsequent settling or suspended particles during the low flow in October.

Total phosphorus exports in the river water leaving the catchment and tributary sub-catchments were calculated from the measured data. Annual export of SRP and total phosphorus from the whole catchment area were thus evaluated at 0.15 and 0.72 $kg/m^2/day$ respectively. These values were then compared with estimations made using evaluations of land use (i.e., values based on studies in literature by crop, vegetation type, livestock population, etc) and of point sources. These figures proved to be coherent : the measured values fell within the ranges predicted.

The predicted export values suggest that the most important sources of phosphorus are sewage, pigs, cattle and sheep, as well as cereals in the lowland areas, with some additional contribution from poultry and grassland.

======== Nitrate run-off ========

The nitrate balance shows little gain or loss of nitrate as the river moves downstream. The small loss in October (9.9%) corresponds to around 200 $\mu mol/m^2/hour$ which is consistent with denitrification in the sediments.

Ammonia, on the other hand, showed a very large loss in February and a significant loss in April. Nitrites were also substantially lost in February but increased significantly in April. Concentrations of ammonia and nitrite, however, were so much smaller than those of nitrates that their changes did not contribute significantly to the nitrate balance.

It was noted that nitrate exports, which averaged 64 kg/km^2/day on an annual basis for the whole catchment, were very much increased in the high flow rates of February, particularly in the lower catchment area which has more intensive agriculture. This is consistent with nitrogen exports coming mainly from diffuse land run-off. However, whilst the spring and autumn export values are close to those predicted from land use information, the winter high flow export is considerably higher.

"A mass balance approach to quantifying the importance of in-stream processes during nutrient transport in a large river catchment", Science of 'the Total Environment, 210/211, 1998.

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SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Ireland

Lake through flow, sediment P and eutrophication

Lake water monitoring results in White Lough (Northern Ireland) for the period 1978-1983 were compared with comprehensive chemical analysis and diatom counts from a sediment core sample. Analysis of the core sample back to 1960 also allowed comparison of past eutrophication states of the lake with land use and water through flow (ie. residence time).

White Lough is a 7.4 ha kettle lake located in the main drumlin belt of Northern Ireland, the mean and maximum depths are 6.2 and 10.7 m. The lake is thermally stratified from late April/early May to September/October.

The catchment is entirely made up of grassland agriculture with no point nutrient sources. **Unusually, the bovine load and intensity of agricultural inputs decreased significantly from 1973 - 1988** with stability or a slight increase since then.

Lake P concentrations at various depths and throughout the year were monitored from July 1978 - October 1983, with a number of further measurements in 1977, 1991 and 1992. P, iron and inflow loads, were also monitored. These results were compared with analysis of a 20 cm sediment core taken in May 1992 from nearly the deepest part of the lake. This core was depth dated using ^{210}Pb, ^{137}Cs, ^{134}Cs and ^{241}Am profiles, giving an approximate accuracy to within 2 years. Sediment levels of potassium, calcium, phosphorus, iron and magnesium plus diatom counts were established for each year from 1960 to 1990.

The dating showed that the lake sediment was dry mass at a rate which doubled from 0.03 to 0.06 g/cm/year over this 30 year period.

======== Accuracy of diatom inferred total P concentrations ========

Sediment diatom count results were compared with a training set based on 49 Irish lakes. **This model proved to give accurate predictions of lake water total P level changes** (annual average levels varied front around 50 to 100 µg/l) but with a tendency to overestimate. This overestimation may be due to a bias in the training set towards (lower) Winter - Spring levels.

Examination of species distribution within the core diatom counts showed **considerable species turnover which probably related to changes in the eutrophication state of the lake** (see below). The expansion of *Stephanodiscus hantzschii* in the lake in the 1970's, for example, corresponds to an eutrophication episode.

======== Eutrophication switch ========

Core diatom counts provide evidence of a strong and rapid eutrophication episode in White Lough from 1973 - 1979. This is confirmed by sediment **calcium levels** which are nearly constant throughout most of the core, but increased in this period. This was probably because of high lake productivity which increased pH and caused calcite precipitation.

The authors suggest that this period of eutrophication was the result of reduced lake water through flow rates since increased residence time equated to reduced flushing. The residence time in White Lough was significantly reduced in 1971, 1973 and 1979, corresponding, when taking into consideration the 2 year accuracy of core-dating, to the eutrophication episode.

Changes in through flow rate can significantly change in White Lough because the average residence time is around one year. Flow rates therefore will significantly affect the flushing of nutrients which are released from sediments at certain times of the year. On the other hand, in lakes with much lower residence times. such released nutrients are flushed out irrespective of flow variations; while in lakes with much longer residence times, the flow changes are averaged out over several years and only small quantities of nutrients are flushed out.

======== Sediment P drop causes eutrophication switch ========

The eutrophication episode corresponds to a significant drop in P sediment levels. This seems contrary to intuition since eutrophication might be expected to lead to deposition of P-rich organic matter as algae die and sink.

The authors suggest, however, that sediment P release is acting as a forward feedback by, accelerating eutrophication which results from reduced flushing. Manganese and, to a more limited extent, iron concentrations in the sediment also drop during the eutrophicalion episode. This suggests that increased lake productivity and algal growth are causing chemical release of these elements and, in particular, P, because of the development of anoxic condition at the sediment-water interface.

Sediment P is therefore acting as a strong positive feedback which results in a rapid move to high eutrophication levels. This occurred in White Lough despite steady or falling external nutrient loads due to reduced agricultural activity.

Following the eutrophication episode, water flow rates returned to more normal levels in the 1977-78 winter. Whilst sediment iron levels returned to normal by 1980 and aquatic P by 1982-83, the **eutrophication condition of the lake, as measured by, the algal growth shown in the sediment core diatom counts, did not recover until 1983-85.**

"Accuracy of diatom inferred total phosphorous concentrations and the accelerated eutrophication of a lake due to reduced flushing and increased internal loading" Canadian Journal Fish. Aquat. Science n°54, 1997.

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SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Canada

Larger zooplankton mean lower chlorophyll levels

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42 deep (>20m maximum depth) oligotrophic - mesotrophic lakes in a broad band across Southern Ontario were analysed in the spring (immediately after the ice-out) and summer in 1986, 1987 and 1988.

Phosphorus concentrations (total P = TP) and chlorophyll concentrations were measured as well as Secchi depth (turbidity), colour and various chemical parameters. The summer zooplankton populations were assessed using a 64µm mesh net dragged from the surface to the lake bottom near the deepest point of the lake.

========= Zooplankton variation =========

The size distribution of crustacean zooplankton was found to be highly variable. Zooplankton length was estimated to contribute 13% of the variation in total zooplankton biomass.

Variations in zooplankton size distribution were related negatively to the proportions of cyclopoids and to the abundance of *Daphnia sp.* Calanoids were the most plentiful crustacean contributing and made the highest contribution to zooplankton biomass, but their biomass did not correlate with mean zooplankton length.

========= Correlations with fish populations =========

Mean zooplankton lengths were not correlated to lakes' chemical or morphological characteristics, but were correlated to the populations of certain fish. Cisco *(Coregonus artedii)* was present in 32 of the 42 lakes and this factor accounts for 21% of zooplankton mean length variation. The presence of *Mysis relicta* (in 21 Out of 42 lakes) also significantly affected zooplankton size, with **the two fish species together accounting for 29% of mean length variation.**

The effects of other fish with planktivorous life stages (eg yellow perch *Perca flavescens* present in all of the lakes) was not taken into account. As a consequence, fish population variations probably have a greater effect on zooplankton size than indicated by the above figures which are based on the absence or presence of only two species.

It is noted that many, of the lakes have lost the native deepwater lake trout *(Salvelinus namaycush)* which is capable of regulating populations of cisco and other planktivores.

========= Zooplankton size and phytoplankton =========

Zooplankton mean length was negatively related to chlorophyll concentrations (r=-0.42) and to chlorophyll/TP ratio (r=-0.31). There was no relationship between zooplankton length and water clarity, turbidity or spring phosphorus levels. However, **there was a correlation with the decline in phosphorus front spring to late summer and thus with summer TP levels** (r =-0.31 in both cases).

Further analysis showed that summer TP levels were related both to spring TP levels (strongly, 0.89) and to mean zooplankton length (significantly but less strongly, -0.23).

The authors conclude that **changes in the size and structure of zooplankton populations, which can result in modifications to fish populations, could produce changes in trophic status for lakes** in this southern area of the Canadian Shield. The most likely situation is that of smaller zooplankton, resulting from the introduction of planktivorous fish and the exploitation of piscivorous species, leading to increases in summer chlorophyll and phosphorus levels.

"Zooplankton size and its relationship to trophic status in deep Ontario lakes" Canadian Journal of Fisheries and Aquatic Science, no.54, 1997.

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SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Northeast USA

N:P ratio as an ecological indicator

Aquatic biological and chemical parameters for 365 lakes in the Northeast of the USA were analysed and compared with studies of zooplankton populations and information regarding latitude, land use and other external factors.

Twenty-one of the initial 385 lakes ill the data set were excluded because of specific external influences (e.g., road run-off, calcinareous soil, etc ...). The 364 lakes studied had a median size of 26 ha and a watershed of 706 ha. Total dissolved N ranged from 7.14 to 180 µM/l (median 23.8) and total P from <0.01 to 5.7 µM/l (median 0.32).

The N:P ratios ranged from 13 to 1765 with a median of 74. Over 97.0% of the lakes had an N:P ratio < 300.

======== Zooplankton and N:P ratio ========

Zooplankton were collected from each lake in a net haul which was located at the deepest point of the lake and operated from 0.5m above the lake bottom through to the surface of the water.

The results showed that zooplankton populations were highly correlated ($p<0.01$) with lake water N:P ratios. High N:P ratios corresponded to lakes with more large zooplankton such as omnivorous *clodocera* and calanoid copepods. Low N:P ratios corresponded to populations with a high proportion of small zooplankton such as rotifers, nauplii and other juvenile stages of cyclopoid copepods. Large cladoceran herbivores tended to be more prominent at intermediate N:P ratios.

These results correspond to theoretical expectations in that intracellular N:P ratios are known to vary between different zooplankton types, decreasing, for example, from 35-50 down to 15-25 through omnivorous calanoids, omnivorous cladocerans and herbivorous cladocerans (Steiner et al. 1992, Sterner & Hessen 1994). Opportunistic r-selected species such as *Daphnia* and small cladocerans have higher requirements for P relative to N, than the slower growing k-selected competitive species such as calanoid copepods and cyclopods. This difference is attributed to the higher cellular RNA content needed for protein production for rapid growth.

Carniverous and omnivorous zooplankton require more N relative to P than do herbivores such as *Daphnia*.

In high N:P ratios, the phytoplankton will be P-limited so that food source quality may constrain the growth and reproduction of certain zooplankton. This may explain the dominance of calanoid copepods over *Daphnia* in high N:P ratio lakes. However, these relationships are much more complex in lake waters due to other factors such as nutrient recycling and predation.

========= N:P ratios and external factors =========

Both total nitrogen and total phosphorus in the lakes' waters were inversely correlated to the N:P ratio when compared with zooplankton variations. **This suggests that it is this N:P ratio and not the ambient concentrations of N and P which explain compositional changes in the zooplankton food web.**

The N:P ratio and total nutrient concentrations were found to be strongly influenced by watershed land use, i.e., relative proportion of different forest types, wetlands, agriculture and residential use.

It is suggested that the difference between a lake's observed N:P ratio and the value expected from its watershed type can provide an indicator of anthropogenic disturbances such as excessive run-off, soil disturbance or point source pollution. The "pre-disturbance" N:P ratio in lakes can be inferred from sediment diatom counts thereby further reinforcing the information offered by this indicator concerning recent lake changes.

However, other ecological disturbances may also cause observed zooplankton composition to differ from expected values. For example, either excessive small fish stocking or destruction of cool-water refuges used by predatory fish will both lead to a dominance by small zooplankton.

The authors conclude that the N:P ratio is a simple and robust indicator of lake status, changes from natural conditions and related ecological risks.

"A Zooplankton N:P ratio indicator for lakes" Env. Monitoring and Assessment no. 51, 1998.

R. Stemberger, Dept. Biology and E. Miller, Environmental Studies both Dartmouth College, Hanover, NH 03755 USA.

SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Scotland

Algal bio-indicators show neither P nor N limitation

Experiments using alginate film immobilised algae show that they can be a reliable and simple indicator of eutrophication (as related to water quality). Algal growth in two tributaries of the River Dee is thus shown to be significantly different and related to water quality, but in neither case limited by P or N.

Experiments were carried out both in the laboratory, using collected river water and bioassays of free algal cells, and in the field using algae immobilised in alginate film. Both local and exotic algal species were included in this test regime.

The water samples were taken from two tributaries of the River Dee in North East Scotland, upstream of Aberdeen, both with catchments of around 40 km^2. The Water of Dye has an upland catchment in the Eastern Cairngorms, draining mainly heather moorland and rough grazing land. The water is therefore of high quality but acidic (average pH 6.5) with naturally very variable flows. Long term average orthophosphorus-P and nitrate-N concentrations are 8.3 and 310 µg/l, respectively. Leuchbar Burn, on the other hand, drains from the eutrophic Loch Skene which has a catchment dominated by arable and mixed agriculture. Its flow is thus nearly constant, of lower quality and average pH 7.9. Nutrient concentrations are higher with long term average orthophosphorus-P and nitrate-N concentrations of 56 and 2800 µg/1 respectively.

======== Neither N nor P limitation ========

As a first stage, laboratory algal bioassays were carried out using unfiltered water from each tributary and three strains of algae. These were the reference isolate *Scenedesnus subspicatus* NIVA-CHL.55 from the Norwegian Institute of Water Research and two native strains isolated from the River Dee which were preliminarily identified as *Scenedesmus* strain UD16 an unicellular cyanobacterium strain UD32.

Growth bioassays were carried out using free algal cells over a five day period with algal growth measured by light absorbency. Growth response consistently increased in the order: cycanobacterium UD32, Scenedesmus UD 16 and NICA-CHL.55 ($p<0.001$).

Growth of all three strains was always greater in the Leuchar Burn water than in that from the Water of Dye ($p<0.001$).

However, the addition of N (by up to 10x in the oligotrophic Water of Dye) and P (up to 50x) had no influence on the growth response of the algal cells from either site, indicating that algal growth was not limited by either N or P in either tributary.

The authors note that, contrary to general assumptions, P is not the limiting factor for algal growth in these two tributaries. They suggest that the limiting factor in the upland water may organic carbon content, either through limitation of light penetration or due to direct toxicity of certain humic acids.

========= Reliability of immobilised algae =========

Sheets of immobilised algae were produced by making cell suspensions in aqueous sodium alginate then gel hardening onto nylon mesh sheets using calcium chloride. The films were suspended parallel to the running water flow of the rivers for two weeks. Films were analysed for algal growth using light absorbance and chlorophyll-a extraction after 2, 7 and 14 days. All the experiments were carried out in films placed in dialysis bags after initial tests had shown that the exposed alginate films could be colonised by water snails.

Field results agreed with those obtained in the laboratory. All three algal strains grew consistently in the Leuchbar Burn, whereas the Scenedesmus strains grew only slowly in the Water of Dye and the cycanobacterium actually decreased. Overall differences in growth rates in the alginate immobilised systems in the field were consistent with the differences between the three algal strains observed in the laboratory.

The authors conclude that in situ alginate immobilised algae provide a robust and reliable indicator of the real algal growth potential of waters, as opposed to the nutrient status.

The strain *Scenedesnus subspicatus* NIVA-CHL.55 proved to be an effective and sensitive biomonitor. The inclusion of native algal strains allowed the development of biomonitors adapted to specific local conditions.

Such relatively simple methods provide useful information on the actual algal growth potential of waters as opposed to nutrient loading. This data could be used as the basis for a realistic water quality index which takes into account local habitat conditions.

"Algal growth responses to waters of contrasting territories of the River Dee, North east Scotland" Water Resources vol. 32 no. 8, 1998.

H. Twist, A. Edwards, Macaulay Land Use Institute, Craigbuckler, Aberdeen AB 15 8 QH, Scotland, UK. G. Codd, University of Dundee, Dundee DD1 4 HN, Scotland UK.

SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Korea

Phosphate precipitation from night soil

Highly concentrated organic waste (night soil) was used to examine interactions between biological nitrogen/phosphorus removal (aerobic, anaerobic and anoxic phases), their effect on pH, and phosphate precipitation as struvite and calcium phosphate (hydroxyapatite).

The night soil used had very high organic and nutrient levels, with P:N and N:COD ratios quite similar to piggery wastes.

	nightsoil used	**piggery waste**
pH	7.8	7.8
total P (mg/l)	810	236
total N (TKN mg/l)	4,480	1,258
TCOD (mg/l)	45,800	10,580

Laboratory scale batch sequencing reactors were used to access N and P removal kinetics employing screened night soil from existing treatment plants at Seoul, Korea. Different aeration cycles were tested:

Hours	**anaerobic**	**aerobic**	**anoxic**
Mode 1	4	16	4
Mode2	6	12	6
Mode3	8	12	4

Nutrient concentrations were measured hourly and sludges were tested after fractionation in order to distinguish cell-R Ca-P, Mg-P, Fe-P, Al-P, adsorbed P and soluble P.

======== Nitrogen removal and pH ========

Using Mode 1, nitrification was incomplete. The longer aerobic periods in Modes 2 and 3 enabled complete nitrification but nitrites were not completely removed in the shortened aerobic period. Nitrate levels, for all three Modes, were around 90 mg/l after 24 hours.

Denitrification, which was high in the initial anaerobic period, leaded to a pH increase from below pH 8 to around pH 8.3. Once air feed aeration was turned on, however, nitrification took place and pH decreased again from pH 8.3 down to around pH 7.6.

======== Phosphate kinetics ========

In all three Modes, soluble phosphate levels (PO_4-P) fell from 150-180 mg/l to around 60 mg/l by the end of the initial anaerobic period. However, they, then rose progressively, during the aerobic period, before beginning to fall again during the anoxic Period (to 110-155 mg/l final value).

This evolution is the opposite of what would be from a biological P-removal metabolism where P uptake occurs in aerobic conditions and P release in the anaerobic phase. It was therefore suggested that P-removal and release were related to chemical precipitation with increasing pH and re-dissolving occurring with falling pH.

X-ray diffraction analysis showed **that the main precipitates were struvite and hydroxyapatite** with the former created during the initial anaerobic period and the latter in the terminal anoxic stage. Struvite could not be found during this anoxic period due to the absence of ammonia.

Overall, the reactors over 24 hours reduced soluble phosphate ($P0_4$-P) from 440-780 mg/l to 110-155 mg/l, ie. to around 17% of influent levels. Removed phosphate was found to be mainly chemical precipitants (42% of influent P) and as cellular phosphates (36%), with the remainder being adsorbed into sludges (5%).

"Phosphorus removal from night soil with sequencing batch reactor (SBR)". Water Science Technology vol. 36 no. 12 1997.

S. Oa. Dept. Civil and Env. Engineering, WooSong University San 7-6 Jayang-dong, Dong-ku, Taejeon 300-100 Korea. E. Choi, Dept. Civil and Env. Engineering, Korea University, 1-5 Ka Anam-dong, Sungbukku, Seoul 136-701, Korea.

SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Korea, Turkey

Nutrient removal using struvite precipitation

Two separate studies look at the precipitation of struvite (magnesium ammonium phosphate) as a method for removing nutrients from wastewaters: the first study, (Tünay *et al*) uses wastewaters from the leather tanning industry; in the other (Shin and Lee) the toxic industrial wastewater is of unspecified origin.

Both studies involve laboratory beaker tests to establish appropriate chemical conditions for struvite precipitation: pH, concentrations and ratios of magnesium, ammonium and phosphate. The effects of interfering or inhibiting molecules such as calcium are also considered.

Tünay *et al* work with ammonium and phosphate concentrations from 200 to 1800 mg/l. They indicate an **optimal pH of 9.** Shin and Lee working with concentrations of 100 mg/l suggest **increased N and P removal up to pH 10.5.**

Tünay *et al* indicate that above molar concentrations of magnesium and phosphate did not significantly improve ammonium removal (at pH 9). Shin and Lee indicate that ammonium and phosphate removal both increased up to an optimum at a 2:1 (N:P ratio) and ammonium removal up to a 1.5:1 (magnesium:N ratio). Tünay *et al* indicate a high ammonium removal with a magnesium at +30% above molar ratio.

Tünay *et al* indicate that the addition of coagulants such as $FeCl_3$ and $Al_2(S0_4)_3$ did not affect ammonium removal.

======== Effective ammonium and phosphate removal ========

Tünay *et al* indicate ammonium removal rates mostly over 75%. Shin and Lee indicate **ammonium and phosphate removal levels of 82.6% and 97% respectively, at pH 10.5.**

Both studies used $MgCl_2$ to provide the concentrations of magnesium necessary for struvite precipitation but Shin and Lee also tested **other magnesium sources : sea water and bittern** (the bitter solution of salts remaining after sodium chloride is extracted from brine). Bittern and sea water offered somewhat lower ammonium removal rates (72% and 52% compared to 83% for $MgCl_2$) but similar phosphate removal rates (99% and 95% compared to 97%).

======== High P levels in precipitated struvite ========

Shin and Lee found the P:Mg ratio in the struvite produced to be around 1.8, which was higher than the theoretical ratio of 1.3. This confirmed previous figures obtained from struvite in anaerobic digesters (Maqueda, Rodriguez & Lebrato, Wat. Res. 29, 1994)

Shin and Lee indicate that the reaction time needed to be at least 10 minutes and preferably 20 minutes. They provide data concerning precipitated particle size and formation which indicate that struvite precipitated mainly as hexagonal plate crystals of size 1.5 - 7 µm with good settlability. They indicate that 80% of the struvite redissolves at pH<8, making the retained nutrients available if the product were to be used as a fertiliser.

Both studies conclude that struvite precipitation is a potentially effective method of ammonium removal from wastewaters. Tünay *et al* suggest that leather tanning wastewaters can be brought down to 50 mg/l ammonium. Shin and Lee indicate that around 97% of phosphorus can also be removed.

"Ammonia removal by magnesium ammonium precipitation in industrial wastewaters" Wat. Sci. Tech. vol 36 no. 2-3, 1997.

O. Tünay, I. Kabdasli, D. Orhion, S. Kolçak, Istanbul Technical University, Civil Engineering - Environmental Engineering Dept., Ayazaga Kampüsü, 80626, Istanbul, Turkey.

"Removal of nutrients in wastewaters by using magnesium salts", Environmental Technology vol 19, 1997.

H. S. Shin, S. M. Lee, Dept. Civil Engineering, KAIST, 373-1 Kusong-dong, Yusong-gu, Taejon, 305-701 Korea.

SCOPE NEWSLETTER

SCOPE N°30 - 01/1999 - Phosphate recycling

Possibilities for P recovery from animal manure

The phosphate industry's joint research association CEEP (Centre Européen d'Etudes des Polyphosphates) has published a study assessing the potential amount of phosphorus in Dutch animal wastes which is feasibly accessible for recycling. Report available on request.

Holland has one of the largest concentrations of farm animals in Europe : 4.4 million cattle (including 740,000 veal calves), 15 million pigs and 93 million chickens (1997).

As a consequence, Holland imports 214,000 tonnes of phosphorus per year (net) and uses a total of 269,000 tonnes in agriculture with the difference coming from recycled crop wastes. The study includes a flow chart of quantified phosphorus pathways indicating that **an estimated 77,000 tonnes (P) accumulate each year in Dutch soils** and 12.000 tonnes (net) **are exported to the sea.**

========= Increasing recovery potential =========

The report suggests that animal manure is the waste flow with the greatest potential for recovery of phosphorus for recycling in Holland. **The 86,000 tonnes/year of phosphorus in anima manure corresponds to around 200,000 tonnes P_20_5 of which around 7.5% is currently excess to agricultural spreading limitations and thus potentially available for P recovery. This proportion will rise to 10% by 2002.**

Despite developments, such as reductions in animal numbers/concentration, or reduced inputs from animal feeds, which may reduce the manure excess or P availability, the general tendency towards tighter manure spreading standards and the limitation of manure exports will continue to increase available manure.

========= Obstacles to manure processing =========

One of the main obstacles to P recovery from animal manure, identified by the report, is the resistance to centralised manure processing initiatives. Farmers are unwilling to pay the costs of such processing and financiers are unwilling to invest after the failure of recent large projects. Furthermore, regulators are unwilling to force farmers to pay and local residents are consistently opposed to such installations.

Some of these obstacles may diminish with time. **Very large intensive livestock farms, which are increasingly developing, are more prepared to investigate new manure processing methods.** Farmers are currently willing to pay manure disposal prices of NLG 15/tonne though this may increase with with tighter manure spreading and export regulations.

======== Veal calves : a recycling installation is already running ========

Cattle are not a significant potential source of manure for recovering phosphorus for recycling by the phosphate industry. This is because cattle farms are generally non-intensive, with large areas of land which allow manure to be disposed of by agricultural spreading.

Veal calves, on the other hand, are raised in intensive installations and produce a highly fluid slurry in which around half the phosphorus is present in a dissolved form. **The report estimates that around 50% of veal calf manure is feasibly accessible for P recovery** : **1,000 tonnes P_20_5 per year.**

A 100.000 m^3/year plant is already producing struvite magnesium- or potassium ammonium phosphate) from veal calf manure at Putten. The process route involves struvite precipitation by the addition of magnesium oxide to the aerobically digested manure.

======== Pig manure : not readily accessible for P recovery ========

The report concludes, for two reasons, that pig manure will not provide a source of P for recycling in the foreseeable future. First, manure processing is too expensive for pig farmers as evidenced by recent failures of centralised manure treatment projects. Second, the phosphorus in pig manure is 90% undissolved, so that any P recovery process would necessitate an additional preliminary biological or chemical digestion stage.

======== Chicken manure : considerable potential for incineration ========

Chicken waste from modern intensive rearing units is relatively dry and has both a high energy and phosphate content. These two factors, along with the move towards very large industrialised chicken production units, mean that incineration **for energy purposes or gasification of chicken wastes are likely** to develop. **P_20_5 Contents of 23.2% are reported for the incineration ash.**

Two chicken waste burning electricity generating plants are already in operation in the UK and a third is under construction. Total projected capacity for the three: 665,000 tonnes of waste/year, almost 65% of generated chicken waste.

Although there are a certain number of potential obstacles (local opposition to plant licences, tightening of flue gas standards, current low electricity prices), **the report considers that incineration of chicken wastes is likely to develop in Holland. It is estimated that 29,000 tonnes/year P_20_5 are potentially available for P recovery from this source.**

"Phosphate recovery from animal manure - the possibilities in the Netherlands" report commissioned and published by CEEP (Centre Européen d'Etudes des Polyphosphates), 1998.

L. van Ruiten, F. van Vooreburg, P. ten Have, Van Ruiten Adviesbureau, Holland.

NEWSLETTER

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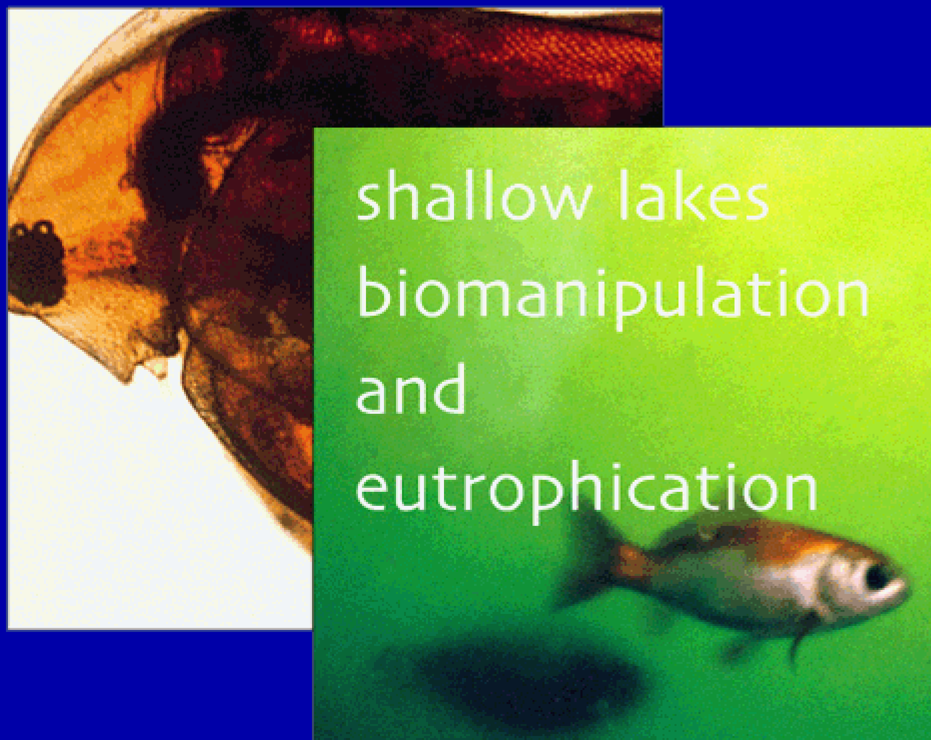

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contents

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - Germany
Deviations from the OECD phosphorus/chlorophyll model

Three shallow soft-water reservoirs in the Wupper River catchment area (Rheinishe Schiefergebirge) were studied to assess the possible reasons for chlorophyll levels not corresponding to the OECD model.

This model (Clasen 1981) suggests that chlorophyll-a levels are linearly related to total phosphorus levels. Whilst such a relationship can be found for some reservoirs in this area, the three reservoirs studied gave the following results.

mg/m^3	chl.-a	total P
Brucher	4.4	55
Wupper	8	30
Lingese	22.6	58

========= Fish populations and large daphnids =========

Significantly different balances of both fish and zooplankton grazer populations were identified in the three reservoirs :

- **Brucher** zooplankton was dominated by large red coloured daphnia and diaptomids, whilst fish population was very reduced with no re-stocking
- **Wupper** contained a varied zooplankton population of medium size grazers. The fish population was also varied with cyprinids of large adult size regulated by pike and zander.
- **Lingese,** on the other hand, had a zooplankton community dominated by small rotifers. The cyprinid fish population was very dense with many individuals of small size.

After considering other variants (light, temperature, other nutrients, etc.) the study concluded that a

healthy zooplankton population is the key factor for limiting algal development in these reservoirs, and that large daphnia play a particularly important role because of their grazing efficiency. Overstocking with cyprinid fish prevents the development of such a zooplankton grazing community.

======== Using particulate organic nitogen for zooplankton assessement ========

The study also looked at possible experimental methods for assessing zooplankton communities. Results were compared between microscope population counts and netting with different meshes.

The use of particulate organic nitrogen (PON) measurements after netting with a 780µm net was suggested as giving a reasonable estimate of the numbers of medium-large zooplankton grazers, and thus the **zooplankton community's grazing efficiency.** Mean PON>780µm measurements in the three reservoirs studied were, for example, 6.2µg/l in Brucher, 0.1µg/l in Wupper and zero (undetectable) in Lingese.

No algae were ever found in the 780µm net hauls but results need to be corrected by ensuring that carniverous zooplankton (eg. *Leptodora*) are not present.

"Derivations from OECD predictions in softwater reservoirs: effects of the zooplankton structure". Arch. Hydrobiol. 138-3 1997.
W. Scharf, Wupperverband Limnological Lab., Zur Schafbrücke 6,
D 42283 Wuppertal, Germany.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - USA

Estuarine ecology - Copepod grazing affected by toxicants

The short term effects of very low copper concentrations on the grazing behaviour of three copepod species were compared to long term toxicity. Significant reductions in algal grazing were shown to result from sublethal copper levels comparable to those often found in estuaries situated near industrial areas.

Two estuarine copepods (*Acartia tonsa* and *Acartia hudsonic*a) and one nearshore marine copepod (*Temora longicornis*) were used for these assays. Both water and organisms were collected from the Mullica River estuary near Tuckerton, New Jersey, USA.

As a first stage, acute toxicity was studied, using 72 hour exposure to copper concentrations in the range pCu 13.1 – 9.51 (ie. 1 part copper per 1013.1 to 1 part per 109.51). This showed that significant mortality resulted only from copper concentrations above approximately pCu 9.8 – 9.5 for both *Acartia tonsa* and *Temora longicorni*.

======== Significantly reduced algal grazing ========

Nine different feeding experiments were then carried out using the three copepods. Bottles containing the copepods were suspended in the estuary or placed in controlled incubators designed to imitate natural conditions (light, temperature). The copepods were first exposed to different copper levels without food for 24 hours, then fed the estuarine diatom alga *Skeletonema costatum* for 2 hours. They were then immediately filtered out, washed and frozen. Analysis for pigments (chlorophyll-a and pheopigment-a) was used as the indicator of food uptake.

Grazing rate was found to increase in copper concentrations in the range pCu 12 – 11, but to significantly decrease at concentrations above pCu 10.1 – 10 (pCu 11 for *Acartia hudsonica*). These concentrations are comparable to those found in estuaries near industrial areas (pCu 12 – 10, Stearns & Sharp 1994), whereas unpolluted estuarine and coastal waters normally have copper levels around pCu 13.

The authors conclude that **levels of copper occurring in coastal waters around industrial countries**

can have significant detrimental effects on the rate of algal grazing by copepods, with consequent deterioration of copepod egg production and destabilisation of population dynamics.

"Sublethal effects of cupric ion activity on the grazing behaviour of three calanoid copepods", Marine Pollution Bulletin vol. 34, n° 12, 1997.
A. Sharp and D. Stearns, School of Civil and Env. Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332-0355, USA.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - Canada
Motor boats and phosphorus

Two similar shallow lakes in the Whiteshell Provincial Park, Manitoba, Canada, were studied to assess the changes resulting from intensive use by motor boats.

The two lakes are similar in depth, temperature, watershed geology and vegetation and both had little external pollution. Brereton Lake, on the one hand, has significant motor boat use, including a water ski club, whilst motor boats are not allowed on Lyons Lake.

Water samples were taken in the spring and autumn from both lakes and a number of criteria compared.

========= Turbidity and phosphates =========

Turbidity was higher in Brereton Lake both in spring and in autumn. However, whilst turbidity decreased in Lyons Lake during the summer (probably by settling of particles brought in with the spring snow melt), it rose in Brereton Lake.

The same phenomenon was noted for both total P and ortho-P in the lake waters. Ortho-P in Lyons Lake fell from around 0.01 mg/l in the spring to around 0.005 mg/l in autumn, whereas levels in Brereton Lake rose from around 0.017 to around 0.021 mg/l.

Visually, Lyons Lake contained nearly 1m of submerged plant growth and little surface algae. Brereton Lake, on the other hand, had developed by the autumn **significant growths of surface algae and a slight water odour.**

The authors indicate that a 10 hp (horse power) motor boat mixes water down to a depth of 1.8m, increasing to 4.6m for a 50 hp motor, and that certain water ski boats are significantly more powerful than this, reaching 300 hp.

In general, the phosphorus entering a lake will accumulate in the top layers of the lake sediments. This takes place particularly through the spring and summer as a result of stratification and of assimilation by plants and algae which subsequently die and sink to the lake bottom. **Mixing by motor boats will**

recirculate this sediment phosphorus back into the water, increasing P levels and enabling algal growth. Motor boat mixing and algal growth both increase turbidity.

The authors conclude that motor boat activity may have significantly increased aquatic phosphorus levels and thus may have effectively switched Brereton Lake to the early stages of eutrophication problems.

"The effects of motor boats on water quality in shallow lakes", Technological and Env. Chemistry, vol. 16, 1997.
D. Nedohin and P.Elefsiniotis, University of Manitoba, Dept. Civil and Geological Engineering, Winnipeg, Manitoba, Canada.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - Australia
Sources of phosphorus input

The Suma Park Reservoir is the main water supply for Orange City, New South Wales. It has a history of nuisance algal blooms, with up to 70,000 cells/ml of cyanobacteria being recorded. The only other reservoir in the catchment, spring Creek, has also recorded blue-green algal problems.

A two year study of the catchment was launched in 1995 to assess the causes of and possible solutions to this problem. This concentrated on origins of phosphorus input, since P levels in the reservoirs had been identified as being above those estimated low enough to control algal growth (10µg/l). winter total P concentrations in Suma Park Reservoir varied from 70 to 490µg/l in deep water and 60-100µg/l in surface water.

Several hundred water samples were collected and analysed from 12 sites on the main tributaries and in the reservoirs from August 1995 to January 1996. Further samples were taken during storm flows. Samples were analysed for total P, reactive P and suspended solids. Rainflow and water flow velocities were also measured.

========= High phosphorus levels =========

The results confirmed that all the watercourses and reservoir sites in the catchment showed high P levels (total P > 50µg/l). Examination of these results, however, suggested that this was **not due to anthropogenic sources :**

- there was no significant variation in P concentration with stream length
- no significant variation appeared with point sources, in particular of the concentration up and downstream of Lucknow, the catchment’s main urban centre
- the lowest P levels were found at the lower end of Brandy Creek, which flows through the most intensively farmed area of the catchment

The authors conclude that the primary source of phosphorus in the catchment’s waters, and in

particular in the reservoirs, is the subsoil. This is made up of tertiary basalt and ordovician igneous rocks, which can contain up to 1% phosphate.

======== Primary phosphorus input is from soils ========

This phosphorus, bound up with fine suspended sediment, is believed to be transported to the waterways from unfertilised subsoil by gully and bank erosion. It is then released from suspended and bottom sediments and becomes bioavailable.

The paper concludes that strategies for reducing algal bloom problems should focus in the short term on better water management in the reservoirs (rather than P limitation) and in the long term on **reducing erosion and sediment transport in the catchment.**

"Phosphorus inputs to a reservoir in Orange, New South Wales" Water, July-August 1998.
Mosharel H. Chowdhury and Dr. Dhia Al Bakri, Orange Agricultural College, University of Sydney, PO Box 883, NSW 2800.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - River Wey, England
Sediments - River water
Phosphorus dynamics

Water and sediment chemistry were measured, over different seasons, at 6 sites upstream and downstream of a significant point source pollution (sewage works outflow) on the river Wey in Southern England. Results were compared with a laboratory fluvarium channel and mathematical models of phosphorus dynamics were established.

The river Wey is a lowland river with particularly hard water (Ca concentrations of up to 3.9 mmol/l) with a flow of 0.3 – 0.8 m3/s, increasing to over 3 m3/s in winter when the river is in spate. Total phosphorus (TP) concentrations upstream of the sewage works outflow are in the range 2 – 8 µmol/l).

The Alton sewage treatment works (>10,000 pe.), with a discharge flow of 0.1 – 0.15 m3/s, increases total phosphorus levels very considerably to 30 – 80 and periodically over 200 µmol/l.

======== Phosphorus removal to sediments in spring and summer ========

Measurements at four points from 0 to 6 km downstream of the sewage treatment works showed that **significant amounts of the phosphorus in the discharge was being removed from the water to sediments in spring and summer :**

Total phosphorus in river water (µmol/l)

	Immediately downstream of STP outflow	average 2-6 km downstream
spring	36.9	20.2
summer	83.0	48.6
autumn	73.7	53.7

This corresponded to increases of phosphorus and calcium contents of the sediments from the winter through to the summer.

Sediment phosphorus levels fell again in the autumn and winter, as the river bed was scoured by high flows. In the winter, when the river was in spate, total phosphorus levels did not fall as the water moved downstream from the sewage works outflow.

========= Mechanisms of phosphorus removal =========

The river water is generally supersaturated with regard to calcite, so that some of the loss of water phosphorus to sediments can be explained by coprecipitation of calcium phosphates with calcite. Changes in the calcium content of the water suggest that only a part (and at most 53%) of the phosphorus reduction is a result of this mechanism. Other processes such as sorption to clay particles, biological assimilation and settling of suspended particles must account for the remaining uptake of phosphorus by sediments in spring ñ autumn.

Mathematical models were established for these different effects and tested and calibrated using a laboratory fluvarium channel. Data simulated by the model for phosphorus take-up by the river bed sediments corresponded closely to those measured in the field (outside the winter period, when the sediments were releasing phosphorus by scouring).

"Phosphorus dynamics in a lowland river". Wat. Res. vol. 32 no. 6 1998.

W. A. House, F. H. Denison, Institute of Freshwater Ecology, River Laboratory, East Stoke, Wareham, Dorset BH 20 6BB, UK.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - Science

New territories of water pollution

New areas of knowledge currently opening up regarding water pollution (pharmaceutical drug contamination of waters, levels of accumulated toxins in sediments) pose significant concerns regarding human health implications, but also raise questions about possible effects on the ecological community and on fish and zooplankton populations.

Now that analysis methods have evolved to allow their detection, pharmaceuticals are being found in both surface water and in drinking water in concentrations of 1 – 100 nanograms/l.

Widespread and variable pharmaceutical drug contamination

The chloresterol lowering drug clorifibric acid has recently been detected in Switzerland in various waters, ranging from rural mountain lakes to rivers flowing through urban areas. This product is not manufactured in Switzerland, so the source would seem to be its presence in sewage, resulting from human use. This drug was found by accident, because of its resemblance to the herbicide Mecoprop, studied by Drs M. Müller and H-R. Buser of the Swiss Government research institution. Concentrations found are comparable to persistent pesticides such as Lindane. (Env. Sci. and Technology, Jan. 1st 1998).

Clofibric acid has also been found for example in Berlin tap water at levels up to 2 ppb (T. Heberer and H-J. Stan, Berlin Technical University, to be published in Int. J. Env. Analytical Chem).

When T. Ternes, working with the municipal water research laboratory in Wiesbaden, Germany, looked for traces of 60 common pharmaceutical drugs, he found 30 of them, not only in raw and treated sewage but also in streams and rivers. Concentrations in the natural environment were generally in the parts-per-trillion range but reached 3 ppb for some drugs. **Residues of drugs detected included lipid-lowering drugs, antibiotics, analgesics, antiseptics, beta-blockers** (to be published in Water Research). There is virtually no literature regarding the potential health and environmental consequences of such widespread exposure.

======== Estrogens and antibiotics ========

There is particular concern about estrogen-like drugs. S. Synder of Michegan State University has found concentrations of human and pharmaceutical estrogens of up to 20 ppt in sewage works outflow. **This would be sufficient to affect fish reproduction.**

Antibiotics also raise concerns, A. Hartmann of the Swiss Federal Technology Institute has found 0.5µg/l concentrations of fluoroquinolone antibiotics in sewage plant outflow. **These levels may be sufficient to potentially develop bacterial resistance.**

In the past, the assessment of pharmaceuticals has concentrated on health effects, with little attention being paid to the risk of ecological impact or to biodegradability. The appearance of methods enabling detection at low concentrations and the discovery of generalised environmental contamination may lead to changes in this approach.

======== Toxins in sediments ========

The six year UK government project "Land Ocean Interaction Study", looking at British pollution of the North Sea, has identified **significant deficiencies in the way water pollution is monitored.**

Firstly, only certain pollutants, such as nutrients and metals, are measured regularly. The lack of monitoring of other substances, in particular organic compounds, may give a misleading picture.

Secondly, **river sediments are rarely sampled.** This study, looking at both floating and river bed particles, found concentrations of toxic chemicals thousands of times higher than those monitored in water. Chemicals discovered included pesticides and organic industrial products.

For example, phtalates, which are estrogen imitating chemicals used in plastics, were found in every sediment sample taken in the Humber river.

Toxic substances in sediments not only pose risks to organisms and plants living on the river bed but can also be flushed into the river water during storms and floods.
"Drugged waters" by Janet Raloff, Science News, vol. 153, 21st March 1998.
"Muddy waters" by Fred Pearce, New Scientist, 16th May 1998.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - Landscapes
Buffer vegetation for nutrient removal

Bands of natural vegetation left, or more generally reconstructed, along watercourses can act as very effective buffers removing nutrients from surface and subsoil water and preventing them from reaching the river system.

Although the value of buffer zones in preventing non point source nutrient pollution is now widely recognised, few studies have attempted to accurately identify the mechanisms of nutrient removal functioning or to assess the factors influencing the nutrient removal efficiency of such buffers. Furthermore, **the majority of literature available concerns nitrogen removal, with few figures developed for phosphate removal.**

========= 100% N removal =========

Where measurements have been carried out, 20 – 30 metre bands of riparian forest vegetation have been shown to achieve near 100% N removal, both through uptake by vegetation and through denitrification (permanent removal of nitrogen to the atmosphere). Widely varying rates are reported under differing conditions. However a significant part of the nitrogen removal generally occurs in the first few metres of the buffer zone (edge effect), due to higher carbon availability and plant growth (access to light) in this area. The soil/watercourse interface is also an important area for nutrient retention.

A width of 30 metres is suggested as sufficient to generally ensure near 100% nitrogen removal, with 7 – 20 m being able to offer similar results in the case of dense vegetation.

Removal rates are related to retention times of subsoil water within the buffer zone's underground root system. Because subsoil water flows are generally oblique to the watercourse, these times can be relatively long : for example, 5 – 190 days in a 17m buffer zone alongside the Thames (Haycock and Pinay, 1993).

Forest vegetation is more effective at nitrogen removal than, for example, grassland, but up to 20 years may be necessary to establish a mature forest system.

======== Water levels and hydraulics ========

Nitrogen removal is maximised if the forest roots reach water and the soil is partly water saturated. Low oxygen levels in wetland soils create a demand for nitrates as an electron acceptor, resulting in denitrification and N removal rates significantly higher than rates of plant uptake. This poses problems in areas where modifications of the watercourse have led to a lowering of the water table.

Variations in water levels are also important. Riparian forest is adapted to these natural variations and requires them if it is to develop effectively. Water level variations also ensure varying oxidation in soil, which contributes to nutrient uptake and denitrification, and enable the deposition of sediments in the riparian zone.

Riparian vegetation is also very effective at retaining sediments. Restoring 10% of a watershed's surface area to wetlands can ensure retention of more than 70% of sediments. Sediment retention is largely permanent with vertical accretion rates in riparian areas reported in the 0.13 – 1.5 cm/year range.

======== Phosphorus removal and transformation ========

Phosphorus removal rates may be significantly lower than those for nitrogen. One study suggests 30% P removal in a strip achieving 68% N removal. In this case calcium (39%) and magnesium removal (23%) were also measured. (Lowrance et al, 1984).

However, **vegetation buffers transform phosphorus from soluble inorganic phosphates to particulate organic forms through plant uptake and assimilation** (Johnston 1991). **This significantly reduces bioavailablility. Furthermore, buffer strips tend to retain phosphorus during the growing season and release it during the winter which also considerably reduces the potential impact on surface water quality** (in winter, surface waters are not subject to eutrophication problems and high flow rates can wash nutrients downstream).

A Swedish study suggests that a mixture of low forest (brush) and grassland is more effective in retaining phosphorus than either forest or grassland buffer strips (Vought et al, 1994).

======== Landscape and wildlife ========

Creation and protection of riparian vegetation zones is proportionally most effective along headwaters of a water shed : flow rates are much lower here, whilst most of the downstream water originates in headwater streams.

The lack of precise information regarding buffer strip nutrient removal efficiencies suggests that their definition should be largely based on landscape and wildlife criteria, for which they can have a very high value.

An essential point is that of reestablishing suitable hydrologic conditions : preventing lowering of water tables, ensuring that wetlands stay wet, and maintaining natural variations in water levels and flow rates.

"The effectiveness and restoration potential of riparian ecotones for the management of nonpoint source pollution, particularly nitrates", Critical Reviews in Env. Science and technology 72(4) 1997.
M. S. Fennessy, Dept. Geopgraphy, University College, London WC1H 0AP, UK. J. K. Cronk, Dept. Agricultural Engineering, University of Maryland, MD 20742, USA.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - UK
Variations in ecological community response to nutrients

Indices based on measurements of the photosynthetic community have been developed as indicators of eutrophication. The author emphasises, however, that it is difficult to demonstrate that changes in the ecological community are related to nutrient inputs and that other factors can have important effects.

Biological monitoring techniques for assessing the impact of organic pollution have been developed into quite sophisticated multivariate tools, essentially based on invertebrate community indices. **It is generally accepted, however, that these indices do not reliably reflect eutrophication,** and community indices based on measurements of the phytosynthetic community have been developed (eg Mean Trophic Rank index, based on the macrophyte community, Holmes 1995, and Trophic Diatom Index, based on the diatom community, Kelly & Whitton 1995, Kelly 1997).

Other models have been constructed which relate point nutrient load changes to final river concentrations (Whitehead et al. 1997). Predictions of the resulting ecological changes, however, have proved difficult, even for lakes, where eutrophication and restoration processes have been widely studied. Rivers provide even more difficult systems to model.

======== Impact of factors other than nutrient load ========

The author suggests that it is misleading to use phytocommunity indices as a proxy indicator of eutrophication. Other factors, and in particular other components of sewage works discharges, affect flora and algae. *Potamogeton pectinatu*s can develop in organically polluted water because of increased silting, and *Rhynchostegium riparioides* and *Amblystegium riparium* were seen to develop downstream of a paper mill with a high BOD effluent which was low in nutrients.

It is not possible to consider nutrients in isolation in a lowland river. The effects of organic pollution, reduced oxygen concentrations, ammonia and suspended solids must also be taken into account.

On the other hand, at very low aquatic P concentrations, although P may be limiting in absolute terms, it is often pH that represents the primary gradient affecting community structures of organisms adapted to low nutrient levels.

======== Upper limit of sensitivity ========

Studies of lakes suggest that there are **four distinct levels of response to reductions in phosphorus loadings:**

I. initial limited reductions in P loading : no biomass response to P reduction
II. limited reductions in P loading : physiological or behavioural response
III. significant P loading reduction : biomass reduction but no floristic change
IV. considerable reduction in P loading : biomass reduction and floristic change

The principles of this model can also be applied to rivers. Reduction of P loading will only modify the ecological community if the reduction is large enough to reach level III or IV. The author suggests that this will rarely be the case in UK rivers with water quality class 2 or below.

======== Nitrogen and phosphorus ========

Where improving sewage treatment leads to a reduction in P load falling into the levels I or II of the above model, other factors such as nitrogen or carbon may affect ecological community response.

A survey of UK rivers found 20% of sites with N:P ratios below 10, suggesting that nitrogen may be limiting. These sites often corresponded to rivers targeted for sewage works nutrient removal under the EC Urban Waste Water Treatment Directive.

Phosphorus removal in sewage works will usually bring with it reductions in nitrogen loads, but also reductions in suspended solids and biological oxygen demand. Community-based indices remain a valuable tool as rapid and cheap indicators of ecological status, including eutrophication, but care has to be taken to not simplify interpretation by assuming that observed ecological responses are due only to nutrient loadings.

"Use of community-based indices to monitor eutrohication in European rivers" Environmental Conservation 25 (1) 1998.
M. G. Kelly, Bowburn Consultancy, 11 Monteigne Drive, Bowburn, Durham DH6 5QB, UK.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - USA
Guide to nutrient removal technologies

"Biological and chemical systems for nutrient removal" is a special publication (1998) of the Technical Practice Committee of the Water Environment Federation (WEF). It is intended to provide background information through a review of operating procedures, research and practical experience.

The 400 page book includes a brief look at :

- nutrients, their effects on the environment and control policies
- analytical techniques for measuring phosphorus and nitrogen
- design of chemical phosphorus stripping
- design of biological phosphorus removal
- design of biological nitrification/denitrification
- process models for biological nutrient removal
- aquatic systems for nutrient removal (ponds, wetlands)
- testing and evaluation of nutrient removal systems
- costs of nutrient removal with chemical or biological systems

A number of figures are given regarding phosphorus in waste waters and phosphate removal.

======== Detergent phosphates ========

Average USA waste water phosphate levels are indicated **before and after laundry detergent phosphate bans :**

mg/l	before ban	after ban	difference
total P	8	5.44	-32%
ortho-P	6.06	3.68	-39%

======== Iron dosing ========

For chemical P stripping using iron chloride dosed to the primary sewage treatment, **estimates of iron dosages** are given:

- to achieve outflow levels of 0.2 mg/l ortho-P :
  molar iron/phosphorus ratio of 5
  (calculated on the basis of [ortho-P inflow] - [outflow 0.2 mg/l])

Such iron chemical stripping is estimated to increase settling in the primary treatment as follows :

- TSS (suspended matter) removal increased from 50% to 75%
- BOD (oxygen demand) removal increased from 30% to 50% (both referring only to removal in primary treatment stage).

======== Sludge increases and costs ========

Where iron P stripping is applied as above, **primary sludge solids are estimated to be increased by a total of 94%** : 50% due to increased TSS removal plus 43% due to precipitation chemicals.

Costs are estimated for biological nutrient removal (BNR), on the basis of 370 such plants operating in the USA. **Actual capital costs of these BNR plants are considered to be comparable to capital costs of other new secondary treatment installations.**

Operating costs are estimated at US$ 6.66 – 57.1 per 1,000 m3, with an average of US$ 22.6. Running costs are strongly dependent on the availability of suitable organic carbon source to "feed" biological P removal.

Sludge P content is compared for sewage works with and without biological P removal. Conventional secondary biological treatment is estimated to achieve 10 – 30% total P removal, depending on BOD/P input ratio and operating conditions. This gives a waste activated sludge P content of 1.5 – 2.5 %. Biological P removal (85 – 95% P removal), however, will produce sludges with a P content of 2 – 7 %

======== Struvite precipitation ========

The fate of phosphorus in the anaerobic sludge digesters of biological nutrient plants is considered. Significant proportions of P may precipitate out at this stage of treatment : this proportion can reach 70% (eg. York River Plant, Randall et al. 1992), in particular as struvite.

======== Wetland systems ========

Artificial and natural wetlands are considered as effective nutrient removal systems for small sewage works. Phosphorus removal results from a combination of plant uptake, soil microbe uptake, soil particle retention and chemical precipitation within soil water.

It is estimated that a 71,000 m2 wetland system should be able to ensure P removal from 10 down to 1 mg/l for a 1,000 m3/day influent loading.

This surface is approximately twice that considered necessary to reduce nitrogen from 30 to 5 mg/l and BOD from 80 to 15 mg/l.

"Biological and chemical systems for nutrient removal" Water Environment Federation special publication, 1998, ISBN 1-57278-123-8. Prepared by the WEF task force chaired by Movva Reddy. Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994, USA.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - Struvite recovery
Struvite crystallisation in anaerobic sludge digester effluent

P recovery can significantly improve the effectiveness of biological nutrient removal (BNR) by preventing phosphate release during sludge handling or anaerobic digestion. Struvite precipitation from the anaerobically digested sludge supernatent offers one route for achieving this.

Struvite crystallisation conditions were explored using the liquid from the dewatering section (belt press) of a 100,000 pe. sewage works equipped with nitrification, denitrification and anaerobic sludge digestion. This supernatent had Mg and Ca contents 10x higher than stoichiometric demand for struvite [struvite = MAP = magnesium ammonium phosphate = $MgNH_4PO_4$] or for hydroxyapatite [HAP = $Ca_5OH(PO_4)_3$] :

Chemical analysis of the supernatent used :

pH = 7.3	PO_4 = 18 mg/l	Mg = 53 mg/l
Ca = 184 mg/l	NH_4 = 220 mg/l	
CO_3 = 0	HCO_3 = 1430 mg$CaCO_3$/l	

An initial investigation was carried out on the ageing properties of this supernatent, with and without the addition of phosphate (as Na_3PO_4), in order to simulate the anaerobic supernatents of BNR processes. This showed a gradual increase of pH, probably due to loss of CO_2 to the air, and a fall in P levels. P removal levels after 3 days were 81% for a liquid with initially 164 mg/l PO_4 down to 53% for initial 18 mg/l PO_4.

Crystallisation of struvite but not of HAP

As a second stage, the supernatent curves of HAP and struvite at different calcium concentrations were evaluated for different synthetic phosphate concentrations and then compared with those found in the real effluent. This showed that **phosphate precipitation was occuring in the real effluent at a lower pH than for struvite in the synthetic solutions,** but at a higher concentration than for HAP (even at 200 mg/l Ca).

Ion analysis suggested that struvite is nonetheless being formed in the effluent, and that calcium salts are providing a seed crystal. This situation is thought to be related to magnesium and bicarbonate inhibition of HAP crystalliation.

Bench tests simulate P recovery

Following these results, **a bench scale fluidised bed reactor was used to assess the possibility of struvite precipitation from a relatively low phosphate concentration liquid** (<50 mg/l PO_4) using only air stripping to remove CO_2 without chemical addition.

Air stripping raised the pH from 7.9 to 8.3 - 8.6 and enabled up to 80% P removal after around 4 hours. These results were better than those obtained by Fujimoto et al (1991), most probably because of the use of external seed crystals (quartz sand).

"Phosphate removal in anaerobic liquors by struvite crystallisation without addition of chemicals : preliminary results". Wat. Res. vol. 31 n°11, 1997.
P. Battistoni (Institute of Hydraulics, University of Ancona, via Brecce Bianche, 60131 Ancona, Italy), G. Fava, P. Pavan, M. Musacco, F. Cecchi.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - Country : USA
Poor availability of phosphorus in chemical sewage sludge

Experimental agricultural field trials were carried out to determine the availability to crops of phosphorus in different organic wastes : digested dewatered sewage sludge (DS), irradiated sewage sludge (IS), irradiated and composted sewage sludge (CS) and composted livestock manure. The sewage sludge used was from a works using iron precipitation for P removal.

Varying dosages of each waste were applied for two years using three crops (lettuce, beans and petunias), each replicated four times. Dosages of nitrogen and other minerals were maintained in excess so that phosphorus was the limiting factor for plant growth.

The authors note that literature suggests an average of 2.3 % P in sewage sludges in the USA, with 10 – 15% iron (dry weights) where P removal down to <1 mg/l in the sewage works outflow is required. The paper investigates the implications of this iron content on P availability to agricultural crops and soils.

======== Low extractability of P in sewage sludges ========

As a first stage, the total P and its $NaHCO_3$ extractability were evaluated for each waste (Olsen and Sommers 1982 method). $NaHCO_3$ extractability is considered a good representation of the availability of soil phosphorus for plants.

Total P content ranged from 1.2% to 3.6% in the prepared sludge, and from 0.36% to 0.64% in the manure. Iron content ranged from 6 to 24% in the sludge preparations.

However, $NaHCO_3$ extractable P was very low in the sludge preparations, ranging from 0.8 % to 5.6% of total P. In comparison, extractable P ranged from 31% to 69% in manure.

======== No crop uptake of sewage sludge P ========

Mature crop yield was found to depend little on applied phosphorus, probably because adequate P was in any case present in the farm soil. Young crop uptake and growth, on the other hand, correlated well with NaHCO3 extractable P (eg. first cut lettuce).

None of the three sewage sludge products proved capable of increasing crop growth or yield. **Non composted sludge (DS, IS) in fact reduced P uptake by first cut and mature lettuce, possibly by modifications to the physical growing conditions. The composted livestock manure, however, increased P uptake significantly.**

These results correlate well with analyses of extractable soil phosphorus. NaHCO3 extractable soil P was actually lower after two years of application of the different sewage sludge products (55 – 61 mg/kg, not correlated to sludge application dosages) than its initial value (62 mg/kg).

The composted manure, on the other hand, significantly increased NaHCO3 extractable soil P, from 62 mg/kg initially to 67-75 mg/kg.

The fact that the addition of sewage sludge, which contains small quantities of NaHCO3 extractable P, does not increase soil extractable P is thought to be a result of available P in the soil reacting with the added sludge, thus reducing its bioavailability.

"Comparison of phosphorus availability with application of sewage sludge, sludge compost and manure compost", Commun. Soil Sci. Plant Anal. 28 (17 & 18) 1997.
G. Wen and M. Schellenbert, Research Station, Agriculture and Agri-Food Canada, Swift Current, PO Box 1030, Saskatoon, Canada S9H 3X2. T. Bates, P. Voroney, J. Winter, Dept. Land Resource Science, University of Guelph, Ontario, Canada 1G 2W1.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - Honk Kong
95% nutrient removal by immobilised algae

Microalgae are known to provide effective biological treatment systems for both raw and treated sewage, one of the limitations being the difficulty in settling and removing the algae after growth. For this reason, immobilised algae in polysaccharide matrices were tested.

Cultivated unicellular *Chlorella vulgaris* were innoculated into 4mm beads of the two common polysaccharide matrices : alginate and carrageenan, which were extracted from algal cultures.

Triplicated experiments were carried out to test the ability of the Chlorella vulgaris to remove nutrients (NH_4^+ and PO_4^{3-}) from primary settled sewage from Hong Kong's second largest sewage works at Shatin. Sewage water (300 ml) was mixed with : carrageenan immobilised algae, alginate immobilised algae, free algae and a control without algae. Algal densities in each case were around 1 million cells/ml. The flasks were then maintained at around 24°C and exposed to 16-8 hour light-dark cycles.

Nutrient concentrations, calcium concentrations, algal numbers, size and chlorophyll contents were monitored over a period of 5 days.

======== 95% ammonia removal ========

Both of the immobilised algae systems achieved 95% NH_4^+ removal after 3 days. The carrageenan system offered a faster and more regular response, with around 56% removal after one day. The free algae system achieved only around 50% removal after 3 days, reaching 85% after 5 days. The no algae system achieved only 32% removal after 5 days.

======== 94% P removal ========

Phosphate removal was more difficult to interpret due to the effect of calcium phosphate precipitation as well as algal uptake.

P removal was very rapid and effective in the immobilised algal systems, with 94% removal after

one day in the alginate system and both immobilised systems achieving 99% removal after two days. For comparison, the free algal system achieved only 50% removal after 5 days whilst P levels remained more or less constant in the no algae flasks.

Calcium concentration monitoring showed increases of around 50% in the carrageenan system and 60 fold increases in the alginate system. These increases were due to calcium ions present in the polysaccharide gels, in particular in the alginate where a high level of calcium is necessary for gelling. These ions bind with phosphates forming calcium phosphates. Because the gel strength of alginate relies on calcium ions, the presence of phosphates in the waste water will tend to cause release of the algae cells, a phenomenon which was confirmed for the alginate system after 3 days. Very limited cell leakage from the gels was otherwise observed.

The increased nutreint removal efficiency of immobilised algae, compared with free algae, was thought to be due to the constraints posed upon the cells by reduced light and differing access conditions to dissolved ions. **These conditions cause the cells to grow more and stock more nutrients (higher chlorophyll levels) before entering the phase of cellular reproduction.** The carrageenan gel also enchanced algal access to NH_4+ ions.

The study concludes that carrageenan immobilised algae provide a potentially efficient system for nutrient removal whereas alginate gel is not suitable due to its lack of stability in the presence of phosphates.

"Wastewater nutrients (N and P) removal by carrageenan and alginate immobilised Chlorella vulgaris" Environmental Technology vol.18 1997.
P. Lau, Dept. Biology, Hong Kong University of Science and Technology, Clearwater Bay, Kowloon, Hong Kong ; N. Tam, Y. Wong, Dept. Biology and Chemistry, Hong Kong City University, Tat Chee Road, Kowloon, Hong Kong.

SCOPE NEWSLETTER

SCOPE N°28 - 10/1998 - USA / Minnesota
Operating costs of P precipitation

Ferric chloride precipitation P stripping was tested full scale on a fourth of the capacity of the 950,000 m3/day Saint Paul, Minnesota, sewage plant. Costs were found to be much higher than expected due to the additional capital and operating costs required for sludge handling and disposal (54% increase in sludge solids).

Simultaneous P precipitation was installed using injection of ferric chloride and polymer at the head of the primary treatment tanks which covered around a quarter of the plant's total flow. The chemical precipitated waste water stream was then separated from the non precipitated stream throughout the rest of the sewage work's processes, including throughout the sludge thickening and incineration sections.

======== 1.5 : 1 molar chemical use ========

Influent phosphorus levels varied from 2.4 to 8.4 mg total P / l, with an average of 5.2 mgP/l. Ferric chloride had to be dosed at a molar ratio (to P) of 1.5 : 1 to ensure P stripping down to 2 mgP/l. The average P removal rate in the chemical treated stream was then 71% compared to 24% in the untreated stream. In addition, **polymers had to be used at doses of 1.3 mg/l in the primary injection plus 10-12 mg/l at the sludge conditioning stage.** These levels were higher than those estimated before running. This treatment, however, offered 8% better suspended solids removal and 16% better organic material removal (BOD).

======== Deterioration in sludge processing ========

The chemical stripping significantly deteriorated sludge treatment efficiency, increased operational costs and, by reducing effective capacity, increased capital costs.

Solids capture in the gravity thickeners fell from 90.4% to 81% so that the dry solids content of the sludge fell significantly from 7.4% to below 5%. In order to obtain acceptable thickening of the chemical precipitation stream sludge, a gravity thickener loading rate of 78 kg/day/m2 was necessary, equating to around 2/3 the loading for the untreated sludge stream (even then quality was still lower). Capital costs for sludge thickening would thus be multiplied by a factor of 1.5.

Roll press dewatering of the chemical precipitation stream sludge also proved difficult. Increased polymer doses were necessary and the solids content was on average 2% lower (around 29% instead of around 31%). Feed rate to the roll presses was reduced from an average of 49.6 to around 39.7 dry tons/day, implying additional capital costs of around 25% to maintain treatment capacity.

The wetter sludge in the chemical precipitated stream implied a 40% increased fuel use in incineration (rising to 0,136 m3/day/dry kg).

========= 54% increase in sludge solids =========

The chemical pricipitated sludge produced more ash during incineration, increasing operating problems and costs. The 54% increase in sludge solids resulting from ferric chloride P precipitation also caused an overall increase in incinerator ash generated. Arsenic, cadmium, chromium, copper, iron and lead were removed from the waste water and transferred to the sewage sludge and ultimately to the incinerator ash.

After one year's full scale operating experience, the paper concludes that ferric chloride P stripping is much more costly than anticipated because of increased sludge handling and disposal problems.

"Full scale comparison of primary treatment, solids handling and solids incineration with and without chemical precipitation for phosphorus removal".
S. Murphy, S. Straka, P. Craddock, J. Reynods, Montgomery Watson, 545 Indian Mount, Wayzata MN 55391, USA. C. Voigt, Metropolitan Waste Control Commission, 2400 Child's Road, Saint Paul, MN 55106, USA.

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 (Cu^{2+}) for which it has a high affinity. This combination was chosen because the immobilised Cu^{2+} 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

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** (Ca2+, Fe2+, Mg2+) 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 $CaCO_3$) 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 km^2 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 700m^3.

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 Mg^{2+} and Ca^{2+} 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.

SCOPE NEWSLETTER

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POLLUTANTS AND EUTROPHICATION

A major new study of the effects of toxicants on eutrophication phenomena in marine and fresh water. Based on both new experiments and recently published research, this study explores the mechanisms whereby toxicants can inhibit or destabilize zooplankton grazing and permit algal blooms.

This study has been published as a book and is available on request from SCOPE c/o CEFIC (CEEP sector group) - see back page of this Newsletter.

IMPROVING UNDERSTANDING OF P-LOSS FROM AGRICULTURAL SOILS

This Rothamsted Experimental Station report reviews current understanding of soil P-loss problems. Maintaining P availability for crops is essential for productivity but too high soil P levels can lead to losses to surface waters at concentrations liable to contribute to eutrophication.

MURRAY-DARLING BASIN
LAND USE AND WATER QUALITY PROBLEMS

Murray-Darling Bassin Commission authors underline the essential role played by land management practices in affecting all areas of water quality : water tables, salinsation, river flows, eutrophication.

STORM WATERS AND BIOLOGICAL P-REMOVAL

Deterioration of biological P-removal efficiency has been reported from a number of sewage works after heavy rainfall or weekends, but this may be due to excessive aeration rather than dilution or loading.

P-UPTAKE BIOCHEMISTRY IN BIOLOGICAL P-REMOVAL

Experimental research into the relations between biological P-uptake and PHB (poly-hydroxybutyrate) metabolisation. The results enable a better understanding of P-removal biochemistry in wastewater treatment processes under stress conditions or with limiting substrate supplies.

NITROGEN AND PHOSPHORUS BALANCES

60% of N and 80% of P are concentrated in 1% of urban waste water flow : the drains act to dilute and mix. Source separating technologies and reuse of nutrients and carbon from wastewater are necessary for a sustainable water management system.

MODELLING LAKE ECOLOGY RESPONSES TO PHOSPHORUS AND CARBON INPUTS

Whole-lake experiment demonstrates the long delay times for a return to a steady state after nutrient input changes and the importance of modelling dynamic variability rather than steady states.

HIGH ALGAL PRODUCTION IN VERY SHALLOW LAKES

Very shallow lakes produce nearly twice as much phytoplankton biomass as medium shallow lakes with similar nutrient imputs. This is thought to be due to light conditions, mixing and micorbial cell production.

MODELLING EUTROPHICATION DYNAMICS IN MICROCOSMS

Application of modelling techniques to phytoplankton and nutrient dynamics in perturbed microcosms in a Spanish reservoir.

"STATE OF THE ART" OF EUTROPHICATION RESEARCH

Publication of the proceedings of the specialist symposium with this title which took place in Wageningen, Holland, in August 1997.

RESTORING EUTROPHICATED LAKES

The Norfolk Broads Authority publishes a book-guide presenting the environmental mechanisms of lake restoration : nutrients, sediments, pollution, mechanical erosion, fish and plant community management ... A well-illustrated tool for defining or explaining lake management and restoration policies.

CLEAR CONSTANCE: RESTORATION OF LAKE CONSTANCE

The international programme to restore Lake Constance, which provides drinking water for 4.5 million people is considered to have achieved success. The algal population balance has returned to natural equilibrium. Phosphorus levels have been brought down from over 90 ÊgP/l to 16 ÊgP/l, but still significantly higher than natural levels below 5 ÊgP/l.

PHOSPHATE AND NITRATES IN ANIMAL MANURES

A comprehensive overview of the various different treatment methods used or being developed for pig manure. It is shown that 85 - 90% of phosphorus in manure is present as solids. Centrifugal extraction can thus trap up to 90% of the phosphorus from the liquid manure, but less than half of the nitrogen is removed by such methods.

The SCOPE NEWSLETTER is produced by: CEEP (Centre Européen d'Etudes des Polyphosphates), CEFIC Sector Group, avenue E. Van Nieuwenhuyse 4, bte 2, B1160, Bruxelles - Belgium. Tel: (32) 2 6767211. Fax: (32) 2 67673 01. E-Mail: cja@cefic.be

HOLLAND

POLLUTANTS AND EUTROPHICATION

Published in book form, "Toxicant induced changes in zooplankton communities and consequences for phytoplankton development" (R. G. Jak, 1997), this thesis is a major experimental study combined with an updating of available literature and research concerning the effects of toxicants on phytoplankton and zooplankton equilibrium in freshwater and marine aquatic ecosystems.

This research, carried out by TNO (the Netherlands Organisation for Applied Scientific Research), looks at how toxic stress (from chemical pollutants such as heavy metals, pesticides ...) affects the ability of zooplankton communities to control phytoplankton development in nutrient enriched aquatic environments, and thus the role toxicants can play in the occurrence of algal blooms. Studies were carried out with natural plankton communities enclosed in 1.2 - 1.5 m^3 systems over 2-6 weeks. Different toxicants (metals, 3,4-dichloroaniline =DCA, tribuyltin) and varying nutrient levels were tested in both fresh and coastal waters.

The different studies demonstrate how toxicants that have a direct impact on zooplankton communities affect the planktonic foodweb. The results differ between freshwater and marine systems.

In marine plankton systems, toxicants reduce zooplankton biomass production, reducing the proportion of primary phytoplankton biomass being transferred to higher trophic levels, thus potentially decreasing fish production.

In freshwater, toxicants can result in eutrophication phenomena (algal blooms) at lower nutrient concentrations than in the absence of toxicants. Toxicants not only reduce the vigour of zooplankton present, and therefore their grazing and reproduction capacity, but also cause shifts in the species distribution of zooplankton communities, generally towards species which are less efficient in their use of available food.

These zooplankton species dynamics are examined, both as regards shifts between taxonomic groups of zooplankton and between species within the same group. In fresh water, this shift is generally towards smaller species, for example from cladocerans to rotifers. These smaller species are also a less efficient food source for fish.

The studies show that Daphnia magna sensitivity to toxicants in the natural aquatic environment enclosures is similar to that estimated by laboratory studies, but that D. magna may be relatively insensitive to toxicants compared to other grazer zooplankton species, meaning that the impact of toxicants on zooplankton communities (often evaluated using D. magna toxicity data) may often be underestimated.

The study concludes that "the opportunistic species that dominate zooplankton communities under toxic stress are not able to effectively control the phytoplankton development".

For example, in lake water experiments, the toxicant DCA caused inhibition of cladoceran species (eg. D. magna) allowing development of less sensitive rotifer and copepod species. These species, however, could not prevent a phytoplankton bloom when nutrients were added, whereas the zooplankton were able to control algal growth when no DCA was present.

This book is available on request from SCOPE c/o CEFIC (CEEP sector group) - see back page of this Newsletter.

UNITED KINGDOM

IMPROVING UNDERSTANDING OF P-LOSS FROM AGRICULTURAL SOILS

It has traditionally been held that phosphate applied in fertilisers and not taken up by crops is almost entirely fixed in soil in unavailable forms. This 1997 Rothamsted Experimental Station report starts by revisiting the experimental data from Rothamsted from the years 1843 - 1902 which contributed to this approach.

Field experiments in the 1950's, however, showed that soil P-residues derived from fertiliser applications from 1856 to 1901 and farmyard manure applications from 1876 to 1901 could not only still be measured in the soil, but also resulted in a doubling of crop yield if sufficient N was applied.

To ensure agricultural efficiency, soil P should be maintained at levels sufficient to avoid risk of loss of yield. In many developing countries, soil P is certainly well below this critical level, reducing soil fertility and crop production.

In developed countries, more research is clearly necessary to better understand how much phosphate must be added to soil, and in what form (degree of solubility) to ensure that critical levels of available P in different soils are maintained. In particular, the rates of transfer of available P to and from other unavailable forms in the soil need to investigated. The report provides an overview of current knowledge on this question for different types of soil and farm systems.

The report also looks at the question of P-loss from agricultural soils to surface waters by erosion, surface runoff, subsurface runoff (eg. in drains) and by leaching. In each case, P can be lost either in soil particles (insoluble P) or as soluble P in water.

Again, it has traditionally been held that only small amounts of soluble P are lost from agricultural soils. The report points out, however, that very small losses per hectare from soil imply significant P concentrations in drainage water (0.1 KgP/ha can give 100Êg/l runoff). Furthermore, recent experimental results (Rothamsted ; Sweden) show considerable increases in P runoff above a certain total concentration in soil (around 60mg/Kg Olsen P in certain experiments).

The report concludes by underlining the necessity of a balanced fertilisation plan, aimed at ensuring that soil P remains just above the critical level necessary for optimal production (considered to be around 25mg/Kg Olsen P in the UK, for example) whilst avoiding higher levels which might lead to runoff liable to contribute to eutrophication of surface waters.

More research is needed into the capacity of soils to retain P in different forms and into fertilisation techniques which are aimed at adapting P availability to crops needs, rather than simply maintaining high soil P levels.

AE Johnston - "Phosphorus, its efficient use in agriculture and its loss from agricultural soils" IACR Rothamsted Publication n° 1997-03. Rothamsted Experimental Station, Harpenden, Hertforshire AL 5 2 JQ, United Kingdom.

AUSTRALIA

MURRAY-DARLING BASIN
LAND USE AND WATER QUALITY PROBLEMS

An assessment of how land management practices play the key role in influencing water quality in the Murray-Darling Basin was presented by authors from the Basin Commission at the 1996 Australia and New Zealand National Soil Association Conference and has now been published.

This paper explains the economic and environmental importance of the Murray-Darling Basin : 2-3 million people depend on its resources; the basin provides 40% of Australia's agricultural production and 70% of industry in the area is based on agricultural products.

The basin faces major environmental problems as a result of changing land use and, in particular, agricultural irrigation. Soil erosion and soil structure decline are major problems and are already causing crop production losses estimated at $220 million/year. Clearing of forests and inappropriate irrigation are causing high water tables, promoting salinisation of soils and streams from saline subsoils.

Dramatic eutrophication problems have occurred: particularly the massive 1991-1992 algal bloom. Following this event a scientific research programme was launched which highlighted the importance both of nutrient inputs and of reduced river flows. Nutrients were shown to come mainly from erosion of river and stream banks and channels and from irrigated farmlands. External phosphorus inputs to one catchment area were estimated at 50t P from sewage, 169t from irrigated farmland and 140t from dry farmland. Increased salinity can lead to stratified anoxic conditions, stimulating the release of nutrients. Wetlands, which naturally regulate nutrients, have disappeared or lost their water flow.

River water flows are heavily affected by water use, mainly for irrigation. "Drought" type conditions which would occur naturally in the lower Murray every 20 years, now appear two years out of three. The natural pattern of winter/spring flood flows and low autumn flow has effectively been reversed.

The paper underlines water use limitations and good soil management practives, including reducing farming of semi-arid and fragile soils, as key factors in preventing further deterioration of the situation.

D. Blackmore, D. Connell, Murray-Darling Basin Commission, GPO Box 409, Canberra ACT 2601, Australia.

HOLLAND

STORM WATERS AND BIOLOGICAL P-REMOVAL

A laboratory scale biological P-removal system (anaerobic - aerobic - settling sequencing batch reactor) was used to test the effects of excessive aeration on P-removal. A carbon substrate acetate was provided. This was fully consumed during the anaerobic phase giving a highly enriched sludge enabling P-removal during the aerobic cycle. The full batch cycle lasted 6 hours and the system was operated for a total of 200 days.

The system rapidly achieved a stable rate of P-removal near 100%. As of day 112, experiments were performed with excessive aeration during the aerobic phase obtained by bubbling compressed air through the reactor, followed by non aerated batches which enabled the reactor to "recover" (a single batch was sufficient to again achieve P-removal).

Monitoring showed that phosphorus uptake stops or is reduced in excessively aerated conditions because of depletion of PHB poly-hydoxy-butyrate. Relationships with glycogen consumption and maximum cell polyphosphate storage content were also studied. Adding acetate did not help, as phosphate release is accelerated during the anaerobic phase but cannot be taken up again. Glycogen cannot replace PHB for P-uptake in aerobic starvation conditions.

These results have direct practical implications for sewage works design and management. Unusually high water loads and low carbon concentrations, for example after rainstorms or at weekends, require careful control of conditions in the sludge reactors to avoid excessive aeration. Such control is not only essential to ensure efficient P-removal, it can also improve overall nitrogen removal : in particular, nitrate levels need to be controlled during such events to avoid competition between denitrifying bacteria and bio-P bacteria in the anaerobic zone.

D. Brdjanovic et al. "Impact of excessive aeration on biological phosphorus removal from wastewater" Wat. Res. vol 32 n° 1 pp 200-208 1998. International Institute for Infrastructural Hydraulic and Environmental Engineering IHE Delft, PO Box 3015, 2601 DA Delft, Holland.

DENMARK

P-UPTAKE BIOCHEMISTRY IN BIOLOGICAL P-REMOVAL

Biological P-removal results from complex interactions between different intracellular energy components. It is induced by an alternation of anaerobic, aerobic and anoxic conditions together with an extracellular supply of short-chain fatty acids.

In anaerobic conditions, P-accumulating organisms take up these acids, storing them intracellularly as poly-hydroxyalkanoates (PHA) using energy derived from cellular poly-phosphates. This results in a release of ortho-phosphates into the supernatent. Intracellular glycogen may also be necessary for this process. In a second stage, carbon limited aerobic or anoxic, PHA is used for growth, glycogen synthesis and uptake of ortho-P (converted to inracellular poly-P).

This study looked at the relations between PHA availability and bio P-removal in this second, aerobic stage.

Experiments were carried out using an aerobic batch reactor and activated sludge from a biological P-removal pilot plant of the Bio-Denipho type. The loadings of carbon and P to the source pilot plant were low during the experiments, resulting in a high C/P ratio of 30/1. The experimental carbon source was primarily acetate, so that PHAs were assumed to consist principally of PHB. The sludge in the batch reactor was subjected to consecutive anaerobic and aerobic periods to obtain different initial PHB levels ; PHB degredation and P-uptake rates were investigated in the presence or absence of ortho-P in the supernatent in four different batch experiments.

P-uptake rates were shown to be highly dependent on the PHB concentration and not on sludge organism growth rates. PHB was shown to be readily degraded, even without simultaneous P-uptake, but the presence of ortho-P increased degredation rates, thereby confirming that PHB was required for P-uptake.

The availability of PHA in the second, aerobic stage of biological P-removal is thus essential for effective P-removal. Insufficient concentrations can result, in particular, from inadequate organic carbon (fatty acid) levels in the initial, anearobic stage. Process management must however ensure that PHAs are actually used for P-uptake and not wasted by pure oxidation.

B. Peterson, H. Temmink, M. Henze and S. Isaacs, "Phosphate uptake kinetics in relation to PHB under aerobic conditions", Wat. Res. Vol 32 NO 1 pp 91-100 1998. Technical University of Denmark DK 2800 Lyngby, Denmark.

GERMANY

NITROGEN AND PHOSPHORUS BALANCES

The sources and pathways of water, nitrogen and phosphorus are identified and assessed for nutrient input into water courses in Germany. Municipal wastewater and land erosion are the main sources of phosphorus ; groundwater, agricultural landuse and municipal wastewater for nitrogen.

Flow charts of nutrient fluxes show that 60% of nitrogen and 80% of phosphorus in urban wastewaters come from 1% of the input waters : toilets. The drains act to dilute these nutrients and mix them with other products, with modern sewage works then having to concentrate the nutrients again.

The authors suggest that new approaches to sewage management are needed, instead of simply spending more money at the end of the pipe. Waste water separation at source can significantly reduce volumes to be treated and efficiency of treatment. The authors also suggest that reuse of carbon and nutrients from waste waters through recovery is important for a sustainable future.

T. Herrmann and U. Klaus "Fluxes of nutrients in urban drainage systems : assessment of sources, pathways and treatment techniques" Wat. Sci. Tech. vol 36 n¯ 8-9 pp 167-172 1997. InstitÅt fÅr Wasserwirtschaft, Hannover University, Germany.

USA

MODELLING LAKE ECOLOGY RESPONSES TO PHOSPHORUS AND CARBON INPUTS

Lakes are generally classed as oligotrophic (low primary biomass productivity, low humic content, clear water), dystrophic (low productivity, high humic content, brownish water) or eutrophic (high primary productivity, low humic content, greenish water). These are often thought to be alternative stable states, maintained by feedback mechanisms, and resulting from external inputs (climate, nutrients, carbon input, water flow ...). This paper asks whether eutrophy and dystrophy are alternative stable states, maintained by internal processes within a particular range of external factors, or whether they are simply poles of a continuum defined mainly by P and carbon inputs.

The paper includes an assessment of existing literature regarding lake ecosystems and sediments, mathematical models (models of alternate states, chlorophyll-carbon interaction model) and comparisons with actual changes measured in a whole lake experiment carried out in Long Lake, Madison, USA, 1991 - 1994.

In the whole lake experiment, Long Lake was divided by plastic curtains in May 1991, separating sources of organic carbon input which resulted in significantly differing conditions in the two parts of the lake. It was then enriched with N and P after two years of experiment in order to obtain data for a wide range of nutrient and carbon levels.

These experiments showed that the lake takes over 100 days to return to a stable state after a significant change in inputs. Because spring snowmelt brings substantial nutrient and carbon inputs and fish and algal grazer populations vary, it is unlikely that the lake is ever at a stable state. The study thus concludes that it is more important to model dynamic variablility of lake conditions than to model steady states.

Over the long term, changes in land use (agriculture, urbanisation, destruction of wetlands ...) and climate-caused changes in water flow are the key factors in modifying lake status. Low levels of organic carbon, resulting from loss of wetlands and intensification of agriculture, accentuate sensitivity of algal biomass to fluctuations in P input.

Carpenter S. R. and Pace M. L. 1997 "Dystrophy and eutrophy in lake ecosystems : implications of fluctuating inputs" Oikos 78 : 3-14. Contact : S. R. Carpenter, University of Winsconsin, Madison, USA. Email : srclake@macc.wisc.edu.

GERMANY

HIGH ALGAL PRODUCTION IN VERY SHALLOW LAKES

A three-year study of 12 small lakes in the Schmarmützelzee area (East Brandenburg) of Germany compares primary algal growth with various other physical and chemical conditions in lakes of different depths.

The studied lakes are eutrophic to hypertrophic, with total P concentrations of 50 - 120 µgP/l. Nitrogen levels are such that P is the limiting nutrient, in particular because of high nutrient loads resulting from intensive agriculture in the catchment area and from fish management. Nutrient loads have been decreasing since the end of the 1980s, but no changes in phytoplankton development have yet been observed because of the high internal P load in the lakes.

Algal biomass is considerable in all of the lakes, even outside summer, with values in the range 70 - 250 mg Chl *a* /m^3 and as a result soluble phosphorus levels are generally low to very low: below the detection level for several weeks during the summer. Like many lakes in this area of central Europe, the lakes are generally dominated by bluegreen Oscillatoria algae in summer, sometimes other bluegreens such as Planktothrix or Limnothrix, but rarely dinoflagellates.

The study showed that total phytoplankton mass in the "very shallow" lakes (maximum depth < expected depth calculated from area, highly mixed waters) is about twice that in "medium shallow" or deeper lakes, for similar total nutrient loads. The "very shallow" lakes tended to be bluegreen algal dominated.

These results were thought to be because of better light conditions in "very shallow" lakes and optimal light/dark times as algae are cycled from lower waters to the surface by water mixing. Bluegreens are well adapted to this light/dark cycle and to low soluble phosphorus levels.

The "very shallow" lakes were also shown to have a higher community respiration rate, probably due to bacterial turnover which makes nutrients more available to algae.

"Why very shallow lakes are more successful opposing reduced nutrient loading" Hydro-Biologia 342/343 1997. B. Nixdorf and R. Deneke, Faculty of Environmental Science - Water Protection, Technical University Cottbus, Seestrasse 45, D 15526 Bad-Saarow, Germany.

SPAIN

MODELLING EUTROPHICATION DYNAMICS IN MICROCOSMS

This study describes application and adaptation of the Water Quality Simulation Programme WASP5 to daily phytoplankton and nutrient dynamics in perturbed microcosms in the Amadorio reservoir, Alicante province, South East Spain. The microcosms were studied over a 1 - 2 week period after artificial increases in nutrient levels from the natural low levels (< 0,01gP/l) of the reservoir.

The eutrophication model EUTRO5, a component of WASP5, was first applied to a relatively stable microcosm, in order to calibrate parameter values for such factors as light intensity, temperature, nutrient concentration and phytoplankton biomass and respiration rate. The model was then compared with the behaviour of perturbed microcosms.

Although it was demonstrated to be possible to adapt the WASP5 model, designed to model long-term changes, to the daily dynamics of the microcosms, results after application to eight microscosms were descriptive rather than predictive. Factors not modelled, such as initial species composition amongst phytoplankton, significantly affect parameters. The authors consider that if enough experiments could be run, the model could be sufficiently completed and parameter values adequately defined to allow prediction of the behaviour of the main groups of phytoplankton present.

"Modelling Eutrophication Kinetics in Reservoir Microcosms", Hernandez, Ambrose, Prats, Ferrandis and Asensi, Water. Res. vol 31 No. 10 1997. Correspondance to author : pilar.hernandez@ua.es

HOLLAND

"STATE OF THE ART" OF EUTROPHICATION RESEARCH

Proceedings of the specialist symposium organised in Holland 28-29th August 1998 by the Wageningen

Agricultural University, RIZA (Institute for Inland Water Management and Waste Water Treatment), IAWQ (International Association for Water Quality) and NVA (Dutch Association for Water Management). 41 papers concerning nutrient inputs, processes, efects, modelling, management and restoration, management policies.

Regarding phosphate inputs, O. Oenema (Wageningen Research Institute for Agrobiology and Soil Fertility) and CWJ Roest (Winland Staring Centre for Integrated Land, Soil and Water Research, Wageningen) look at losses from agriculture into surface waters. They underline that agriculture has become an important diffuse source of phosphorus and that the "widely held belief" that soils retain phosphates preventing input to surface waters can no longer be upheld.

They indicate that phosphorus saturations of soil of 25, 50 and 75% show concentrations of total dissolved P in upper groundwater of 0.15, 0.45 and 1.35 mg/l respectively. 78% of sandy agricultural soils in Holland are estimated to have over 25% soil P saturation. In 1995, average soil loss of P in Holland was estimated at 2.2 Kg/ha/year through drainage, with the soil itself storing an average of 30.1 Kg/ha/y.

Regarding mechanisms, Scholten et al. (TNO Environmental Sciences, Energy Research and Process, Den Helder, Holland) look at anorexia of daphnids as a critical factor in the developement of eutrophication problems. On the basis of semi-field and indoor multispecies community experiments, a conceptual model is presented to describe the effects of nutrient and toxicant interactions on algal blooms.

Many toxic pollutants (except herbicides) affect the grazing efficiency of daphnids before having other impacts on the ecosystem and, importantly, at lower concentrations than those necessary to reduce algal growth. This effect is termed "daphnid toxic anorexia" and can lead to the developement of algal blooms in the presence of nutrient input.

This paper concludes that populations of daphnids and algae-grazers should be studied and conditions for their healthy development restored before large-scale nutrient input reduction schemes are launched.

Regarding water body management, S. Harry Hosper (RIZA Institute for Inland Water Management and Waste Water Treatment) reviews results of lake restoration programmes in Holland (eg. Lake Veluwemeer). Programmes centred on reducing external P loading from point sources have often not given the results hoped for.

The author presents current thinking on stable states of water bodies, switches, buffers and top-down control. Restoration will often not succeed because certain mechanisms ensure that the turbid, algae-dominated lake remains the stable state, even with reduced nutrient input: these mechanisms include algal blooms (in particular Oscillatoria) which cause P-release from lake sediments, and high populations of grazing fish which prevent zooplankton and plants from developing.

Winter flushing with water low in P and algae in order to reduce algal blooms and fishing of planktivorous fish (bream, roach ...) can facilitate successful restoration by top-down control of algae (in particular by Daphnia grazing).

Proceedings of the "Eutrophication Research - State of the Art" conference, Wageningen, 28-29 August 1997. Organised by IAWQ and Wageningen Agricultural University, Department of Water Quality Management and Aquatic Ecology, Wageningen, Holland.

UNITED KINGDOM

RESTORING EUTROPHICATED LAKES

The state of shallow lakes depends not only on nutrient inputs but also on a number of other factors which affect the balance between domination by higher plants or by algae.

This book is a guide to the management of these factors, with the objective of lake restoration. It provides a "layman's" presentation of the different environmental mechanisms involved, with a large number of photos, charts and diagrams, but also detailed examples of management techniques and field experiences, in particular in the Norfok Broads, a well-studied shallow lake area in South-East England, much used by tourists and with significant natural heritage value.

Shallow lakes can move between two different states : clear water with plant dominance, resulting either from low nutrient levels (preventing algal growth or enabling successful competition of plants for nitrogen) or from effective grazing of algae by Cladoceran (Daphnia) zooplankton ; or turbid water with phytoplankton dominance. Turbid water prevents plant growth, thus eliminating refuges for algae-grazing zooplankton and perpetuating such conditions.

The book explains how different "forward switches" can cause a move between these two states : populations of fish species which can damage plants (by grazing, uprooting, turbidity caused by chrning of sediments ...) or affect populations of zooplankton which graze on algae ; loss of predatory fish, which reduce populations of smaller fish which eat zooplankton ; pollution, which can affect both zooplankton and predatory fish; physical factors (such as boats) which can affect plants ...

Reducing nutrient inputs, in particular phosphates, is important for stable recovery of a lake, but a number of other actions will often also be necessary : removal of "forward switches" such as pollution or boat damage, adjustment of the fish community to favour grazers of algae (biomanipulation) and reintroduction of plants. Removal of a layer of P-rich lake sediment may also be necessary to prevent the release of nutrients into water. The book looks at methods and costs associated with these different actions and provides illustrations from different lakes across Europe.

Tools are presented for defining a lake restoration strategy and choosing different means of action. It is emphasised that in many cases effective restoration may require radical steps, such as manipulation of fish populations or removal of sediment, which may prove unpopular with fishermen or local populations. The first step is to ensure support of the restoration objectives. In some cases, local populations may prefer to have a lake with many algal consuming fish (such as carp), boating activities, clean banks ... rather than clear water, many plants, fewer and smaller fish. The book provides a useful tool for the decision maker and provides valuable material in explaining lake management policies.

"A guide to the restoration of nutrient-enriched shallow lakes". Norfolk Broads Authority, 18 Colegate, Norwich, Norfolk NR3 1BQ, Great Britain. £16.95 including postage (Europe).

SWITZERLAND

CLEAR CONSTANCE: RESTORATION OF LAKE CONSTANCE

Lake Constance on the upper Rhine river, covers an area of 539 km². It is naturally oligotrophic with a catchment area mainly situated in the Swiss and Austrian Alps. Phosphorus is considered to be the key factor limiting primary zooplankton growth.

By the 1970's, phosphorus levels, had risen from a natural level of under 5 µgP/l to over 90 µgP/l, causing changes in the zooplankton species balance with a development of blue green (cyanophyceae) and green (chlorophyeae) algae at the expense of diatoms (bacillariophyceae). At this time, 79% of the annual phosphorus input was estimated to come from urban waste waters, 12% from agricultural run-off, and only 0,5% from natural sources.

Very early in its recent history a major international programme was launched to restore Lake Constance with the first agreement being signed in 1961 when the first signs of changing water quality were observed. Around 6 000 million Swiss Francs have been spent to date to ensure phosphate removal in sewage treatment installations.

This programme has been very effective. Phosphorus levels dropped back to 16 µgP/l in 1996 and the phytoplankton balance has been restored. Phosphorus levels in the lake's sediments have not dropped in parallel with concentrations in the water, but do not seem to be released back into the lake. As nutrient inputs have been reduced, however, fish production has also dropped significantly.

The phosphorus removal installation in sewage works, with the corresponding improvements in water treatment, have also significantly contributed to reducing inputs of other pollutants (including heavy metals, PCBs, dioxins, pesticides, hydrocarbons ...) in the lake's water.

A variety of other actions have been instigated to safeguard Lake Constance. For example, an oil pipeline which ran under the beach at Breganz was removed in early 1997.

For the International Study Group Waterworks Lake Constance (AWBR), which coordinates the lake's restoration, the lake's restoration programme can now be considered a success and the drinking water supply of 4.5 million people in Switzerland, Austria, Germany and Lichtenstein is now secured for future generations.

Source : WQI September/October 1997, pages 30-33.

FRANCE

PHOSPHATE AND NITRATES IN ANIMAL MANURES

The French Government Institution CEMAGREF (Agricultural and Environmental Engineering Research) has published an overview of the different treatment methods for pig manure being developed in France. The study underlines the large quantities of liquid manure produced by intensive pig rearing and the disposal problems posed by this product, often in areas with an excess of other nutrient-rich wastes from chicken farms, veal and milk cattle, ducks or rabbit rearing etc... Because agricultural surfaces available for spreading are often locally insufficient, current European legislation regarding intensive animal farms and nitrates will require increasing treatment of manures.

Treatment methods generally aim to transform liquid manure into a product which can be used for rationalised agricultural spreading, after storage and transport, by concentrating nutrients, reducing volumes and weights and eliminating smell problems. The study underlines, however, that the most effective way to reduce excess manure problems is to reduce nutrient loss from livestock production by modifying agricultural and animal feeding practice.

The study looks at the typical nutrient content and constitution in pig manure. 85 - 90% of phosphorus is present in manure solid particles (75-80% inorganic, 10% organic), the remainder mainly as soluble inorganic phosphate in the liquid. Most of the nitrogen, on the other hand, is present in the liquid (dissolved NH4, in particular), with only about 15% in the solids.

Efficient mechanical separation (floculation using polymers followed by centrifugal extraction) can thus extract around 90% of the phosphorus and 45% of the nitrogen from manure. The solids extracted can be dried to make saleable compost or burnt to provide energy. The reduction in nutrient content significantly facilitates disposal of the remaining liquid, either after regulatory storage time by spreading, or after addition nitrification - denitrification treatment. This treatment method is adapted for large individual production units, having excess phosphorus and nitrogen wastes, or for mobile collective installations which can be used for treating wastes from medium or small units.

The overview study examines the full range of treatment methods for manure : biological nitrification - denitrification of the liquid, heat drying, membrane concentration, chemical precipitation, volatization. It gives for each treatment method an indication of current scale of use, development perspectives, approximate costs.

Document available in French : "Procèdès de traitement des lisiers de porc ètudiès en France: principales techniques adaptèes à la gestion des lisiers en zone d'excèdent structurel" Jean Coillard, CEMAGREF Division Qualitè des Eaux - 3 bis quai Chevreau CP220 - 69336 Lyon Cèdex 09.