SCOPE NEWSLETTER

Water treatment

Sewage treatment
Costing phosphorus removal

The cost of removing phosphorus from sewage shows to be highly variable depending on sewage works configuration, target discharge P concentration and P-removal process applied.

Clarke Prize
James L. Barnard on resource recovery

The 2007 US National Water Research Institute Clarke Prize for outstanding achievement in water science and technology has been given to James L. Barnard, focusing on resource recovery from wastewaters: phosphorus recovery, nitrogen recovery, recycling of nutrients through algae production for biofuels …

Nutrient recycling

Oregon
Ostara struvite recovery projects

Following start-up of a full-scale commercial struvite recovery reactor in Edmonton Canada, another plant is now being designed following successful pilot testing at the Durham sewage works operated by Clean Water Services in Tigard, Oregon.

Japan
Struvite recovery in centralised sludge treatment

Struvite recovery reactor was tested as a solution to scaling problems in pipes taking sludge from sewage treatment works to the Osaka City central sludge treatment installation.

Germany & Japan
Calcium compounds

Calcium phosphate crystallisation facilitated by calcium silicate hydrate (CSH) or calcite as chemical jump start

Egypt
Struvite as fertiliser for broad beans

Laboratory experiments tested bittern as a magnesium source for struvite precipitation. Pot trials tested the fertiliser value of struvite for broad bean plants

Sewage fed aquaculture
Making sewage treatment productive

Most centralised sewage treatment is today centred on degradation and decomposition. Aquaculture systems instead aim to treat sewage with productive processes, producing harvestable biomass in marketable forms.

Phosphorus in surface waters

Eutrophication risk assessment
Using Bayesian probabilistic methods for modelling

A Bayesian calibration process is proposed as a tool to develop robust eutrophication models, giving probability ranges, as a tool for environmental management decision making.

Large rivers
Sewage P-load reduction and improved chlorophyll levels

Major reductions in river total phosphorus, by wastewater works P-removal, was followed by reduced algal development, despite high soluble phosphate levels.

Conferences

Delta water quality workshop
March 25th 2008, Sacramento, California

Technical Workshop on Overview of Delta Nutrient Water Quality Problems: Nutrient Load – Water Quality Impact Modelling.

International Conference
Nutrient Recovery from Wastewater Streams

May 10-13, 2009 - Vancouver, British Columbia, Canada

Water treatment

Sewage treatment
Costing phosphorus removal

A number of different papers present assessments of the cost of phosphorus removal from sewage, looking at costs of adapting existing sewage treatment plants to add P-removal, operating costs of chemical and biological P-removal processes in sewage plants, and costs of phosphorus removal in extensive systems such as wetlands and MAPS (Managed Aquatic Plant Systems).

A study in Georgia, USA (Jiang 2005) uses the software WEST (Hemmis nv, Kortrijk, Belgium) to assess costs of upgrading existing sewage treatment plants according to conditions in Georgia to implement P-removal down to different discharge consent levels for phosphorus, from 2 mgP/l to 0.05 mgP/l. Three plant capacities are considered (1 – 100 million gallons per day) and three different plant configurations (basic activated sludge AS process with chemical addition, Anoxic/Oxic A/O arrangement of the AS process, Anaerobic/Aerobic/Oxic A/A/O arrangement of the AS process).

The software allows **simulation of costs for both chemical P-removal and biological nutrient removal** processes. The costing takes into account necessary capital investment, operating and maintenance costs, energy, chemical use and sludge disposal.

Costs per kilogramme P-removal for upgrading sewage works

Costs per kilogramme of phosphorus removed are significantly higher for smaller plants and for lower discharge effluent phosphorus concentrations (TP standard).

TP limit	2 mgP/l	1 mgP/l	0.5 mgP/l	0.13 mgP/l	0.05 mgP/l
$/kg P removed, including capital, operating, chemicals (alum), sludge disposal					
For capacity 1 MGD :	31-72 $	28-87/$	195-269 $	250-277 $	387-432 $
For capacity 100 MGD:	8-20 $	13-28 $	54-65 $	123-110 $	162-163 $

The **wide variation of cost per kilogramme of P removed** suggests that P-discharge permit trading can significantly reduce the overall cost to society, by enabling P-removal to be implemented where the cost effectiveness is optimal.
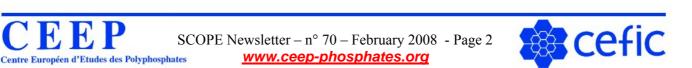
Costs for biomass removal of P from agricultural runoff

A study by the University of Florida (Sano, 2004) assesses the costs of phosphorus removal from agricultural runoff waters, using aquatic plants and biomass, in STAs (Wetland Stormwater Treatment Areas) and MAPS (Managed Aquatic Plant Systems).

STAs are large reservoirs which retain stormwaters so that phosphorus is fixed into soil or plants. The MAPS studied is a more compact system in which phosphorus is retained by a cultivated community of periphytic algae (developed by HydoMentia Inc). The algae are harvested by mechanical scraping and processed into a marketable biomass product.

In the eleven systems studied, **costs of phosphorus removal varied, with costs being higher for lower required discharge concentrations**:

- US$ 268-1,346 per kgP removed for an STA taking phosphorus concentrations down (from 0.04 - 0.18 mgP/l) to a very low discharge consent level of 0.01 mgP/l

- US$ 77 for an STA taking concentrations down from 0.54 to 0.04 mgP/l

- US$24 for a MAPS taking concentrations down from 0.3 to 0.155 mgP/l

Biological P-removal, iron or alum ?

Keplinger et al., 2003, compare different routes for P-removal concluding that **"Biological nutrient removal has become widespread at WWTPs across the US, but is often not cost-effective for small WWTPs"**. The authors provide cost estimations for operation of P-removal using alum dosing (chemical costs, sludge disposal, other operating costs) and for capital costs, for 6 WWTPs in the Bosque River catchment, Texas, with served populations of around 360 - 1,100 - 1,300 - 1,500 - 3,500 - 15,000.

They estimate that to achieve a discharge consent of 1 mgP/l alum must be dosed at approximately 2.1:1 molar ratio to phosphorus.

Emissions trading

The authors estimated that if emissions trading was developed, as opposed to applying straight discharge consents to each WWTP, then the per household costs of achieving the objective phosphorus discharge reductions (equivalent to 1 mgP/l for all WWTPs) would be **reduced from 18 to 11 US$ per household** per year. Opportunities are however limited by P-removal capacity available at certain plants.

Cost estimates for P-removal

Other costings for P-removal in sewage works include the following, again showing a wide range of figures:

- **UK £ 6.50 per kg P removed**, in sewage works > 10,000 pe (Water Service for Northern Ireland, cited in Smith 2005)

- **approx. 9 €/kgP removed** for a 25,000 pe sewage works (calculated assuming 2gP/pe/day from the figure given 6.7€ pe/year), difference between "biological treatment, N+P removal, filtration" and "biological treatment N removal", operating

costs only - investment costs not included (Sweden VA 2002, annex 6)

- **4.8 €/kgP** charged by Stockholm Water to industrial customers (VA 2002, p.17)

- **10 €/kgP**, for Iron sulphate precipitation chemical costs (only) to move from existing EU Urban Waste Water Treatment Directive requirements for 1 or 2 mgP/l discharge consent to 0.5 mgP/l discharge (Helcom 2007)

- **approx. 24 - 31 US$/kgP removed** for 1 mgP/l discharge consent and 56-73 US$/kgP for 0.1 mgP/l discharge, calculated from costs given per household, assuming 2.5 persons per household and 2gP/person/day (USA New Jersey, Platt, 2002)

- **4.6 US $ /kgP** for biological P-removal and $ 11.3 for chemical P-removal (Woods et al., 1998)

- **31 US$/kgP** for a 15,000 population sewage works, up to 100 – 730 US$/kgP for 3,500 to 350 person works, to achieve 1 mgP/l outflow (Keplinger et al., North Bosque Texas, 2003)

- **1 - 9 UK£/kgP** to achieve 2 mgP/l discharge consent for large sewage works (>10,000 pe), UK£ 3-17 for 1 mgP/l discharge and UK£ 4-24 for stringent discharge P consensts (< 1 mgP/l). For smaller sewage works, the estimated costs increase to the range UK£/kgP 6-60 for sewage works of 2,000 pe, and up to UK£ 35 – 146 for very small sewage works (<2,000 pe). The UK water industry (OFWAT, 2005). However, it is estimated that >90% of sewage collected in the UK in potentially eutrophication sensitive areas is discharged to sewage works > 10,000 pe.

Jiang 2005: "Estimation of costs of phosphorus removal in wastewater treatment facilities: adaptation of existing facilities", Feb. 2005, Georgia, USA Water Policy Working Paper #2005-011, F. Jiang, M.B. Beck, University of Georgia , R.G. Cummings, K. Rowles, Georgia State University , and D. Russell, Global Environmental Operations, Inc . Work supported by the Georgia Soil and Water Conservation Commission, US Environmental Protection Agency, U.S. Department of Agriculture.
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VA, 2002: Swedish Environmental Protection Agency, VA Projekt "Cost-effective methods" 2002, n° 1701378000

Helcom 2007: Helcom BSAP Task Force 4-5 June 2007, document 3/12/Add1, Sweden.

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http://asae.frymulti.com/abstract.asp?aid=15543&t=1

Ofwat (2007) "Water Framework Directive - preliminary Cost Effectiveness Analysis. Water Industry working group Supporting Document ", Version 0.3
http://www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/AttachmentsByTitle/wfd_workgroup-suppdoc210807.pdf/$FILE/wfd_workgroup-suppdoc210807.pdf

Clarke Prize
James L. Barnard on resource recovery

CONVERT GALLONS TO LITRES

The 2007 Clarke Annual Lecture, delivered by James L. Barnard recipient of the 2007 Athalie Richardson Irvine Clarke Prize for outstanding achievement in water science and technology, is entitled "Elimination of eutrophication through resource recovery" and outlines the necessity not only to treat wastewaters, but also to move towards sustainability by recovering for reuse the resources such wastewaters contain, and in particular the nutrients phosphorus and nitrogen.

The author emphasises the necessity of effective nutrient removal from sewage in urban areas worldwide, to protect water bodies from eutrophication, and also to reduce salinity or health risks downstream.

The development of biological phosphorus and nitrogen removal can ensure nutrient removal from sewage, without increasing discharge salinity (no inorganic chemical addition), and facilitates phosphorus recovery for recycling. The biological phosphorus removal process concentrates soluble phosphorus in a sidestream from which recovery is feasible.

However, nutrient removal from agricultural pollution sources (livestock, fertilisers) will also be necessary to achieve eutrophication objectives. Sewage provides only 34% of total phosphorus input to waters in Europe compared to 50% from agriculture (16% fertilisers, 34% livestock), and the proportion from agriculture is even higher for nitrogen sources. Only 11% of nitrogen to the Mississippi comes from municipal and industrial sources, for example, despite the presence of Chicago and other major cities.

Phosphate resources

Phosphorus is vital to agricultural production and for feeding the world's population.

President Roosevelt in 1938 stated: **"I cannot over-emphasise the importance of phosphorus not only to agriculture and soils conservation, but also the physical health and economic security of the people of the nation"**. The world's known reserves of phosphate are expected to last around 200 years but severe competition for supplies may develop within just 50 years from today.

Therefore, recovering phosphates from sewage and animal wastes is necessary for sustainability.

Processes are already operational to recover phosphorus from sewage as struvite (magnesium ammonium phosphate), which can be used as a fertiliser. Other P-recovery routes cited by the author

include extracting phosphorus from sewage sludge incineration ash and concentration of phosphorus into biosolids which are then composted to destroy pathogens. The compost can then be stored and applied to land, acting as a soil improver and recycling the phosphorus.

Nitrogen recovery

Ammonia gas can be stripped from waste waters, and then reacted with sulphuric acid to produce ammonium sulphate. However, this is not economically viable in most situations today, compared to the costs of producing mineral nitrogen fertilisers using natural gas energy input. The issue of nitrogen recovery is not resource related, but concerns energy consumption.

Urine separation is presented as a viable route for recovering, for reuse, both nitrogen and phosphorus. After ageing, the pH of urine increases, killing pathogens. The urine is then a complete and well-balanced fertiliser, with available nutrients.

Algal biofuels

Some species of algae contain over 50% natural oils. **Production of algae in shallow ponds, fed by nutrients in wastewaters**, can both contribute to breakdown of remaining organic pollutants in the wastewaters, and produce 20 – 75,000 litres of biodiesel per hectare per year.

Water reclamation

With the risks of climate change, and increased risks of droughts, both water consumption reductions and the reuse of water itself from sewage will become increasingly necessary in many countries. Water reclamation by reuse for fertilising golf courses, biofuel production, forests or other non-crop land, where pathogens are not an issue, enables recycling both of the nutrients and the water itself.

The National Water Research Institute 14th Annual Lecture for the Athalie Richardson Irvine Clarke Prize for Outstanding Achievement in Water Science and Technology: "Elimination of eutrophication through resource recovery", July 12th 2007, James L. Barnard.
www.nwri-usa.org/ClarkeLecture/

Oregon
Ostara struvite recovery projects

North America's first full-scale commercial struvite recovery reactor started operation in Edmonton, Canada, in early 2007 (see SCOPE Newsletter 65). Built by Ostara Nutrient Recovery Technologies Inc., the plant is based on the fluidised bed reactor technology developed by UBC (University of British Columbia) over recent years. The struvite fertiliser produced is marketed under the name of Crystal Green. A pilot plant is was tested at the Clean Water Services Durham Advanced Wastewater Treatment Facility, Oregon and successful tests have also been completed [B] at the Hampton Roads Sanitation District's Nansemond Wastewater Treatment Plant, Suffolk, Virginia (Chesapeake Bay).

The Durham Plant discharges into the slow moving Tualatin River and applies **strict phosphorus removal limits of 0.1 mg/L in the treated effluent**. Sludge fermentation provides an organic substrate to feed biological nutrient removal. However, at present, 30% of sewage works inflow phosphorus and ammonia comes from the sludge dewatering return liquors. **Struvite precipitation for P-recovery can remove this return phosphorus flow, thus improving biological nutrient removal performance**.

The 8 week pilot trial of the Ostara reactor, treating around 1/300th of plant capacity [A], demonstrated expected full scale performance and to enabled footprint and cost effectiveness of a full scale plant to be calculated.

Ostara indicate that the sale of the recovered struvite, as fertiliser, covers plant operating costs once installed. Capital costs are indicated at 1 – 3 million €, recoverable in 3-5 years through savings on sewage works operating costs.

Furthermore, each tonne of struvite fertiliser produced brings 4-6 tonnes of greenhouse gas credits.

Status of Ostara Nutrient Recovery installations in sewage treatment plants (January 2008)		
Site	**Dates**	**Capacity**
Annacis Island wwtp, Vancouver, Canada	2004-2006, see SCOPE Newsletters 56 & 60	Experimental (19-40 litre reactors)
Lulu Island wwtp, Vancouver, Canada		
Penticton wwtp, British Columbia, Canada		
Nansemond wwtp, Suffolk, Virginia, USA	2006-2007, see SCOPE Newsletter 65 and [F] below	
Durham, Oregon, USA	2007 – Pilot 2008 – Full Scale	Design underway for full scale 3 reactor facility with 1500 kg/day struvite production capacity
Gold Bar wwtp, Edmonton, Alberta, Canada	Full scale plant commissioned May 2007 [G] Following pilot reactor trials 2006	Full-scale reactor (1500 kg/day struvite production capacity), treating one fifth of the wwtp capacity

Greenhouse gas credits

In a paper presented at "Wastewater Biosolids Sustainability" conference 2007 (see below [E]), the Life Cycle Analysis of the struvite recovery process is assessed, calculated for the full-scale installation constructed at **Gold Bar Edmonton** treating supernatant equivalent to 200,000 population (one fifth of the sewage treatment works capacity), and based on the operating results of the 6 month pilot plant trial at this sewage works in 2006.

These pilot trial results show that **the Ostara process can recover 75% of soluble phosphate in digester supernatant, as recyclable struvite**.

This would generate 180 tonnes/year of struvite and economise over 2,000 tonnes/year of greenhouse emissions. Extended to the whole sewage works capacity, the struvite recovery process would reduce plant phosphorus load by 20% and nitrogen load by 5%, and would result in a **net greenhouse gas emissions reduction of 12,400 tonnes CO_2 equivalent per year**.

LCA assessment

The Life Cycle assessment compares:

- treatment with struvite recovery and use of recovered struvite as fertiliser

- no struvite recovery: higher wastewater discharge phosphate and ammonia levels, conventional production of mineral fertilisers for the same agricultural nutrient value

Results of the Life Cycle Assessment show significantly lower estimated emissions where struvite recovery is applied

Tonnes per year, for a population of 200,000 (500,000 litres/day) (1/5th of sewage works total capacity)	With struvite recovery	Without struvite recovery
Struvite production	180 tonnes/year	-
Emissions to air (tonnes/year)		
Sulphur dioxide	1.8	4.3
Carbon monoxide	0.7	3.0
Nitrogen dioxide	1.3	5.2
Greenhouse gas emissions (tonnes/year)		
CO_2 equivalent	430	2492
Emissions to soil (kg/year)		
Cadmium	0.1	7.2
Chromium	0.4	64.3
Arsenic	0.2	0.9

Struvite precipitation kinetics

The University of British Columbia team which helped to develop the Ostara reactor technology, is continuing its work into struvite precipitation. Two papers at the IWA Biosolids Management conference, Canada, June 2007, present their ongoing research.

One paper [C] presents results of **stirred beaker lab tests** using pure reagent solutions. An initial phosphorus (PO_4-P) concentration of 30.5 mgP/l was tested with various magnesium and ammonium concentrations and pH in the range 7.9 -8.5. Results show significantly faster struvite precipitation with a Mg:P molar ratio of 1.3:1 compared to 1:1, but no significant increase for a higher ratio of 1.6:1. Mixing speed and seeding with struvite crystals showed to have little effect on the intrinsic precipitation kinetics, possibly because the lower mixing speed used was already higher than the optimum suggested by Wang et al 2006. (see SCOPE Newsletter 60).

A second paper [D] presents further results of experiments using two identical 19-litre volume pilot struvite reactors (see "Pilot scale experiments …" in SCOPE Newsletter 60), using real sewage works sludge centrate at the **Lulu Island Wastewater Treatment Plant** (LIWWTP), Richmond, British Columbia, Canada. The centrate had a soluble phosphate concentration of average 76 mgP-PO_4/l. Magnesium chloride was added to ensure a 1.3:1

Mg:P ratio and sodium hydroxide to ensure an optimal operating pH of 8.2 – 8.3.

Struvite was successfully produced in 0.5 – 3.5 mm pellets. Important issues in reactor operation were shown to be: the mixing and energy at the liquor injection point at the base of the reactor, where spontaneous nucleation (fines) tended to occur because of local conditions even when the average reactor conditions were below supersaturation ; and upflow velocity, with a narrow window of conditions appropriate to ensure mixing but avoid carry-over of fines. 75-85% phosphate removal was thus achieved in the reactor with a liquor recycle ratio of 5-9.

Referenced papers

A] Tigard - Tualatin – Sherwood Times June 27th 2007 *"CWS's Durham treatment plant sludge just may smell like money"*
http://www.localnewsdaily.com/sustainable/story.php?story_id=118299244908679800

B] Ostara News Release, 1st May 2007, Virginia Suffolk pilot plant trials: http://www.onrti.com/news_release1.htm

C] *"Effects of Various Process Parameters on Struvite Precipitation Kinetics and Subsequent Determination of Rate Constants"*, M. Rahaman, N. Ellis, D. Mavinic
http://www.cepis.ops-oms.org/bvsaar/cdlodos/pdf/phosphorusrecovery447.pdf

D] *"Phosphorus recovery from wastewater through struvite formation in fluidized bed reactors: a sustainable approach"*, M. Bhuiyan, D. Mavinic, F. Koch
http://www.cepis.ops-oms.org/bvsaar/cdlodos/pdf/effectsofvarious535.pdf

For both papers, authors: Environmental Engineering Group, Department of Civil Engineering and Fluidization Research Centre, Department of Chemical & Biological Engineering, University of British Columbia (UBC), Vancouver, BC, Canada. dsm@civil.ubc.ca

Both papers: IWA Conference Moving Forward, Wastewater Biosolids Sustainability Technical Managerial and Public Synergy, June 24-27, Moncton, New Brunswick, Canada
http://www.iwabiosolidsmoncton2007.ca

E] *"Value From Waste – Struvite Recovery at the City of Edmonton's Gold Bar WWTP"* http://www.cepis.ops-oms.org/bvsaar/cdlodos/pdf/valuefromwaste575.pdf

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F] *"Nutrient Recovery by Struvite Crystallization Process: Virginia Experience"*
http://www.ostara.com/files/u1/EC_07_Paper_Session_4_Ram_Prasad-_Manuscript.pdf

R. Prasad*****, A. Britton*,2 Bill Balzer******, Gary Schafran*****. Authors: ***** Old Dominion University, Rm 135 Kaufman Hall, Hampton Blvd, Norfolk, Virginia 23529, * Ostara Nutrient Recovery Technologies Inc. as above, ****** Hampton Roads Sanitation District.

G] Ostara News Release, 3rd December 2007 *"Ostara Nutrient Recovery Technologies Inc.: Edmonton Reveals World's First Industrial Scale Sewage Treatment Facility to Recycle Nutrients Into Environmentally-Safe Commercial Fertilizer"*
http://www.ostara.com/files/u1/Dec_3_2007_Ostara_News_Release.pdf

Other papers:

"Prediction of Struvite Precipitation Potential using a Chemical Equilibrium Model", M. Bhuiyan, 2007 BCWWA (British Columbia Water and Waste Association) Annual Conference, 24 April 2007
http://www.civil.ubc.ca/pcwm/Seminars/Iqbal%20Bhuiyan.pdf

"Finding a long term solution to struvite accumulation in biological nutrient removal (BNR) plants", K. Parvez Fattah, 2007 BCWWA (British Columbia Water and Waste Association) Annual Conference, 24 April 2007
http://www.civil.ubc.ca/pcwm/Seminars/Parvez%20Fattah.pdf

See also Thesis by K. Fattah, University of British Columbia – Civil Engineering, 2004 "Pilot Scale Struvite Recovery Potential from Centrate at Lulu Island Wastewater Treatment Plant"
http://www.civil.ubc.ca/department/theses.htm

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Japan

Struvite recovery in centralised sludge treatment

Osaka City is developing centralised sewage sludge treatment, with anaerobically digested sludge conveyed to the central treatment plant through pipes. The operators are concerned by the risk of struvite precipitation in the piping or reservoir tanks because the sewage plants use a high-solids thermophilic digestion process to facilitate the downstream sludge treatment process. At present, this risk of struvite fouling is addressed by adding iron chloride to remove phosphate from the sludge. A pilot scale struvite precipitation reactor (total 156 litre capacity) was tested for six months. The objectives were to avoid struvite deposit problems, avoid the iron chloride addition, and at the same time recover phosphate for recycling as a fertiliser.

The digested sludge contained 100 – 140 mg/l soluble phosphorus, around 1,000 mg/l ammonium nitrogen and around 10 mg/l magnesium.

The struvite recovery installation consisted of a **170cm high pilot-scale fluidised bed struvite precipitation reactor**, with interior baffles and a wider top-reactor zone to enable settling of smaller particles, along with particle separators.

Struvite concentration and separation units

A liquid cyclone was installed downstream of the reactor outflow (reactor top overflow). During day-to-day continuous running operation, struvite particles from this reactor outflow stream were collected at the bottom of the liquid cyclone and returned to the reactor as seed crystals, and the final treated liquor steam overflowed from the top of the liquid cyclone.

Occasionally, struvite particles were also withdrawn from the bottom of the reactor, as a batch operation. In this case, the bottom of the reactor was connected the inflow to the liquid cyclone, and the bottom of the liquid cyclone was connected to a 0.3 mm screen separator. After screen sorting, the particles larger than 0.3 mm were recovered as recycled phosphate granules, and overflow from the liquid cyclone along with rinsing water from the screen separator, which contained fine struvite crystals, were returned to the reactor as seed crystals.

Both magnesium chloride and magnesium hydroxide were tested as magnesium sources, at different pH. Magnesium chloride appeared as a more effective reagent, because of its higher solubility resulting in faster reaction times, thus making it easier to avoid excess magnesium being left in the reactor overflow where it would be susceptible to cause struvite deposit problems downstream. However, magnesium chloride necessitated the addition of sodium hydroxide to achieve an operating pH of 8.5, and was significantly more expensive to purchase.

An objective outflow concentration of 20 mg/l soluble phosphorus was achieved and struvite granules of size 0.3 – 2 mm were recovered, with 60% of particles being in the range 0.425 – 0.8 mm diameter.

Fertiliser

The recovered struvite was analysed for content of magnesium, ammonium and phosphate, showing levels very close to those expected in pure struvite. **Analysis of heavy metals and other contaminants and were below levels fixed by the Fertiliser Control Act in Japan**, so that the recovered struvite could be used as a fertiliser or in fertiliser manufacture.
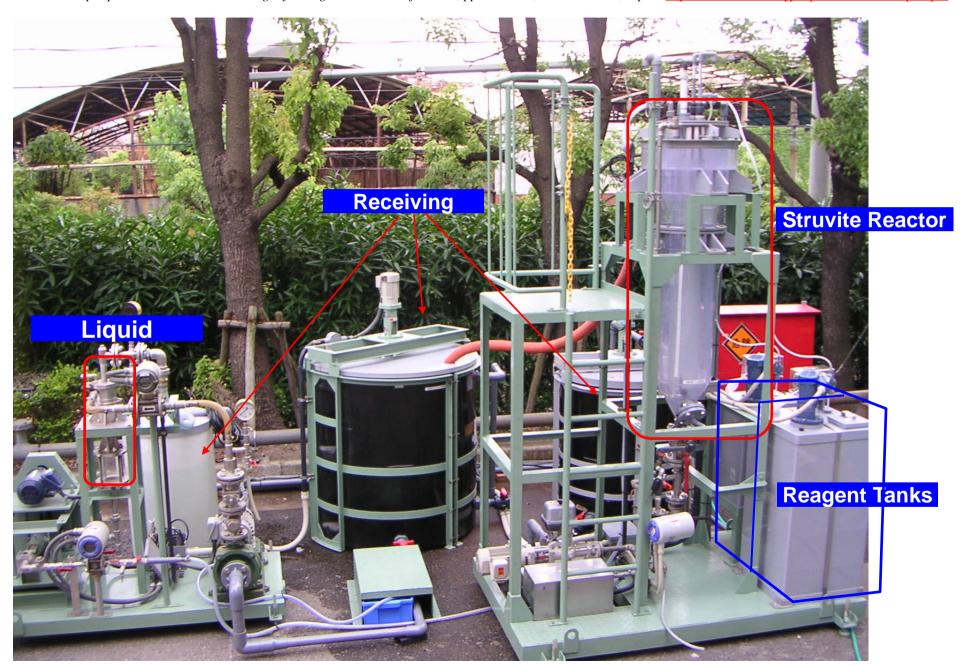
Comparison was made between struvite deposit fouling of piping and stirrer blades in the digested sludge, and in liquor after treatment in the struvite recovery reactor. After 125 days, a 25mm pipe taking digested sludge showed approx 2.5mm thickness scaling, whereas **the pipe for struvite reactor treated liquor showed no fouling**, with similar observations for the stirrer blades.

"Experiment on phosphorus recovery from digested sludge using struvite crystallization method", Takaaki Nakamura, Public Works Bureau Osaka City Government, Japan, Akira Nakabayashi, Tsukishima Kikai Co. Ltd., Takeshi Nakamura, Unitika Ltd, Japan tomohiro-matsushita@unitika.co.jp

Germany & Japan
Calcium compounds

A number of studies in Germany and Japan have looked at the possibilities of using calcium silicate hydrate (crystalline CSH of a tobermorite-like composition and structure) as a seed material to enable the recovery of phosphates from waste waters, by stimulating the crystallisation of calcium phosphates. This follows similar work using calcite (calcium carbonate) and mixtures of calcite and CSH. The CSH proved to be more resistant to inhibition by organic materials present in the wastewater than is calcite.

Previous studies using tobermorite are summarised in SCOPE Newsletter n°60 and using calcite in SCOPE Newsletter N° 49.

The CSH seed material used in the experiments in Germany was a construction industry by-product, rich in tobermorite ($Ca_5Si_6O_{16}(OH)_2*4H_2O$), with grain sizes of 0.6 – 1.3 mm for material A and 0.5 – 1.5 mm for material B.

The previous work (SCOPE Newsletter N°60) had suggested that the **effectiveness of tobermorite in stimulating calcium phosphate precipitation** is related to a leaching of calcium ions, which both increases the pH in the solution near the solid surface (CaOH) and provides available calcium for the formation of calcium phosphates. The tobermorite remained effective as long as reactor outflow pH was higher than inflow pH, that was approximately 3000 bed volumes.

In Berg et al. (2006b) the interrelationship between structural as well as chemical properties and the reaction behaviour have been investigated. As dominant factors the porosity of the material, initial P-concentration and the pH value of the waste water were identified. Porosity controls the efficiency of the P-fixation process, whereas the chemical water composition determines the type of Ca-P mineral formed, with both hydroxyapatite and brushite formed. **The better water solubility of brushite is promising regarding the use of the reaction products as a fertiliser**.

In the experiments presented in Berg et al. 2005 and 2006a, **precipitation was tested in 20 – 100 litre fixed bed and 60 litre stirred reactor experiments**, using treated waste water from the Forschungszentrum Karlsruhe activated sludge sewage treatment plant (with phosphate added up to 10 or 25 mg/l to simulate a biological nutrient removal plant side stream), and from the side stream of a Phostrip biological P-removal plant in Austria.

Results were similar to the previous experiments, but with the B material showing somewhat better performance, remaining **effective up to around 4000 bed volumes**. This material B had lower levels of iron, zinc and copper compared to material A, thus improving the quality of the phosphorus-rich reaction product (lower levels of these contaminants than commercial phosphate rock), it which could thus potentially be used as a phosphate rock substitute. Also the P content of the precipitated hydroxyapatite at 11 – 13% P was similar to that of commercial phosphate rock. Some drying of the recovered phosphate product would be necessary before storage or transport.

Loss of smaller seed crystals in the stirred reactor outflow showed to be a potential issue, which the authors suggested could be addressed by modifying the reactor design (improved sedimentation zone) or operation (long term batch operation). The fixed bed reactor required weekly backwashing (using the liquor to be treated and air) to dislodge organics.

Cost evaluation

A cost evaluation was carried out on the basis of a biological P-removal process side stream liquor, electro-flotation to remove suspended solids from the liquor followed by the crystallisation reactor, with solar drying of the recovered phosphate. The electro-flotation step was considered not necessary if a continuous stirred reactor was used rather than a fixed bed reactor.

Fixed bed experiments, performed with different mixtures of CSH and calcite showed that the efficiency of the P-Recovery process was mainly attributed to the CSH fraction in the mixture (Berg et al., 2007a).

In 2007a, the **efficiency of stirred reactors** was compared, using both municipal and industrial wastewater from the food industry (400 mg/l P). With the industrial wastewater, the calcium phosphate mineral brushite was formed, which is much better soluble than hydroxyapatite, and thus better available for plants if used as a fertiliser.

In 2006b, basic research investigations in the nano-scale and micro-scale (formation of hydroxyapatite or brushite, effect of CSH porosity, pH effects, P concentration) were investigated. In this case, tobermorite from Moriyama from Japan (material C), see SCOPE Newsletter, was also studied. For this material C, a coating only of phosphates was precipitated, whereas with materials A and B the behaviour was similar to a sponge.

The total estimated costs for the CSH P-recovery process ("P-RoC", Berg et al., 2007b) were 2.14 – 2.9 €/PE/year, compared to 1.55 – 1.86 €/PE/year for conventional P-removal by chemical precipitation, including sludge disposal (Berg et al., 2007c).

Calcites

Song et al, 2006, presented further phosphate precipitation experiments using two different calcites as seed materials, following on from the work presented in SCOPE Newsletter N°49. Synthetic wastewater solutions were made from tap water, containing magnesium, sulphate, sodium, carbonate, potassium and orthophosphate ions 10 - 30 mg/l phosphorus). The two calcites used were Juraperle, a mined calcite crushed to 1.2 – 1.8 mm particle size (specific surface area SSA 0.4 m^2/g) and Coccolith, a deep-sea sludge of tiny calcite particles of algal origin, with particle size 1-2 mm and SSA 4.6 m^2/g.

The calcite seed showed to considerably increase calcium phosphate precipitation after 1 – 2 days in shaken bottles, raising phosphate removal from around 50-60% in unseeded experiments to 80-90% in seeded experiments after 14 days. The Juraperle calcite showed to be slightly more effective, despite its lower SSA (specific surface area).

The authors suggested that the effect of the seeding may be a result not only of providing a crystallisation surface for phosphates, but also to inhibition of calcite precipitation, thus increasing the phosphate

precipitation in calcite/phosphate co-precipitation, and increasing the phosphate content of the recovered product.

However, **the most effective seed material was re-used calcite seeds** (with effectiveness increasing with the number of re-uses, tested up to 5 times). In this case, the re-used seed is covered with a 700 nm layer of precipitated phosphate. Its effectiveness as a seed is presumed to result from the similarity in properties between this surface and the precipitating phosphate. This confirms the results of the previous work summarised in SCOPE Newsletter N°49.

Recovery as a fertiliser

Karageorgiou et al. 2007 also present laboratory experiments on phosphate removal from synthetic solutions using natural calcite ($CaCO_3$). Artificial orthophosphate solution, made by dissolving K_2HPO_4 in tap water, and hand collected calcite from a quarry (98% pure calcite), crushed and sieved to < 0.2 mm, were used.

The effect of time, adsorbent/orthophosphate ratio and pH was investigated, showing that most phosphate uptake occurs in the first 15 minutes, pH is the most important parameter and adsorption is efficient even for high phosphate/adsorbent ratios. Phosphate removal ranged from around 70% at pH 7 to 100% at pH 12. The phosphate removal is considered to be a combination of electrostatic adsorption at lower pH (7 to 8) and chemical interactions producing calcium phosphates (at higher pH). The authors note that **the resulting product (phosphate adsorbed onto calcite) can be used as a phosphate fertiliser on acid soils**.

Tobermorite

The use of calcium silicate hydrate (tobermorite) as a seed for calcium phosphate precipitation was also studied at the laboratory scale by **Moriyama et al**. (2001, 2003 and previous paper summarised in SCOPE Newsletter 36), suggesting that the use of such seed material could avoid the degassing (CO_2) removal from wastewaters generally found necessary upstream of calcium phosphate precipitation. This work, using sewage treatment works sidestream liquors, also suggested that the seed crystals were resistant to biofilm growth or fouling.

Fertiliser tests

Recovered material with up to 6.7% phosphorus (P) content was produced, which showed to **act positively as a fertiliser in pot trials of komatsuna Chinese cabbage** (Brassica campestris L.): live weight index of 135% compared to 101% of control for standard fertiliser application after two weeks.

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K. Karageorgiou, M. Paschalis, G. Anastassakis, School of Mining Engineering and Metallurgy , National Technical University of Athens (NTUA), 9 Heroon Polytechniou Str., Technical University Campus, 15780 Zographou, Athens, Greece ganastas@metal.ntua.gr

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Egypt
Struvite as fertiliser for broad beans

Struvite precipitation (magnesium ammonium phosphate MAP) can be used for phosphate or nitrogen removal or recovery from wastewater. Because magnesium concentrations are low in waste waters, relative to ammonia and phosphate concentrations, the cost of adding magnesium salts can be a major economic constraint to the use of struvite crystallisation for nutrient recovery. Bittern, a by-product of salt manufacture, contains mainly magnesium chloride with smaller amount of other inorganic compound.

Bittern was tested as a magnesium source for struvite precipitation, both in pure chemical solutions (ammonia + phosphates solutions) and in an industrial wastewater (ammonium nitrate fertiliser plant effluent with average ammonia concentration around 2560 mg/l). Work by other authors testing bittern as magnesium source for struvite precipitation is presented in SCOPE Newsletter n° 66.

Bittern magnesium source

The effectiveness of struvite as a fertiliser was then assessed in 45-day greenhouse pot trials using broad bean plants (*Vicia faba*).

The struvite precipitation tests were carried out in beakers over the pH range 7-11 and at $Mg:NH_4:PO_4$ ratios of 1:1:1 and 1.6:0.6:1. The bittern used contained 6.1 mg/l magnesium, 45 mg/l ammonia and 2.7 mg/l total phosphorus.

Results in both synthetic solutions and in the industrial wastewater showed **optimal struvite precipitation at pH 9.6, with adequate precipitation occurring above pH 8.5**. Struvite formation is rapid, within around 10 minutes, with crystal growth continuing for three hours, resulting in larger particles which would facilitate recovery for recycling.

XRD (X-ray diffraction) results show that the precipitates are mainly struvite with presence of potassium, chlorine, calcium and carbonate compounds.

Pot trials

Struvite was precipitated using bittern as a magnesium source in pure chemical solution as above was tested in the pot trial fertiliser experiments.

The greenhouse pot trials compared the fertiliser effectiveness on broad bean plants of struvite (at 2% addition to dry soil by weight), NPK fertiliser (ammonium nitrate, superphosphate and potassium sulphate at 20/50/400 mg/kg soil NPK) and a no-fertiliser control.

Struvite fertilisation resulted in the greatest fresh and dry plant weight increases (+250% dry weight after 45 days for struvite, +120% for NPK compared to the control). Struvite also generally resulted in higher uptakes of N, P and K (% in plant tissue) than did the NPK fertiliser.

The authors conclude that bittern is an effective source of magnesium for struvite precipitation, and that struvite is an effective fertiliser for broad bean plants.

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SCOPE Newsletter – n° 70 – February 2008 - Page 14
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Sewage fed aquaculture
Making sewage treatment productive

Biological wastewater treatment uses organisms to emulate natural processes occurring in the environment. Most modern centralised (urban) sewage treatment plants emulate decomposer communities of organisms and degradation processes (eg. activated sludge sewage works), breaking biological organic molecules to CO_2 or methane and nitrogen gas which is released to the atmosphere. Wastewater fed aquaculture, on the other hand, emulates productive biological systems, optimising assimilation, both by metabolism and by processes such as retention, filtration and flocculation.

Sewage fed aquaculture systems have a long history, for example series of lakes used for fish culture and fed with waste waters of medieval monasteries in Europe. Recent studies have shown that such series of ponds are effective in hygienisation, with a series of 3 ponds ensuring 92% - 100% reductions in fecal coliforms.

Today aquaculture systems can be designed both to produce a wide variety of different biomass products, depending on local markets, sewage characteristics and logistics:

- **food** for humans : edible plants, shellfish, fish …

- **animal feeds** : phytoplankton, plants, zooplankton, worms…

- **raw materials** : fibres, isolation materials, algae for pharmaceutical applications …

- **renewable energy** biomass

- **agricultural inputs** : fertilisers, composts

- luxury **products** : decorative fish, pearls, ornamental plants …

Depending on the space available and the sewage loads to be treated, wastewater fed aquaculture systems may be extensive (passive systems such as ponds) or intensive (with aeration, circulation). Intensive systems remain fundamentally different from sewage treatment systems designed for decomposition.

Nutrients

Nutrient recycling is considered to be the key feature of wastewater fed aquaculture (WFA), enabling plants to fix solar energy and thus convert around 1gN and 0.1gP into biomass per square metre per day. A well managed WFA is considered to be able to convert 40% of inflow nutrients to biomass, with the remainder being eliminated by denitrification, or fixed in sludge accumulation.

Calcutta

The fertilisation of ponds by municipal sewage and industrial wastewaters began in Calcutta in the 1930's and is now probably **the largest wastewater fed aquaculture system in the world**. The sewage is first sedimented in anaerobic primary settling ponds to reduce its BOD by around one third, followed by mixing with fresh water in a second aerobic pond, to ensure appropriate conditions in the aquaculture ponds. This is then followed by a flow-through series of several aquaculture ponds. Every one to four years the ponds are emptied and dried, and limed, to ensure hygiene.

Product species include various carps, bass, tilapia, catfish, Indian buffalo fish and prawns. Production is of several tonnes per hectare of pond per year.

Nutrient removal in the whole systems varies from 30 – 90%. Data on the bacterial quality of the fish production is not available to date. A large number of people derive their livelihood from this production.

Controlled testing

Controlled tests of biomass production of zooplankton for fish food, using different nutrient sources, were carried out in India. The zooplankton *Moina micrura* was cultured for 3 months, using 24 outdoor tanks of 4500 litres. The following liquid nutrient sources were tested: human urine, cow urine, human and cow urine mixed with faeces, cow dung, poultry droppings, vermin-compost, and mixed compost - cow – poultry dung, each at addition rates of 0.11 mg/litre or ml/litre per day (plus a control: ground water only). Productivity was measured by assessing the evolution of the number of zooplankton per litre, and the number of offspring per zooplankton

lifetime. Bacterial concentrations were also measured.

Human urine showed to be the optimal nutrient source, confirming its value as an "**excellent liquid waste that can be used for the mass production of zooplankton … for rearing of commercial fishes**".

Otelfingen, Switzerland

An example of intensive wastewater-fed aquaculture plant consisting of a 65m x 7m basin, divided into 36 sub-basins, with a total area of 360 m^2, depth 0.5 or 1.5m, was constructed at Otelfingen, Switzerland. It was charged with effluent from a methanisation plant processing organic household waste and operation was started in spring 1998. The aquaculture was split into modules and stocked with organisms of different environmental requirements. The modular structure, as opposed to traditional one-pond polyculture, allowed manipulation and better nutrient budgeting of the system.

Besides treating the effluent (total organic carbon [TOC], total nitrogen, nitrate [NO_3-N], ammonium [NH_4-N], and total phosphorus concentrations being 670 g/m^3, 255 g/m^3, 150 g/m^3, 95 g/m^3, and 52 g/m^3, respectively) according to Swiss law requirements, the research focused on the search for **suitable aquatic organisms**, their testing at different environmental conditions, and on maximizing the nutrient recycling efficiency.

Production of different types of biomass

Thus a wide array of modules, producing biomass such as algae, fish, zooplankton, and aquatic macrophytes *(Eichhornia, Pistia, Ipomoea, Lemna, Azolla)* which were suitable for sale on the Swiss market, were tested. Different arrangements of modules, of water and wastewater-flows, and of nutrient concentrations were tested.

During the 16 week experiment (summer: July – October), **a total of 2.15 tonnes fresh weight of biomass** (97% floating macrophytes, mainly water hyacinth and water lettuce) was harvested. Over 98% of inflow nitrogen and phosphorus were removed in the basin system, of which 25 – 35% were recovered in the harvested biomass.

The research showed that aquaculture can be set up to either produce treated wastewater ready for discharge into surface waters or to maximize nutrient recycling through biomass production. A wastewater-fed aquaculture facility resembles an integrated production plant rather than a wastewater disposal site. In addition to that, it has potential to prove advantageous over the highly developed conventional wastewater treatment plants established in Middle Europe.

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Phosphorus in surface waters

Eutrophication risk assessment
Using Bayesian probabilistic methods for modelling

The authors propose a methodological framework to combine mechanistic and statistical modelling, using Bayesian analysis. The objective is to provide support for environmental management decision making, in particular for step-by-step adjust-as-you-act management. The methodology is applied to eutrophication modelling of Lake Washington, USA.

Data used in environmental modelling includes large degrees of uncertainty, inherent to modelling (data are individual points, and cannot fully represent the natural variation in ecological parameters), natural variation (over time and space) and resulting from the model itself (simplifications of natural processes). Previous authors have shown however that **the majority of aquatic modelling published to date does not adequately take into account the effects of uncertainty on model predictions**. This is important when model predictions are used as a basis for environmental management decisions, which can have high economic or social costs, and also environmental impacts.

Furthermore, in many cases "model calibration" often only provides the best fit of model parameters to the existing dataset, but is specific to that dataset, and does not ensure adaptation as further new data becomes available.

Lake Washington eutrophication model

Lake Washington is mesotrophic, with surface water chlorophyll concentrations peaking at 10 µg/l in Spring, some three times higher than in summer when the water is phosphorus limited. In the summer stratified period, recycling of phosphorus by zooplankton (consuming algae and excreting phosphorus) accounts for 60-90% of the available phosphorus supply for algal growth. The Lake has been the object of a closely followed restoration project, based on deviation of sewage outflows away from the Lake. The dataset used for model calibration came from a 1995-2001 monitoring campaign covering 12 stations in the Lake.

The eutrophication model used was simple, considering only four compartments: phytoplankton (algae), zooplankton (grazers), detritus and soluble phosphate, and 17 parameters/ rate constants. Two probabilistic models were developed, using the assumptions that the model is a perfect /non-perfect simulator of the ecological system.

Probabilistic model

The model used prior probabilistic distributions of the different parameters, established on the basis of observed data from the lake, laboratory experimental data, literature and expert judgement, by estimating maximum and minimum values and 95% confidence limits and then fitting a Gaussian probability curve.

Numerical approximation iterations for posterior distributions were then made using **Markov Chain Monte Carlo (MCMC), general normal proposal Metropolis algorithm in WinBUGS software).** From the iterative results, mean and standard deviation for each parameter were derived.

The probabilistic method gives results for both models above which are reasonably close to observed results, in particular **observed eutrophication data are within the confidence limits predicted by the model**.

Application to management

The authors summarise the advantages of such Bayesian iterative probabilistic methods for modelling:

- the model predictions can be **adapted progressively as a management strategy** is step-by-step implemented, enabling adaptation or modification of the management decisions if observed ecological response is not conform to initial predictions.

- **monitoring programmes** can also be progressively adjusted appropriately

- by giving **probability ranges**, rather than "average" or "expected" results, managers and stakeholders are less likely to be disappointed by ecological results not corresponding to expectations

- the issue of correctly defining the **parameters** and processes in the model are reduced, because these can be corrected progressively by iteration

- Bayesian iteration can take into account the **results of two or more different models** of the system

- the **computer capacity** necessary for Bayesian computation requirements does not seem to be an obstacle, because simple algorithms can be used, such as the general normal proposal Metropolis used in this case.

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Large rivers

Sewage P-load reduction and improved chlorophyll levels

Data covering 29 years from the lower Rhine river (Europe) and 31 years from the lower Sacramento river (California) were used to assess the impacts of 2.7 and 1.5 fold reductions in river total phosphate concentrations. In the Rhine, this reduction occurred progressively over the whole study period, mainly as a consequence of nutrient removal in sewage works. In the Sacramento river, the reduction occurred rapidly, as a result of a sudden reduction in the amount of food industry (cannery) waste ("must") received for treatment by the facility after most of the canneries moved out of the facility's service area during 1991 – 1993 (2 fold reduction in sewage works phosphate discharge)

The Rhine data used are from the Lobith monitoring station, in The Netherlands, near the Rhine delta. Here the **Rhine** is a slow-flowing river, with long-term average flow of 2300 m^3/s, average depth 6m, and relatively high salinity resulting from industrial and mining activities upstream.

The Sacramento data are from the **Sacramento – San Joaquin Delta, California**. The data used is from three freshwater channels which carry water from the Sacramento river across the delta, with average depth ranging between 5 m and 12.5 m. The average flow of the Sacramento is 560 m^3/s.

Other nutrients

At the Rhine site, mean summer total nitrogen in the river, and also dissolved ammonium also showed considerable reductions over the study period, and soluble nitrate/nitrite nitrogen and suspended solids a smaller reduction. Soluble silicate on the other hand showed a small increase. Because of the more important decrease in total phosphorus concentration in the river (divided by 2.7), TP/TN ratios approximately doubled over the study period. Summer soluble reactive phosphate concentrations were also considerably reduced.

In the Sacramento River, mean summer total phosphorus concentrations were divided by a factor of 1.5. Suspended solids concentrations fell, whereas total nitrogen increased progressively over the whole period. Summer soluble reactive phosphorus concentrations were very variable, but appear to show a significant reduction after the abrupt decline in phosphorus output from the wastewater treatment faciltiiy.

Chlorophyll

In both rivers, the total phosphate reductions were clearly not related to changes in river flow, despite significant variations in annual flows over the study period. Also, both rivers showed relatively high summer soluble phosphate concentrations (10 – 100 µg/l) and soluble/total phosphorus ratios, indicating that a high proportion of phosphate was coming from sewage works.

In both cases, **significant reductions in summer chlorophyll** (indicative of algal growth in the water) were clear over the study period: a 4 fold reduction in the Rhine and a 2.6 fold reduction in the Sacramento. In both cases, this reduction could not be attributed to changes in flow, light or nitrogen concentrations.

The author concludes that "**reductions in wastewater loading led to substantial reductions in mean summer total phosphorus and chlorophyll concentrations [in both rivers] despite their continually high (> 40 µg/l) soluble reactive phosphorus concentration and initially shallow (<1.5m) euphotic depth**".

That is, sewage works P-removal can effectively address eutrophication symptoms in slow rivers, even where these show high nutrient levels, and poor light penetration.

Furthermore, the reductions in chlorophyll paralleled those calculated using a **total phosphorus – chlorophyll relationship calibrated for a broad cross section of flowing waters** (Van Nieuwenhuyse & Jones, 1996). In this comparison of 292 literature data points, summer mean chlorophyll concentrations in temperate streams were correlated to mean total phosphorus concentrations, with a curvilinear log-log relationship (showing a shallower gradient of chlorophyll increase above around 2 µg TP/l).

Chlorophyll / phosphorus ratios were significantly correlated to stream catchment area, predicting a 2.3x increase in this ratio from 100 to 100,000 km^2.

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Delta water quality workshop
March 25th 2008, Sacramento, California

Announcement of Technical Workshop on Overview of Delta Nutrient Water Quality Problems: Nutrient Load – Water Quality Impact Modeling

The California Water and Environmental Modeling Forum (CWEMF) will offer a technical workshop devoted to Sacramento San Joaquin Delta Nutrient Water Quality Modeling.

The Delta provides domestic water supply for 23 million people and millions of irrigated agriculture in the California. The Delta is in a resource and water quality management crisis. One of the major water quality problems of the Delta is excessive fertilization of its waters. The objective of this workshop is to present an overview of the water quality impairment issues of the Delta that are associated with aquatic plant nutrients (N and P). The focus will be the current state of information available, and still needed, to model and manage excessive fertilization in the Delta.

The workshop is being organized by Drs. G. Fred Lee and Anne Jones-Lee based on their over 40 years of experience in evaluating nutrient caused water quality problems in the US and other countries as well as their work on Delta water quality issues over the past 18 years. The workshop will be held on March 25, 2008 in Sacramento, CA. The details of workshop agenda and list of speakers is available at *http://www.cwemf.org/workshops/NutrientLoadWrkshp.doc*

The workshop is available at no charge for CWEMF members; $50 for non-members; $10 for student non-members. To register, please email your name and affiliation to *technicalworkshop@cwemf.org*. Information on CWEMF is available at *www.cwemf.org*

Further information on the organization of the workshop is available by contacting G. Fred Lee at gfredlee@aol.com

International Conference on

Nutrient Recovery from Wastewater Streams

May 10-13, 2009 - Vancouver, British Columbia, Canada

Closing the loop for nutrients in wastewaters (municipal sewage, animal wastes, food industry, commercial and other liquid waste streams) is a necessary, sustainable development objective, to reduce resource consumption and greenhouse gas emissions. Chemistry, engineering and process integration understanding are all developing quickly and new processes are already coming online. A new "paradigm" is emerging, globally. Commercial marketing of recovered nutrients as "green" fertilizers, or recycling of nutrients through biomass production to new outlets such as bio-fuels, is starting to happen.

This conference will bring together the various waste stream industries, regulators, researchers, R/D and process engineers and commercial managers, to develop intersectorial understanding and joint projects for phosphorus and nitrogen recovery and reuse from waste waters.

Abstracts are solicited in particular in the following areas:

- Phosphorus and nitrogen recovery from different wastewater sources
- Process design and plant integration
- Marketing and use of recovered nutrient products
- Struvite, K- Struvite and calcium phosphate precipitation
- Ion exchange nutrient recovery processes
- P-recovery from biosolids incineration ashes
- Leading-edge research and innovative technology

In addition, there will be an Open Session, devoted to "new thinking" for this emerging paradigm, in concert with an expert panel discussion. Dr. James L. Barnard (2007 Clarke Prize) will be the Keynote Speaker and will address the audience during the Plenary Session, on the opening day of the conference.

The Conference Programme will also offer visits to phosphorus recovery installations (Ostara/UBC struvite recovery process) recently commissioned in municipal sewage works in Edmonton, Alberta.

ABSTRACT DEADLINE: March 28th, 2008.

Please send abstract submissions to
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