FOREWARD

Wim Chardon (Vice-President) and I have had many debates over the title of COST Action 832 – ‘Quantifying the Agricultural Contribution to Eutrophication’. The title was left deliberately open to allow for debate on the role of nitrogen (N) as well as phosphorus (P), and so neither nutrient appears. As it happens we have concentrated on P, largely because eutrophication response has been most commonly related to P inputs. We have also debated whether ‘methodologies’ should appear in the title because this was the main focus of the Action from the start. But methodologies represent only one slice of the eutrophication cake. Through our respective meetings and discussions, we have developed a better and more uniform understanding of the range in P losses across Europe, the processes by which P loss occurs and the complex array of landscape and land management factors affecting P transfer rates. So we have left our title as it is for this final meeting.

COST (Co-Operation in Science and Technology) was set up to encourage networking and information transfer between EU scientists. Our Cost Action 832 started in July 1997 and has involved 18 countries and 150 scientists. Short–term missions have been undertaken by 7 young, (and not so young), scientists and both national and international projects have been instigated as result of our activities over the last 5 years. Our objective was to develop a common methodological framework for assessing P loss from agriculture to water in order that the agricultural contribution to eutrophication within the EU can be more uniformly assessed and used as a basis for mitigation policies. The Action comprised 4 working groups which have focused on: an understanding the use and cycling of P inputs in European agriculture (WG 1), processes of P loss at the field scale (WG 2), processes of P loss at the catchment scale (WG 3) and finally the relative impacts of diffuse P inputs on different waterbody types (WG 4). The deliberations of these working groups have been published.

A number of key subject areas have been explored including terminology, sampling and analytical procedures, principles of fertilizer and feed recommendations, soil inorganic and organic P cycling and release, erosion, leaching, incidental loss, P loss risk assessment, hydrological pathways, scaling issues and approaches to modelling. We also embarked on a soils exchange programme. This conference brings together the conclusions of the working groups/subject areas with the work that has been undertaken within the diffuse pollution cluster of the EU Fifth Framework. Since our conception, the Water Framework Directive has been introduced and Nitrate Vulnerable Zones have been redesignated. This conference provides an opportunity to discuss these developments and how our improved understanding of the sources, processes, pathways and impacts of P loss can be directed towards meeting the requirements of these policy initiatives. Finally there is also opportunity to build on the progress made within COST 832 into follow-on Actions and accompanying projects within Framework 6.

I welcome you to this conference and hope you will enjoy the historic surroundings of Clare College.

Paul J A Withers
President COST 832

COST 832 FINAL MEETING
QUANTIFYING THE AGRICULTURAL CONTRIBUTION TO EUTROPHICATION

Programme

Thursday 31 July 2003

08.45-09.00 Opening address and organisation

09.00-13.00 Session 1 Eutrophication in Europe
Chairman: Louise Heathwaite

09.00-09.30 Diffuse phosphorus and eutrophication – policy, programmes or paralysis?
Bob Foy, Northern Ireland

09.30-10.00 Evaluation of standard values for nutrients in several water bodies in the Netherlands.
Lowie van Liere, The Netherlands

10.00-10.30 Assessing and controlling the risks and impacts of nutrient pollution in UK waters.
Rachael Dils, UK

10.30-11.00 Coffee

11.00-11.30 Ecological assessment of the lakes of County Clare: Relationship between catchment landuses and in-lake nutrient status.
Kenneth Irvine, Ireland

11.30-12.00 Water quality in agricultural Finnish Lakes.
Petri Ekholm, Finland

12.00-12.30 Implementation of the EU Water Framework Directive – a case study.
Barbro Ulen, Sweden

12.30-13.00 Discussion of Session 1

13.00–14.30 Lunch

14.30–16.00 Session 2 – Sources and mobilisation of agricultural phosphorus
Chairman: Peter Csatho

14.30-15.00 Sources and mobilisation of agricultural phosphorus.
Oscar Schoumans, The Netherlands

15.00-15.30 Soil phosphorus – a long-term source.
Philip Ehlert, The Netherlands

15.30-16.00 Do different methods used to estimate soil phosphorus availability across Europe give comparable results?
Jean-Auguste Neyroud, Switzerland

16.00–16.30 Edge of field losses of phosphorus in overland flow from grassland field plots to water.
Hubert Tunney, Ireland

16.30–18.30 Posters

Friday 1 August 2003

09.00-11.00 Session 2 - (continued)
Chairman: Wim Chardon

09.00-09.30 Phosphorus losses from a forested feedlot for bulls.
Jaana Uusi-Kamppa, Finland

09.30–10.00 The effects of tillage and reseeding on phosphorus transfers from grassland.
Patricia Butler, UK

10.00-10.30 Sourcing and control of phosphorus loss in two small catchments in England
Robin Hodgkinson, UK

10.30-11.00 Discussion of Session 2

11.00-11.30 Coffee

11.30-13.00 Session 3 – Dynamics of phosphorus transfer in catchments
Chairman: John Hilton

11.30-12.00 Characterising phosphorus transfers at different scales: the importance of dynamic approaches.
Philip Haygarth, UK

12.00-12.30 Phosphorus export dynamic of different temporal scales from catchments of Lake Sempach.
Patrick Lazarotto, Switzerland

12.30-1.00 Phosphorus content of suspending sediment in the Marne Watershed: an indicator of particulate phosphorus losses from runoff?
Julian Nemery, France

13.00–14.30 Lunch

14.30-15.00 Phosphorus and sediment loads in the Oona Water catchment, Northern Ireland – scale and flow regime isssues.
Wayne Menary, Northern Ireland

15.00-15.30 Discussion of Session 3

15.30–18.20 Session 4 – EU Diffuse Pollution Cluster
Chairman: Peter Grathwohl

15.30-15.50 BUFFER – Kenneth Irvine, Ireland.

15.50-16.10 PROWATER – Ralph Meissner, Germany

16.10-16.30 DESPRAL – Paul Withers, UK

16.30 –17.00 Tea

17.00-17.20 AGRI-BMP – Ramon Laplana, France

17.20-17.40 INCA-P – Paul Whitehead, UK

17.40-18.10 Discussion of Session 4

Saturday 2 August 2003

09.00–11.00 **Session 5 – Phosphorus loss risk assessment and control.**
Chairman: Bob Foy

09.00-09.30 Decision support frameworks to assess the risk of phosphorus loss at field to national scales.
Louise Heathwaite, UK

09.30-10.00 Measures to reduce phosphorus load from agricultural land in the catchment area of the lake of Sempach.
Josef Blum, Switzerland

10.00-10.30 Effectiveness of treatments to reduce P runoff losses from grassland soils.
Tobias Vollmer, Switzerland

10.30-11.00 Discussion

11.00-11.30 Coffee

11.30-12.30 **Session 6 – Conclusions from COST832**
Chairman: Hubert Tunney

11.30–12.00 Integrated Soil and Water Protection: Risks from Large Scale Diffuse Pollution (SOWA)
Peter Grathwohl, Germany

12.00-12.30 COST 832 – Past, present and future.
Paul Withers, UK

12.30–13.30 Lunch

13.45 –16.00 Excursion to ADAS Boxworth

ABSTRACTS

Oral presentations

Diffuse phosphorus and eutrophication – policy, programmes or paralysis?

Bob Foy

Agricultural and Environmental Science Division, Newforge Lane, Belfast BT9 5 PX.

Although point source controls on P almost always result in lower concentrations of P in surface waters, parallel improvements in ecological water quality have not always been observed as P concentrations in European lakes and rivers remained above the threshold concentrations of P that cause eutrophication. The initiation of COST 832 in 1998 reflected a belief that agriculture could be a significant source of P loading to water and the outputs of subsequent COST workshops have provided convincing evidence that the loss rates and concentrations of P in surface runoff and drainage water from agricultural land are often above the levels of P that result in eutrophication. The continued monitoring of lakes and rivers in Europe also provide evidence of the widespread persistence of P concentrations that can support eutrophic conditions. From these observations it may be concluded that improvements in water quality require a lowering of P losses from agricultural land and this appears to be mandated by the passing into law of EU Water Framework Directive, with its goal of restoring all surface waters to a good ecological water quality standard, that is to be defined by allowing only slight deviation from reference conditions. However the magnitude and diversity of the tasks required to achieve this goal are daunting and the uncertainties of outcomes may be combining to act as an impediment to initiating action programmes.

In most agricultural regions the numbers of non-impacted lakes and rivers are small and, in the absence of reliable historical data, defining reference conditions relies on indirect methods. These however may provide different outcomes and/or low levels of precision. In the absence of precise targets for future P concentrations it is difficult to convince the agricultural industry to agree to programmes for reducing P losses. Moreover the effectiveness of mitigation measures or their impact on agricultural profitability remains uncertain. The role of agricultural P surpluses was often highlighted in the 1990s as they inevitably result in elevated levels of soil P and the reduction of P surpluses has been included within the PARCOM programme to reduce marine eutrophication. However the experience of those Baltic countries formerly within the Soviet Union, where fertiliser use collapsed but nutrient losses showed little response suggests that reducing surpluses may be only a blunt tool for water quality management.

A further and new complicating factor is that the role of N as a factor in freshwater eutrophication has gained greater scientific prominence and a judgement of the European Court of Justice in 2002 appears to require the designation as Nitrate Vulnerable Zones of agricultural catchments that drain into eutrophic lakes. The extent to which controls on manures required under the Nitrates Directive will also control P losses remains uncertain. Finally if N is impinging, perhaps un-welcomed into the area of freshwater eutrophication, there is evidence that P may be a more important factor in the eutrophication of coastal marine waters than previously accepted and that reducing P losses to coastal areas off the Netherlands has resulted in lower concentration of phytoplankton.

Evaluation of standard values for nutrients in several water bodies in the Netherlands.

Lowie van Liere and Paul Boers

Netherlands Environmental Assessment Agency, POst-box1, 3720 BA Bilthoven, The Netherlands.
lowie.van.liere@rivm.nl
National Institute for Integral Water Management and Wastewater Treatment, Post-box 17, 8200 AA Lelystad

Critical characteristics (loading, concentration) have been evaluated indication of the switch from the eutrophic status to the recovered clear-water status. Reduction of the nutrient load was assumed to be the only factor of any weight in making this switch. The choice made for the desirable ecological status of the water body in question was the authors'. To safeguard vulnerable downstream waters, values for some cases were calculated; this avoided a 'shift' of high concentrations of upstream waters (downstream protective standard). The observed very low values ascertained in the switch indicated the need to study additional measures to speed up recovery. Results of lakes, fen lakes, ditches and small stream will be presented. Calculations of downstream protective standards for River Rhine will be presented using safeguarding of the lake IJsselmeer and the coastal zone of the North Sea.

Water (type)	Ecological target	Nutrient	'Standard' Value or. Bandwidth (average)	Unit
Small Streams	'natural' and 'near to natural' streams	Phosphorus Nitrate	0.022 0.28	mg P l^{-1} mg NO_3^--N l^{-1}
Ditches	< 50% duckweed	Phosphorus	1.8 – 10.2 (4.7)	g P m^{-2} y^{-1} (water surface area)
	Coverage (modelled)	Nitrogen	12 – 44 (22)	g N m^{-2} y^{-1} (water surface area)
Lakes	Clear water	Phosphorus Nitrogen	0.05 1	mg P l^{-1} (summer-average) mg N l^{-1} (summer-average)
Heathland lakes/	No acidification	Nitrogen	5 – 10	kg ha^{-1} y^{-1} (in atm. dep.)
Moorland pools	No increased growth on shore	Nitrogen	14	kg ha^{-1} y^{-1} (in atm. dep.)
	No eutrophication	Nitrogen	20	kg ha^{-1} y^{-1} (in atm. dep.)
IJsselmeer	No blue-green algal scums	Phosphorus	0.06	mg P l^{-1} (summer-average)
Coastal waters	50% reduction of algae	Nitrogen	0.6	mg N l^{-1} (summer average)
Downstream protective standard				
Rhine	No floating layers of blue-green algae in IJsselmeer	Phosphorus	0.08	mg P l^{-1} (summer-average)
	50 % reduction of algae in coastal waters of the North Sea	Nitrogen	1.8	mg N l^{-1} (annual average)

Van Liere, E. and Jonkers, D.A., 2002. Standard values for nutrients in several surface-water bodies (in Dutch with an extended English abstract). Report 703715005/2002 National Institute of Public Health and Environment.

Assessing and controlling the risks and impacts of nutrient pollution in UK waters

Rachael Dils and Simon Leaf

Environment Agency, Evenlode House, Howbery park, Wallingford, Oxon, OX10 8BD, UK

The EU Water Framework Directive (WFD), which came in to force at the end of 2000, is fundamentally changing how water is monitored, assessed and managed in the UK and across Europe.

The WFD introduces the concept of ecological objectives, designed to protect, and where necessary, restore the structure and function of aquatic ecosystems. A key objective for surface waters is to achieve at least ‘good ecological status’ by 2015. The shift to ecologically defined objectives has significant implications for the UK in terms of the way we monitor and assess the quality of our waters. Both the Environment Agency (England and Wales) and Scottish Environment Protection Agency, have historically focused on classifying the quality of rivers according to measures of chemical, biological, nutrient and aesthetic quality. Nutrient trends across England and Wales show evidence of an increase in river nitrate concentrations and a significant decrease in river phosphate concentrations between 1990 and 2001. These trends reflect the general improvement in wastewater treatment and the increased relative contribution from agriculture. For lakes, and other surface waters, similar chemically based classification systems have been developed, for example, based on total phosphorus concentrations for lakes. The WFD, however, requires the development of reference-based ecological classification systems that demonstrate the impact of all human pressures. Due to the complex relationship between nutrients and ecological response, a number of different biological tools for assessment and classification are under development, which will be described.

The second key concept is the introduction of integrated management of river basins and a river basin management planning (RBMP) system. This will provide the decision making framework within which costs and benefits can be properly taken into account when setting environmental objectives. The current regulatory drivers for nutrient control tend to be focused on controlling point or diffuse nutrient sources, rather than a combined approach. The WFD, however, requires an assessment of risks from all human activity, which combined with information on the sensitivity to the pressures, will identify those waterbodies at risk of failing to meet the Directive’s environmental objectives. Progress with the initial risk assessment for nutrients will be presented.

For each river basin district, a programme of measures must be established to achieve the environmental objectives. Under article 11(3)(h) of the WFD there is the provision to establish measures to prevent or control the input of pollutants from diffuse sources liable to cause pollution. These provisions will enable existing controls that apply to diffuse pollution from agricultural activities to be complemented by additional measures to protect particular vulnerable waters. In order to achieve the WFD objectives through the programme of measures, a strategic management framework is needed for dealing with the risks and impacts of diffuse nutrient pollution from agriculture. English Nature and the Environment Agency have been developing such an approach which will be presented. The framework includes national and local approaches for the identification and prioritisation of sites requiring action, appraisal of problems and solutions, and an integrated package of policies to apply a range of practical management measures. Underpinning research to develop cost-effective soil and nutrient management practices is currently being undertaken.

Successful implementation of the WFD will rely on a partnership approach involving public bodies, water users, academic organisations and other key stakeholders. The WFD is a participatory process, with one of the elements of the RBMP being public participation and consultation.

The Environment Agency has developed an aquatic eutrophication management strategy which has similar principles to the WFD and will contribute to its delivery. The strategy, which was produced following extensive consultation with interested parties, promotes a more co-ordinated framework for action and a partnership approach to eutrophication management in England and Wales. The aim is to maximise the environmental benefits and cost effectiveness of control action, through developing improved approaches to assessing and managing eutrophication.

Ecological assessment of the lakes of County Clare: Relationship between catchment landuses and in-lake nutrient status

Alice Wemaëre and Kenneth Irvine

Zoology Department, Trinity College Dublin

County Clare in the west of Ireland has a land area of 3200 km^2 and contains about 360 lakes. Most of these occur in the southern half of the county and can be broadly divided into those lying within catchments dominated by either limestone, or shales and similar rock types. Old red sandstone and Silurian quartzite comprise an important part of the geology in some catchments. The limestone catchments are generally low-lying, with well-drained soils such as brown earths, rendzinas and grey-brown podzolics. The shales and sandstones are generally associated with higher elevations and poorly drained gley soils and/or peats. Landuse throughout the region is mainly grassland. The county represents many of the landscape characteristics, and pressures which illustrate the importance of diffuse phosphorus transport, that occur throughout Ireland.

Between 2000 and 2001, estimates of the relationships between land-use and water chemical variables were made for sixty-nine lakes in the county. Frequency of monitoring was *high* (For 11 lakes mainly *n*=8 per annum), *medium* (*n* = 4 to 6 samples for nineteen lakes) and low (*n* = 1-2 samples for thirty-nine lakes). Lakes ranged from high to low nutrient status. Underlying bedrock was associated with soil types, with carboniferous limestone positively correlated with rendzinas and grey brown podzolics soils, and shales and similar rock types positively correlated with gleys and peats. Alkalinity, pH and conductivity were positively correlated with carboniferous limestone bedrock, but negatively correlated with shales and similar rock types. Colour was positively correlated with occurrence of peats. Overall, nutrient status of lakes increased with measures of cattle density, total area farmed and total silage in the catchments, but impact of land-use intensity was proportionally greater in catchments dominated by shales compared with carboniferous limestone.

Comparison of means from *high* intensity sampled lakes with *medium* regimes demonstrated that four samples collected across the year provided reasonable (mostly within 95% C.L.) agreement with TP and chlorophyll *a*. Single estimates of TP and chlorophyll *a* did not, however, provide a good fit with annual means and management strategies based on single in-lake measurements of these response variables to nutrient load are ill-advised.

Multiple regression analyses using pooled data of *high* and *medium* sampling intensity demonstrated that good (r^2 >0.6) predictors of annual TP export from catchment to lake were census data of total hay and log mixed pasture (r^2= 0.74; d.f. = 15) and for mean in-lake chlorophyll *a* were census data of permanent hay, mean catchment slope and (negative effect of) both log lake altitude and log lake volume (r^2= 0.63; d.f = 25). Dividing the catchments into their two geological typologies found that in no values of r^2 > 0.6 related to catchment characteristics for lakes on the shales and related rocks, but highly predictive relationships of TP export with census data of total farmed area and (negative effect of) % grey brown podzolics (r^2= 0.68; d.f = 8); log mean in-lake TP with census data on total farmed area, log mean lake depth and % redzinas (r^2= 0.82; d.f = 7); and log mean in-lake chlorophyll *a* with census data on total farmed are and (negative effect of) % peat soils (r^2= 0.67; d.f = 8). A similarly powerful predictive relationship (r^2= 0.67; d.f = 8) for the limestone lakes was found for maximum chlorophyll *a* response to log human population density and (the negative effect of) low productivity grassland.

Overall, the results of the work show that while general predictive regression models can be powerful for the estimation of both nutrient load (TP) and impact (chlorophyll *a*) to lakes, separate models may need to be applied across broad catchment types. This has importance for the quantification and risk of nutrient load to standing freshwater, and clear relevance for the implementation of the Water Framework Directive (2000/60/EC).

Water quality in agricultural Finnish lakes

Petri Ekholm & Sari Mitikka

Finnish Environment Institute, PO Box 140, FIN-00251 Helsinki, Finland, Petri.Ekholm@ymparisto.fi

Agriculture was identified as the greatest single source of nutrients to Finnish surface waters already in the 1980s. We examined the development of water quality in 20 Finnish lakes affected by agriculture. Currently, most of the lakes are eutrophic or hypertrophic according to the OECD classification. A nonparametric trend analysis (Kendall's *tau*-b) performed using data for years 1976–2002 revealed that 4 out of 13 lakes with adequate data had increasing trends in chlorophyll *a*. Increasing trends were also found for the surface water concentrations of total phosphorus (4/18 cases) and total nitrogen (3/18) in the summer. In addition, some of the lakes had become more turbid (6/13). Alkalinity increased in 5/10 lakes. NH_4-N and NO_3-N tended to decrease in surface water during the summer. O_2-saturation in near-bottom water decreased in 4/16 lakes in the summer and in 2/17 lakes in the winter. Only one site, subject to in-lake restoration activities, showed decreasing chlorophyll *a* levels. In conclusion, signs of any improvement in the lakes studied were rare. This is in accordance with the recent findings that, despite serious efforts, agricultural loading to aquatic systems has not decreased in Finland.

Implementation of the EU Water Framework Directive – a case study

Barbro Ulén* and Teresa Kalisky**

*Department of Soil Sciences, Division of Water Quality Management, Swedish University of Agricultural Sciences Box 7072, SE-750 07 Uppsala, Sweden, Barbro.Ulen@mv.slu.se
** Regional Planning and Urban Transportation, Stockholm County Council, Teresa.Kalisky@rtk.sll.se

A case study of local initiatives for a river basin in accordance with the European Water Framework Directive was carried out in the county of Dalecarlia, in central Sweden. The catchment has erosion problems and the recipient Lake Brunnsjön suffers from eutrophication. Several measures to reduce the phosphorus (P) load and enable the lake to attain a good chemical and ecological status were proposed and/or demonstrated locally. In a local plot experiment the long-term surface runoff of particulate phosphorus (PP) via surface runoff from different types of autumn-ploughed soil was 0.22-0.32 kg ha^{-1} $year^{-1}$ while corresponding transport from spring-ploughed soils was 0.15 kg ha^{-1} $year^{-1}$. According to stakeholders the following measures were considered feasible and ranked in order of importance: improved soil fertility > measures at or in the stream > measures in the lake itself > improvements to single household wastewater treatment systems. The conclusion from the meetings and interviews during 2000-2001 was that the target of "improved soil fertility" would be preferable to the present local one "to be able to swim in the lake" in order to motivate the stakeholder group of farmers. This would mean improved organic matter concentrations in the mineral soil. A weak but significant decreasing trend of particulate phosphorus (PP) concentration (- 0.0001 mg l^{-1} $year^{-1}$) and of total nitrogen (TN) concentration (0.005 mg l^{-1} $year^{-1}$) was demonstrated in the water entering the lake during 1993-2002. Although there are several management measures to reduce P concentrations and P loads, a much longer time span than the Water Framework Directive's deadline of 2015 is needed to successfully reach a good ecological status in the lake. Two years during which funding was available to cover 35% of investments resulted in poor implementation of measures in the streams and of improvements to the single household sewage outlets. Sustained financial backing is crucial and it has been proposed that this funding must be secured to implement the actions decided upon.

Sources and mobilisation of agricultural phosphorus[1]

Oscar F. Schoumans[2], Wim J. Chardon[2], Phillip A.I. Ehlert[2], Jean Pierre Destain[3]

[2]Alterra, P.O. Box 47, NL 6700 AC Wageningen, The Netherlands.
[3]Centre de Recherche Agronomique, Département Production Végétale, 4 Rue de Bordia, 5030 Gembloux, Belgium

Key words: phosphorus, crop production, fertiliser use, sustainability, balances, environment, losses, pathways, leaching, erosion, detachment, solubilization.

Application of phosphorus (P) in agriculture is needed to achieve optimal crop production and crop quality. However, unnecessary and excessive use of phosphorus from manures and fertiliser has caused P loss from agricultural land to surface water and the marine systems and has led to eutrophication of these systems in the end. Therefore, the phosphorus use at farm and field scale should be balanced with crop requirements, taking into account the phosphorus availability in soils and the effectiveness of the phosphorus source and environmental standards.

Many phosphorus response curves were established in the past, and in addition critical phosphorus levels were defined, mainly based on the economics of fertilisation. Differences between countries using the same soil P tests (STP) in calibration of crop requirements were found and it is not always clear why these differences occur. Purchased feed concentrates have led to excessive application of phosphorus, without taken soil P status or efficiency of P from manures into account. This was not considered as a major problem in the past, since phosphorus was assumed to be strongly fixed to the soil system and was thus considered as immobile, especially in comparison with other important nutrients like nitrogen and potassium. The environmental impact of fertiliser or manure is seldom included in current fertiliser models.

At present 17 different soil P tests are used in the EU for assessing fertiliser requirements; another 13 methods are used for assessing the loss of P to the environment. There is a large disparity between fertiliser recommendations systems, which makes them difficult to compare. Although soil P tests seem to fulfil their role for assessing crop requirements well, in general there is no correlation between STP and a soil P test for assessment of environmental loss. In the 1980's the knowledge of the influence of soil physical, chemical, biological and hydrological processes on the mobilisation of phosphorus increased remarkably. The **buffering capacity** of soils for P needs to be made more explicitly in fertiliser recommendation systems, in order to tune fertiliser requirements with both crop requirements and environmental standards for soil quality. Only if STP is related to soil characteristics like soil P buffer capacity, **potential** P loss areas can be indicated. In order to achieve a more sustainable agriculture, farmers need a new, more fundamental and environmental sound approach for soil P testing and P management, and a new interpretation of critical levels of soil P status.

Today, policy makers are well aware of the adverse consequences of high phosphorus status of soils, especially under specific hydrological circumstances, so called

[1] Oral Presentation held at the final conference of COST action 832 "Quantifying the Agricultural Contribution to Eutrophication" from 31th July to 2th August 2003 at Clare College, Cambridge, UK

phosphorus vulnerable areas. Policy makers need risk assessment parameters, indexes or models to assess the ***actual contribution of phosphorus losses*** from soil to surface water, and to assess the effectiveness of nutrient and land management strategies for the reduction of P loss. Based on literature survey, outcome of laboratory and field experiments and expert judgement it is clear that these parameters, indexes and models need to take into account the large temporal and spatial variation in P transfer from individual fields arising from (a) changing but predictable factors such as land use, soil P status, P application rates, forms and ways of fertilisation and spreading, (b) predictable but inherent factors such as soil type, soil dispersivity, slope and hydrological routing, and (c) unpredictable weather factors such as rainfall amount and intensity.

In this paper we discuss in more detail the possibilities of setting up a more environmental sound approach for soil P testing for farmers and P risk assessment methodologies for policy makers, based on the present knowledge of phosphorus fertilizer recommendations, phosphorus behaviour in soils, and migration of phosphorus through the soil and over the soil surface. An overview based on the outcome of discussions within COST action 832.

Soil Phosphorus, a long-term source

Phillip Ehlert[1], Peter Dekker[2] and Kees van Wijk[2]

[1] Wageningen University and Research Centre (WUR), ALTERRA, PO box 47, 6700 AA Wageningen, the Netherlands
[2] Wageningen University and Research Centre (WUR), Applied Plant Research (PPO-AGV), PO Box 430, 8200 AK Lelystad, the Netherlands

Three long term field experiments with phosphorus (P) fertilizers have been carried out during periods of 17 till 33 years on calcareous clay and one long term field experiment was situated on noncalcareous sandy soils. During this period large differences were created in P budgets, leading to differences in soil test phosphorus values (STP) of water extractable P (Pw) or ammonium lactate acetic acid extractable P (PAL).

A cumulative surplus up to 2300 kg P per ha or an annual surplus of 77 kg P per ha did not lead to a proportional increase in Pw or PAL. The major part of the fertilizer residues was not found in an increase of these STPs. On the other hand, negative P budgets did not lead to a substantial decrease of the STP values even after 30 years on the calcareous soils; the soil were buffering these STP's at moderate P levels in the soil. Negative P budgets on the noncalcareous sandy soil even gave rise to a slight increase of water soluble P in the soil (figure 1). It is suggested that this is caused by a reduction of the depth of the plough layer in the course of the field experiment. On the sandy soil fertilizer residues from rock phosphate had an insignificant effect on the increase of Pw but PAL values did increase with cumulative

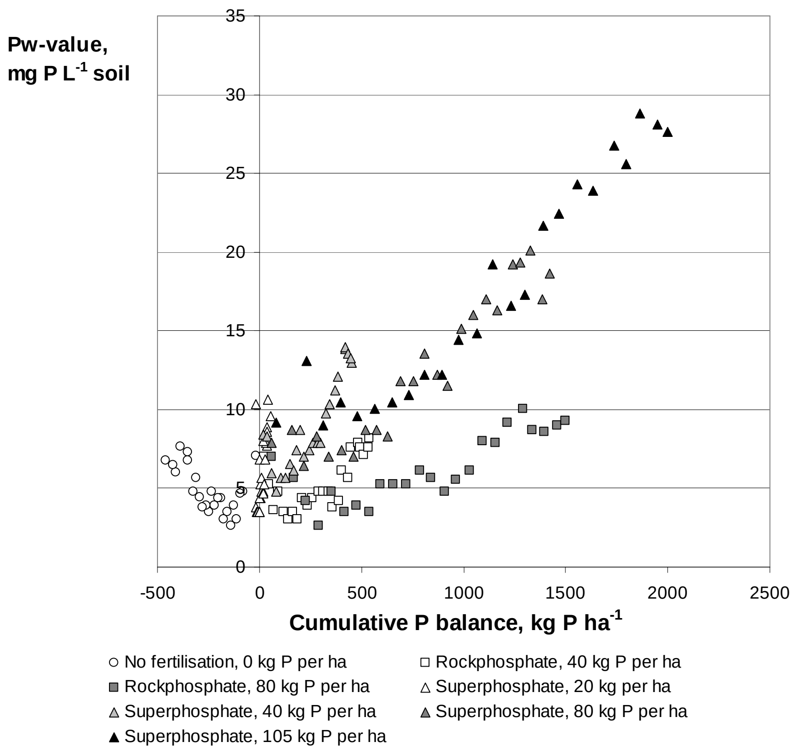

Figure 1 Relation between the soil test P status of the soil determined by water extraction (Pw-value) and the cumulative P balance for a non calcareous sandy soil for treatments with superphosphate and rock phosphate

surplus, the Pw declined following the same pathway as during the period of enrichment of the soil. Treatments with a moderate surplus however showed a lower rate of decrease indicating hysterese. High surpluses did lead to an increase of the soil P status in sub horizons but low or negative P surpluses did not lead to changes in the soil P status.

To be published soon in J. Plant Nutrition and Soil Science

Do different methods used to estimate soil phosphorus availability across Europe give comparable results ?

Jean-A. Neyroud[1*] and Peter Lischer[2]

[1]Station fédérale de recherches en production végétale de Changins, CH-1260 Nyon, Switzerland
[2]ConStat Consulting, CH-3095 Bern, Switzerland

Each european country is using its own method for the determination of phosphorus availability to plants, together with an appropriate interpretation scheme of the P-status and fertilizer recommendations. In order to compare systems, a soil exchange program was organised: 16 P-methods were compared on 135 soils from 12 countries. The amount of extracted P decreased in the order $P_{total} > P_{oxal.} > P_{AL} > P_{Me3} > P_{Bray} > P_{AAEDTA}$, P_{DL}, $P_{CAL} > P_{Olsen} > P_{paper\ strip}$, P_{AAAc}, $P_{Morgan} > P_{H2O}$, P_{CO2}, P_{CaCl2}. Isotopically exchangeable P was also measured. A large variability was observed in the results obtained by laboratories using the same method, thus demonstrating the great importance of an identical lab procedure as a prerequisite to any comparison. The traditional correlation/regression approach showed its limitations when applied to inhomogeneously distributed data and was replaced by more robust techniques that showed laboratory differential bias and confidence intervals of the log-transformed values. Even if all the methods reacted in the same way to growing amounts of added P in several trials, there were wide differences between results obtained with different methods. The interpretation schemes for P-status were also compared and revealed that about 50% of the tested soils were P-deficient. This last observation appears not to be in line with a generally high P fertilization during the last decades in Europe and should lead to a better evaluation of the plant-available soil phosphorus.

Edge of field losses of phosphorus in overland flow from grassland field plots to water.

Hubert Tunney[1], Isabelle Kurz[1] and Martin McGarrigle[2]

[1]Teagasc, Johnstown Castle, Wexford, Ireland. [2]EPA, Castlebar, Co, Mayo, Ireland.

Eutrophication of surface waters, attributable in part to phosphorus (P) loss from agricultural sources, is increasing in Ireland. This paper summarises the results of overland flow studies on a range of grassland soils at Johnstown Castle, Wexford.

Objectives: The objectives of this work were to make field measurements of the loss of dissolved reactive P (DRP) and other P fractions in overland flow from six grassland fields. The range of the losses and how they varied over the season were studiedMethods: Six grassland field sites with an area of 0.4 to 1.4 ha were isolated hydrologically so that overland flow water, from each site, was channeled to a central point. The flow was estimated every five minutes, when overland flow occurred, by the water height in a V-notch. Flow proportional samples were taken using an America Sigma automatic sampler and flow meter. Water samples were analysed for P and other nutrients. The loads of water soluble P, other P fractions, nitrogen (N) and potassium (K) were calculated. Measurements were made over two twelve month periods in 1997-1998 and 2000-2001.

Results and discussion: Average soil test P (STP) in Ireland increased ten-fold (from <1 to 8 mg l^{-1} Morgan's P) over the past 50 years. Grassland accounts for more than 90% of farmland in Ireland. The P concentrations in overland flow varied within and between sites over the season and varied from 0.02 to 8 mg DRP l^{-1} with the lowest P loss site averaging less than 0.1 mg DRP l^{-1} and the highest site averaging more than 1 mg DRP l^{-1}. Annual DRP losses varied from less than one to several kg DRP ha^{-1} on the sites. DRP accounted for 75% of total P loss in these grassland sites. In the year 2000/2001 there was an evident wash out effect in DRP concentration over the autumn at all sites. There was no overland flow for six months from April to September 2000, and the highest DRP concentration occurred in the first overland flow events and gradually decreased and leveled off. There was a significant exponential relationship between STP and DRP loss. The higher the STP and degree of soil P saturation the higher the DRP loss to water. Results indicated that sustainable grassland production and water quality could be compatible when the STP is at or near the lower limit for optimum grassland production.

Phosphorus losses from a forested feedlot for bulls

Jaana Uusi-Kämppä[1)] and Arto Huuskonen[2)]

[1)] MTT Agrifood Research of Finland, Environmental Research, FIN-31600 Jokioinen, Finland, jaana.uusi-kamppa@mtt.fi
[2)] MTT Agrifood Research of Finland, North Ostrobothnia Research Station, Tutkimusasemantie 15, FIN-92400 Ruukki, Finland

Raising cattle outdoors in winter is becoming more common in certain areas of Finland, although there is little information available on the effects of this practice on the environment. In our study, 10 bulls were raised outdoors on a forested feedlot (10 000 m^2) all year round at Ruukki, North Ostrobothnia (64°42'N, 25°00'E). Ten Herefords were on the lot from November 1999 to October 2000, and ten Finnish Ayshire bulls from November 2000 to December 2001. During the two-year experiment, we measured the change in easily soluble phosphorus content (P_{AAAc}) in the feedlot soil, using the Finnish method for soil testing (0.5 M NH_4-acetate–0.5 M acetic acid at pH 4.65; Vuorinen & Mäkitie 1955). The losses of total phosphorus (TP) and orthophosphate phosphorus (PO_4-P) in the run-off water from the lot were also determined.

Before the experiment, soil samples were taken from the feedlot in October 1999 in order to analyse P_{AAAc} at depths of 0–5, 5–30 and 30–60 cm. Sampling was continued in May 2000, October 2000, May 2001 and October 2001. Six soil samples were taken from the front part of the lot, where a 3-wall shed was set up, six samples from the middle part, and six samples from the rear of the lot. Water samples were taken from a ditch adjacent to the lot. A V-notch weir was used to measure water volume. In the snow melting period, water samples were taken three times a day; during other periods, water was sampled once a day. The concentration of TP was determined in unfiltered water samples. For the determination of PO_4-P, water samples were filtered through a membrane filter (0.2 µm).

According to the Finnish classification of soil test results (Viljavuuspalvelu 2000), the mean concentration of P_{AAAc} was low (5.0 mg/) in surface soil (0–5 cm) in the forest before the experiment. After the first experimental winter the mean P_{AAAc} was 7.3 mg/l, corresponding to a fair status for cultivated soil. After the raising of bulls for one year in the pens, the mean P_{AAAc} was 21 mg/l (4.5–71 mg/l), which indicates a high soil status. In 2001, the mean P_{AAAc} was 17 and 14 mg/l in spring and autumn respectively. The contents were the highest in the front part and in the middle part near the fence dividing the lot into two pens.

In 2000, the concentrations of PO_4-P and TP in ditch water were usually below 0.5 mg/l and below 1.0 mg/l respectively. In spring 2001, the PO_4-P concentration was 3–4 fold compared to the PO_4-P concentration in April 2000. The annual loads of PO_4-P and TP from the lot were 0.5–0.6 and 0.8–1.0 kg/ha respectively. PO_4-P and TP was leached from dung to a ditch along with the melting water. The TP and PO_4-P loadings were the same as those from Finnish cropped fields but several times higher than the loading from virgin forest soils. The loading is likely to increase if raising is continued at the feedlot.

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The effects of tillage and reseeding on phosphorus transfers from grassland

P. J. Butler[1] and P. M. Haygarth[1]

[1]Institute of Grassland and Environmental Research, North Wyke Research Station, Okehampton, Devon, EX20 2SB, UK. Telephone: 01837 883534 Fax: 01837 82139.
Corresponding author e-mail: phil.haygarth@bbsrc.ac.uk

The effect of tillage and reseed on the phosphorus (P) transfers from grassland was investigated. The first study was a controlled experiment using soil blocks under controlled rainfall conditions. Two treatments were imposed: - tilled bare soil and ‘permanent pasture’. Initially, the soil blocks were given low and high rainfall treatments, followed by a 'storm' generating overland flow. Losses of total phosphorus (TP) (Eisenrich *et al.* 1975), reactive phosphorus (RP) and suspended solids (SS) were determined and were greater from the tilled soil than from the permanent pasture, though there was no statistically significant difference. Total P losses were much greater following the ‘storm’ event, and showed a significant difference between permanent pasture and tilled bare soil, in the surface run-off and deep leachate.

The second study used one-hectare lysimeter plots, hydrologically isolated from neighbouring plots at Rowden, North Wyke in Devon, England, as described in Scholefield *et al* (1993) and Haygarth *et al* (1998). There were two hydrological treatments, undrained plots with composite (surface plus inter-) flow and drained plots, which also had mole drains at 60 cm depth. Two drained and two un-drained plots were studied following reseeding (in June 1998) and one drained and one un-drained plot was also studied under permanent (i.e. non–reseeded) grassland. Sixteen days after reseeding, 94 mm of rain fell, with 57 mm over 22 hours and this resulted in 7.5 tonnes of soil lost from one plot. The estimated load in the soil lost was 3.75 kg P ha^{-1} as compared with normal annual losses of around 0.8 kg ha^{-1} (Haygarth and Jarvis 1999) on adjacent non-reseeded treatments. Over the whole year concentrations of total P lost from undrained reseeded pasture were greater than from permanent pasture (means 107 – 124 $\mu g\ L^{-1}$). On drained land the trend was opposite; whereby the reseeded plots had lower P concentrations than the permanent pasture (45 – 89 $\mu g\ L^{-1}$ from the 0 – 30 cm flow and 48 – 59 $\mu g\ L^{-1}$ from the drained flow).

The third study looked at the long term solubilisation of P within the soil itself; as well as more qualitatively at P transfers generated during short term 'events' in ‘real’ fields. The long-term solubilisation study showed that P solubilisation stabilises over time, correlating with increasing sward cover. This study also confirmed that P losses can be high from tilled soil with little sward cover, but that they can be affected by the increasing sward presence.

All three studies show that in the short term, soil and P loss can be vulnerable to weather conditions directly after tillage and reseeding with resulting catastrophic effects on total P exports particularly on undrained grassland. This may be especially common on grassland soils that are on sloping land. In the medium to longer term, once the sward has developed, the effects on soil detachment are minimal; mechanisms of solubilisation are more prominent, with reseeded swards under drained conditions apparently buffering lower TP concentrations in contrast to the swards under permanent pasture. However, concentrations of P transfer are higher on reseeded grassland in undrained conditions. Drained soils appear to respond differently to undrained soils because tilling and reseeding soil allows percolation of P into the soil, reducing P transfer.

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Sourcing and Control of Phosphorus Loss in Two Small Catchments in England.

R A Hodgkinson

ADAS, UK

The results of two studies are reviewed with the specific objective of identifying the magnitude and importance of P losses from arable agriculture relative to those from grassland in England. Differences between these two broad land uses may be due to a different susceptibility to erosion/mobilisation or due to secondary factors such as connectivity to the watercourse. The data used are from two small catchments ADAS Rosemaund and the Gilwiskaw Brook (Hodgkinson and Withers, 1996)

Rosemaund is a predominantly arable catchment located in Herefordshire, dominated by dispersive silty clay soils. P losses were monitored in a stream that takes the drainage from a 150 ha catchment; this includes the inputs from the farmstead and farm cottages. A 30 ha arable sub-catchment (nested) and 3 arable tile drain catchments were also monitored. The results show that P losses to the stream from the smaller arable catchment ranged from ca. 0.2 kg ha^{-1} to ca. 4.2 kg ha^{-1} and that loss was strongly linked to runoff rather than to changes in agricultural management. Tile drain flow was found to be an important pathway for loss P loss with measured rates ranging from 0.05 kg ha^{-1} to ca 3.4 kg ha^{-1}. Particulate P (PP) was found to represent the dominant form of loss both in the stream system and in tile drain flow. In wetter years the importance of PP was enhanced whereas soluble P became increasingly important in drier years, and in the larger catchment due to farmstead inputs.

Results are presented from catchment monitoring of Phosphorus (P) loss from a pair of rural catchments that form the headwaters of the Gilwiskaw Brook near Ashby de La Zouch, Leicestershire, and UK. These catchments contain a good mix of agriculture and include both deep free draining sandy soils and heavier clay soils. The smaller catchment (Cliftonthorpe-90 ha) takes drainage from agricultural land only, while the larger (Lower Smisby-260ha) also included a small rural sewage works. Point source inputs were separated out by monitoring a 30 ha sub catchment that contained the sewage works. A tile drain from a grass field was also monitored for a short period. The results show that P losses from the agricultural catchment ranged from 0.1 kg ha^{-1} to 4 kg ha^{-1} and that climatic variation was the main driver. For part of the period for which data are presented, the Cliftonthorpe catchment was further broken down into 3 smaller sub-catchments; this allowed the influence of different proportions of arable land on P concentrations in runoff to be separated out. The lower grass dominated part of the catchment that is used for dairy farming was found to be a more important P source than the arable areas.

Finger printing to identify sediment sources (Russell et al, 2001) and sediment budgeting (Walling et al, 2002), based on erosion measured by Cs_{137} techniques were undertaken on both catchments. These were used to estimate the relative amounts of sediment and hence particulate P emanating from arable and grass areas respectively. At Rosemaund, the grass was found to contribute between 0.2 times and 0.8 times the amount of sediment coming from arable land depending on connectivity. At Clithonthorpe and Smisby, grass was found to contribute 1.0 to 1.8

times the amount of sediment coming from arable land. The difference between these sites was ascribed in part due to location of the grass fields within the landscape.

Losses of P through tile drains from arable land at Rosemaund and ADAS Boxworth (Hodgkinson et al, 2002) were evaluated against other published data (Catt et al, 1998) to try and determine key factors disposing arable system to P loss.

Current work on BMP's aimed at reducing losses of sediment and P from arable land is discussed.

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Characterising phosphorus transfers at different scales: the importance of dynamic approaches

Phil Haygarth[1], Adrian Joynes[1], Trevor Page[3], Gavin Woods[2] and Keith Beven[3]

[1] Soil Science and Environmental Quality Team, Institute of Grassland and Environmental Research, Okehampton, Devon, UK
[2] Department of Environmental Sciences, Lancaster University, Lancaster, UK
[3] National Soil Resources Institute, Silsoe, Bedfordshire, UK

Historically, studies on phosphorus (P) fluxes through agricultural soils have been agronomically driven, originally for production requirements and this necessitated the use of lysimeter and plot scale studies. More recently, lysimeter and plot studies were adapted to suit pressures for environmental quality, particularly of water and air. We wish to sound a cautionary note about much of the data that has arisen from such approaches, for four reasons:

1. Lysimeters and plot studies provide data that is of limited use because they dry up during the summer months, yet streams often persist with summer base flows when ecological impacts are greatest. In grassland systems this means we have little or no data when grazing animals are present.
2. Plots provide limited potential for assessment of delivery and connectivity to real watercourses.
3. The resolution of data gathering has mostly varied from days to weeks and using this type of information there has been a tendency to gather data to calculate loads and fluxes in annual time steps. But are there critical storm impacts on biogeochemical cycles that we have been missing because of too low resolution sampling?
4. There has been a tendency to collect information at the hydrological output (lysimeter 'pipe', weir, runoff collector) without full or proper adherence to what has actually happened, in real time, within the unit of study. For example, rarely do we have high quality chemical time series with flow that is supported by knowledge of, for example, livestock movements or fertiliser or manure management.

Thus our view of the 'agricultural soil' has tended to be focussed at a particular scale and resolution and our conceptual models have been conceived with these limitations. Furthermore there has been a tendency to rely on 'static' indicators of transfer, such as soil P status, when in fact 'dynamic' data can be of greater value. Thus we advocate data collection at the first order catchment scale that attempts to overcome these problems, in particular the importance of gathering information on the perturbations that occur in catchments, as without such information we literally have only half the knowledge we need.

As an example of the value of dynamic data collection, we demonstrate a simple means for classifying the temporal circumstances of concentration (P*c*) – discharge (Q) relationships terms of functional types of response. Our example uses new experimental data at the upstream interface of grassland soil and watershed systems from a range of scales (lysimeters to headwater catchments). Type 1 is where P*c* remains unchanged in relation to Q. Type 2 is where P*c* and Q are inter-related and Type 3 is where P*c* varies yet Q is unchanged. The approach reveals differences that can be explained mechanistically and in terms of functionality in P delivery. These occur in relation to (i) scale of study (with a tendency towards Type 1 in small scale lysimeters), (ii) hydrological pathways (with matrix flows as Type 1 versus preferential/overland flows as Type 2), (iii) soil type (with a tendency towards Type 1 in catchments with free draining soils) (iv) P form (with a tendency for Type 1 for soluble (i.e.<0.45 μm P forms) and (v) P sources, with Type 3 dominant where availability overrides transport controls. The classification provides a simple framework for development of a more complex and quantitative classification of P*c* – Q relationships that could be further developed to contribute to models for P transfer. The overriding single factor controlling P transfer is the temporal dynamics of antecedent conditions, as this integrates all 'static' effects. Ultimately, the approach has considerable value in helping to understand risk of delivery of P to streams and to mitigate P transfer from land to water.

Phosphorus export dynamic of different temporal scales from catchments of Lake Sempach (Switzerland)

P. Lazzarotto[1, 2], C. Stamm[3], V. Prasuhn[2], H. Flühler[1], F. Herzog[2], E. Butscher[4], C. Crespi[4]

1 Institute of Terrestrial Ecology, Soil Physics, ETH Zurich, Switzerland

2 Swiss Federal Research Station for Agroecology and Agriculture, Zurich, Switzerland

3 Swiss Federal Institute for Environmental Science and Technology, Zurich, Switzerland

4 Environmental Protection Agency, Cantone Lucerne, Switzerland

We report on the short-term P export dynamics of two catchments draining into Lake Sempach (Switzerland). The two catchments (3 and 7 km^2) are predominantly used as intensive grassland and many soils are P-saturated . Two different monitoring methods have been running by the Environmental Protection Agency of Kanton Lucerne: (1) time and discharge proportional sampling of total P, total dissolved P and dissolved reactive P (DRP) since 1984 and (2) high time-resolution monitoring of DRP during one year (1993) in the larger and since 1998 in the smaller catchment, respectively. The method comparison with time- and discharge proportional sample revealed a reasonable agreement (R^2=0.63, no bias). Still the deviations indicate that uncertainties have to be considered when comparing different catchments or years. In both catchments, DRP concentrations increased with discharge during the growing season. Often a time delay between peak flow and maximum concentrations was observed. This was especially pronounced in the smaller catchment. We observed decreasing time delays and decreasing variations in time delays with rising antecedent soil moisture. During the winter period, DRP exhibited hardly any relationship with flow in the small catchment whereas in the larger one the concentration-discharge relationship showed no dependency of the seasonality . Comparing datasets from 1993/94 with those of 1998 - 2002 we observed a clear tendency for decreasing DRP concentrations. This possible positive effect of the ecological measures to reduce agricultural P losses, introduced in 1993, was partially counterbalanced by increased particulate P concentrations. Stormflow events in the summer period for the years 2000 until 2002 revealed noticeably smaller peaks in DRP concentrations than for similar stormflow events for the years 1998 and 1999.

Phosphorus content of suspending sediment in the Marne Watershed: an indicator of particulate phosphorus losses from runoff?

Némery Julien, Garnier Josette and Billen Gilles

Sisyphe Laboratory, CNRS & UPMC, Paris, France nemery@ccr.jussieu.fr

In large man impacted river systems like the Seine basin phosphorus (P) is considered to be the major nutrient responsible for eutrophication. Comprehensive studies devoted to reduce eutrophication were conducted in the framework of the PIREN-Seine programme. On the basis of the biogeochemical model of ecological functioning of the Seine River (RIVERSTRAHLER: (Billen *et al.*, 1994; Garnier *et al.*, 1995), it has been shown that a reduction of eutrophication can only be obtained by reducing P-point sources by 90 %. As the public authorities have become aware of the importance of point sources in eutrophication problems, an effort has been made to progressively reduce the polyphosphate content in the washing powders and increase phosphorus retention in sewage treatment plants (SWTs). As a result, the P-point sources decreased at the benefit of the P-diffuse sources in the Marne watershed, and an improvement of the representation of the P-diffuse sources in the model was therefore needed. Therefore, we evaluated the various P sources, as well as the P-pathways and budgets through a nested watershed approach (Némery *et al.*, 2003). We studied the Blaise sub-basin (607 km^2), dominated by livestock, the Grand Morin sub-basin (1202 km^2), dominated by agriculture, and the Marne basin upstream Paris (12 832 km^2), influenced by both agriculture and urbanized areas.

Results showed that diffuse sources could account for more than 50 % of the total P-flux i.e. 20 tP y^{-1} at the Blaise river outlet and 46 tP y^{-1} at the Grand Morin river outlet, whereas they represented 30 % at the Marne river outlet, i.e 659 tP y^{-1}. Particulate Phosphorus (PP), considered to originate mainly from diffuse sources (point sources are dominated at 75-90 % by dissolved form), amounted to 33 to 60 % of the Total P fluxes.

To go further, diffuse sources were then determined as a contribution of both leaching through drainage (0.118 kg P ha^{-1} y^{-1} at 65 % as particulate form) and runoff (0.26 to 0.47 kgP ha^{-1} y^{-1} at 75-80 % as particulate form). Specific phosphorus flux from leaching was estimated from a 8 year monitoring database gathered at the outlet of a 15 ha cultivated and drained area (Riffard at al., 2002). P losses from runoff were determined by two approaches leading to similar results: i) the difference between total flux at the outlets and the sum of all other documented fluxes, ii) a calculation using the lowest P content in suspending sediment during high flow periods and the annual total suspending sediment load. Note that we did not take into account bank erosion which could nevertheless contribute significantly to PP load in rivers (Dorioz *et al.*, 1998; Laubel *et al.*, 1999).

The minimum threshold of P content reached for high discharge at different basin outlets has been shown to be very close to the P content of corresponding soils. For the Grand Morin and the Blaise sub-basins, homogeneous in land use and soil types, we respectively found a P content in soils of 0.51 gP kg^{-1} and 0.7-0.9 gP kg^{-1}, very close to the P content in suspending sediment at high water fluxes, equalling 0.50 gP kg^{-1} and 0.65 gP kg^{-1}. For the whole Marne basin clusters, characterized by an important range of pedo-geological units and agricultural practices, the P content varied between 0.51 and 1.42 gP kg^{-1} in cultivated soils (0.97 gP kg^{-1} in average) and was estimated at 0.9 gP kg^{-1} from suspending sediment at high flow period. These results clearly evidence the direct role of soil quality on PP transfers in the river.

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Phosphorus and sediment loads in the Oona Water catchment, Northern Ireland – scale and flow regime issues

Wayne Menary[2] and Philip Jordan

School of Biological and Environmental Sciences, University of Ulster, Cromore Road, Coleraine, Northern Ireland, BT52 1SA

Eutrophication is the main water quality problem in Ireland and agricultural soil phosphorus (P) is considered to be the principle cause. Part of an initiative to develop polices to reduce P losses from non-point sources to waterbodies has been an integrated cross-border project to investigate the relationship between scale, soil P chemistry and soil hydrology in three disparate Irish catchments. We report on the 2001-2002 results from one of the study catchments, the Oona Water, Co. Tyrone, a sub-catchment of a major influent river of the hypertrophic Lough Neagh.

The Oona Water catchment is a drumlinoid basin dominated by surface water gleys and grassland agriculture. Overland and bypass flow are the main storm flowpaths. This is characteristic of farming conditions in a large part of Northern Ireland.

Automated sampling equipment was added to an extensive hydro-meteorological network on the Oona Water within the framework of the Catchment Hydrology and Sustainable Management (CHASM) project. Automated sampling of storm events and discrete sampling of low flows provided a high sampling resolution so that up to 40% of high flows (>Q10) were sampled. Analyses of suspended sediment (SS), total (T)P, total soluble (TS)P and soluble reactive (SR)P were undertaken at flow monitoring stations adopting a nested catchment approach of field (12ha), farm (62ha) and meso (9200ha) scales.

Annual precipitation of 974mm for this hydrological year was reflective of wetter conditions and patterns of potentially extreme intensities were recorded (equivalent of 50mm/hour for summer storms). Suspended sediment loads of 32, 23 and 29 t km^{-2} yr^{-1} exhibit a strong dependence on flow at all scales. Similar loads of TP (1.73 kg ha^{-1} yr^{-1}, 1.88 kg ha^{-1} yr^{-1}), PP (1.17 kg ha^{-1} yr^{-1}, 1.3 kg ha^{-1} yr^{-1}) and SRP (0.29 kg ha^{-1} yr^{-1}, 0.29 kg ha^{-1} yr^{-1}) were obtained for the 12ha and 62ha respectively. Lower stream gradients between 12ha and 62ha controlling coarse sediment deposition and continued fine sediment transport appear to explain the relative SS and PP differences between these scales. Increased loads of TP (2.3 kg ha^{-1} yr^{-1}), PP (1.35 kg ha^{-1} yr^{-1}) and SRP (0.6 kg ha^{-1} yr^{-1}) at 9200ha are reflective of chronic background TP concentrations of up to 200µg L^{-1} at low flow.

From these results it appears that erosion and/or enrichment of P with suspended sediment are more dominant mobilisation processes than desorption of soluble P. At the meso-scale, it appears that sources not allied to storm runoff are contributing to the ongoing eutrophication of this river system. Scale is implicated as an important consideration when monitoring the effectiveness of eutrophication management.

[2] Contact author: w_menary@ulster.ac.uk

BUFFER

Kenneth Irvine[1], Ian Donohue[2] and David Styles[3]

[*]Department of Zoology, Trinity College, University of Dublin, Dublin 2, Ireland
[†]Department of Geology, Trinity College, University of Dublin, Dublin 2, Ireland

The transport of nutrients, principally nitrogen and phosphorus, and their impact on lake ecology varies significantly among catchments owing to different physical, chemical and biotic factors. Qualitative and quantitative differences in nutrient pathways within lakes and catchments make it difficult to apply common standards and for the reliable prediction of nutrient loads. The work described here was done as part of the EU-funded BUFFER project, which involves eight partners from seven countries across Europe. Principal aspects of the project involve the assembly of nutrient budgets for a large number of lakes across Europe, the intensive study of a selection of these lakes, and investigations into the factors, biotic and abiotic, that affect the transfer of nutrients from soil to water, and within rivers and lakes. A central aim of the project is to develop nutrient transport models that account for critical physico-chemical and ecological differences among lakes and their catchments.

The catchments of Loughs Carra and Mask in the west of Ireland have been studied intensively for the last two years as part of the BUFFER project. Predictions of nutrient export coefficient models of phosphorus loads of 14 subcatchments in the Carra/Mask system agreed well with measured loads (minimum $r^2 = 0.94$). In-depth analysis of nutrient-discharge dynamics found that the relationships between river flow and the concentrations of each of molybdate-reactive P, total P, total N and suspended solids differed significantly both among the rivers and with season. For phosphorus, for example, although the concentration-flow relationship was always positive, concentrations during high flows were significantly greater during summer and autumn compared with winter and spring. These findings are important to the implementation of the Water Framework Directive, as defining risk to degradation of ecological quality waters from catchment activities is needed to drive programmes of measures. Insufficient or inappropriate risk assessment will likely inhibit or prevent effective implementation.

Diffuse phosphorus export from re-wetted peat land: Results of the EU-project PROWATER

Meissner, R.[1)], Leinweber, P.[2)],Rupp, H.[1)], Schlichting, A.[2)], Shenker, M.[3)], Litaor, I.[4)], Sapek, B.[5)], Ottabong, E.[6)], Robinson, S.[7)] & Hacin, J.[9)]

[1)]UFZ Centre for Environmental Research Halle-Leipzig, Department of Soil Science, Research Station Falkenberg, Dorfstrasse 55, D-39615 Falkenberg
[2)]University of Rostock, Agriculural and Environmental Faculty, Institute of Soil Science and Plant Nutrition, Justus-von-Liebig-Weg 6, D-18051 Rostock
[3)]Hebrew University of Jerusalem, Faculty of Agricultural Food & Environmental Quality Sciences, Department of Soil & Water Sciences, PO Box 12, Rehovot, IL-76100
[4)]Tel-Hai Academic College, Department of Biotechnology and Environmental Sciences, Upper Galilee, IL- 12210, Israel
[5)]Institute for Land Reclamation and Grassland Farming, Soil and Water Chemistry Department, Falenty IMUZ, Raszyn, PL-05-090, Poland
[6)]Swedish University of Agricultural Sciences Uppsala, Division of Plant Nutrition and Soil Fertility, Department of Soil Science, Box 7014, Ulls veag 17, Uppsala, S-750 07
[7)]The University of Reading, Department of Soil Science, PO Box 233, Whiteknights, Reading, UK-RG6 6DW
[8)]University Ljubljana, Biology Center, Vecna Pot 111, SI-1000 Ljubljana

The cultivation of fen peat soils carried out in Europe for about 250 years resulted in a severe degradation and oxidation of peat and loss of ecological value and functions of fenlands. Currently, some of degraded fenlands are under restorations programmes, in which re-wetting is a central measure. Soil chemical considerations and initial results in the literature arouse suspicion that large scale re-wetting of previously cultivated fenlands may be intensively accompanied by the mobilisation of phosphorus (P), its transport to adjoining aquatic systems, an accelerated eutrophication and deterioration of water quality. Therefore, the project PROWATER (Program for the prevention of diffuse pollution with phosphorus from degraded and re-wetted peat soils) was initiated to develop scientifically based guidelines for the use and restoration of fen lands at minimised risk of P transfer to waterways.

The presentation gives an overview on the project components and general achievements. This helps to integrate the contributions of individual project partners. The first step of the project was to accomplished harmonised data sets on main factors controlling the P mobilisation. This was achieved by the installation of field measurement stations in six countries which included representative fen land sites along a climatic gradient from Scandinavia to the Mediterranean. Soil moisture and temperature, redox potentials and ground water levels were recorded continuously and correlated with P concentrations and forms in soil solution, surface and ground water. The results obtained so far strongly indicate that great P proportions will become soluble if the degraded peat will be set under anaerobic conditions. In a second step process analyses regarding the transformation of P forms under peat degradation and re-wetting have been carried out by sequential fractionation methods. Furthermore, microcosm experiments showed that depending on peat degradation and reaction temperature proportions of P were solubilized that exceeded threshold values for the freshwater eutrophication. Based on field studies and laboratory experiments in a third step the model MORPHO (**MO**delling of **R**egional **PHO**sphorus Transport) has been adapted to fen soils and used for calculation of P losses and transport in soil profiles. The quality of the model was improved by introducing an plant accumulation term into the transport equation. Different scenarios have been calculated for the consequences of re-wetting measures under various boundary conditions. In a fourth step risk assessment along with socio-economic considerations will form the basis for the development of a decison support system (DSS) which will be the final outcome of the project PROWATER. The DSS will be tested with local end users and stakeholders.

An Environmental Soil Test to Determine the Potential for Sediment and Phosphorus Transport in Run-off from Agricultural Land (DESPRAL).

P.J.A. Withers[1], E. Barberis[2], H. Hartikainen[3], N.J. Quinton[4], P. Strauss[5], I. Sisak[6] and R. Huggins[7]

[1]ADAS Catchment Management Group, UK; [2]University of Torino, Italy; [3]University of Helsinki, Finland; [4]University of Lancaster, UK; [5]Institute of Institute of Land and Water Management Research, Austria; [6]Pannon University of Agricultural Sciences, Hungary and [7]Environment Agency, UK.

The development of cost-effective mitigation options to reduce soil and phosphorus (P) transfer from diffuse agricultural sources in catchments requires accurate identification of high-risk contributing areas. It also requires an understanding of the relative contribution of landscape (erosion) and land management (soil P status) factors influencing the transport of soluble P (SP) and particulate-bound P (PP) in run-off. To help achieve these aims, DESPRAL investigated the feasibility of a simple laboratory based environmental soil P test to determine the potential risk of soil and P transfer in land runoff. The objective is to incorporate such a test into field and catchment based decision support systems for use in identifying priority areas (high-risk fields) for implementation of best management practices.

The physical, chemical and mineralogical properties of 26 EU benchmark soils have been determined. These soils have a wide range in soil dispersibility and in soil P status. Sorption and fractionation studies have shown that P release is related best to Al-bound P, and can be adequately described by both water-soluble and Olsen-extractable P. Indoor and outdoor rainfall simulation procedures have been developed to collect runoff, sediment and P from the benchmark soils (indoor runs), and from selected field sites from which the soils were obtained (outdoor runs). Three laboratory approaches for determining soil P dispersibility have been compared: gentle shaking of soil in water, chemical dispersion using sodium chloride and an ultrasound method which is designed to mimic the energy of falling raindrops. Comparisons of indoor rainfall simulation data and the results from candidate laboratory dispersion tests suggest simple gentle water dispersion can be used to predict soil vulnerability to particle detachment and initial P mobilisation in fields. In addition, the test can differentiate the background dissolved P signal from the particulate P signal. The dispersed particles appear to have considerably modified soil P release properties compared to the bulk soil. The main factor affecting soil dispersibility was soil organic matter.

Further comparisons between laboratory dispersion data and soil and P transfer from field plots with increasing soil P levels under natural rainfall suggest that soil P status does not influence soil dispersibility, only the associated SP and PP signal. Hence, the most dispersive soils do not necessarily present the greatest environmental risk in terms of P loss. Further work is underway to examine changes in soil P dispersibility across different scales and to combine the test with a hydrological component for use in risk assessment at the catchment scale. The results of the project will lead to the development of practical management tools and guidelines that can be disseminated and operated by end-users as part of integrated river basin management strategies as required under the Water Framework Directive.

A framework to improve the implementation of BMPs: examples from AgriBMPwater project

Ramon Laplana[11], Nadine Turpin[1], Philippe Bontems[2], Gilles Rotillon[3], Ilona Bärlund[4], Minna Kaljonen[4], Sirkka Tattari[4], Franz Feichtinger[5], Peter Strauss[5], Randel Haverkamp[6], Monica Garnier[7], Antonio Lo Porto[7], Giulia Benigni[8], Antonio Leone[8], Maria Nicoletta Ripa[8], Ole-Martin Eklo[9], Eirik Romstad[10], Thierry Bioteau[1], François Birgand[1], Paul Bordenave[1], Jean-Marie Lescot[11], Laurent Piet[11], Frédéric Zahm[11]

1. Cemagref de Rennes, 17 avenue de Cucillé, CS 64427, 35044 RENNES Cedex – France
2. INRA –IDEI, PO Box 27, Chemin de Borde Rouge, 31326 Castanet-Tolosan Cedex – France,
3. Université de ParisX – Nanterre, 200, avenue de la République, 92001 Nanterre – France,
4. SYKE, Finnish Environment Institute, Research Programme for Environmental Policy, PO Box 140, Kesäkatu 6, 00251 Helsinki – FINLAND,
5. IKT: Federal Agency of Water Management, Institute for Land and Water Management Research, Pollnbergstrasse 1, A-3252 Petzenkirchen, Austria,
6. Université Joseph Fourier, Laboratoire d'étude des Transferts en Hydrologie et Environnement, PO Box 53, rue de la Piscine, 38041 Grenoble – France,
7. IRSA, Istituto di Ricerca Sulle Acque, Reparto Sperimentale di Bari, Via De Blasio 5, 70123 Bari – ITALY,
8. Universita della Tuscia, Istituto di Genio Rurale, Via S. Camillo de Lellis, 01100 Viterbo – ITALY,
9. Norwegian Crop Research Institute, Plant Protection Centre, Hogskolevn, N-1432 Aas – NORWAY,
10. Agricultural University of Norway, Department of Economics and Social Sciences, PO Box 5033, Taarnbygningen, N-1432 Aas – NORWAY,
11. Cemagref de Bordeaux, 50, avenue de Verdun, 33612 Gazinet cedex – France,

To help local regulators to mitigate nonpoint source agricultural pollution and implement environment-friendly agricultural practices, a comparison between different existing or simulated Best Management Practices (BMPs) has been carried out in the frame of the AgriBMPWater pluridisciplinary project (FP5 founded). The project has been imagined and built in a pluridisciplinary approach and framework. The approach has been developed through a cost/effectiveness assessment of several BMPs along with the study of their acceptability by farmers. Thanks to the integrated assessment of existing and potential BMPs, a selection grid provides assistance to regulators on how to conduct environmental, economic and sociological analyses for helping decision makers. Water quality problems encountered and dealt with in this project include nitrate, phosphorus, sediment, pesticide loads and acid water concern. Thus, the developed framework allows of a large range of hydrologic and economic models, depending on the environmental problem detected on each watershed.

Concerning Environmental effectiveness, a panel of available models has been used to deal with each specific problem (SWAT, BMP1top, HAPSU EUROSEM, STOTRASIM, GLEAMS POWER and EIQ). As they can take various forms, particular efforts have been carried out to improve BMPs representation in hydrological models. Spatial modelling, at various scales, was used to define critical areas where efforts should be concentrated on. The effectivity has been estimated through the introduction in the previously validated models of pre-designed BMPs as alternative practices. Each BMP's efficiency is determined as a non-dimensional value being the ratio between the initial state and the estimated state after BMP implementation. The results are presented as a cumulative curve which depicts the relation, on each watershed and for each BMP, between the efficiency and the contracted area and/or to the area of application on critical areas.

In order to estimate costs, three mains types of costs have been defined: the amount supported by the regulator (subsidy), the amount supported by agricultural producer (farmers' profit variation) and the amount supported by the rest of the economy (consumer surplus). Three methods have been designed and initiated for the estimation of the costs : a computable general equilibrium model aims at estimating indirect costs on large watersheds, a Principal-Agent model aims at estimating direct costs on large watersheds and a linear-programming model aims at estimating direct costs on small watersheds. The result are presented as a cumulative curve which depicts the relation, on each watershed and for each BMP, between the costs and the contracted area and/or to the area of application on critical areas.

The approach concerning social acceptability has concentrated on looking at farm-level decision-making process. A qualitative method has been defined and applied in one watershed .For the others watersheds a simplified approach has been proposed. The studies concern the concrete related changes in the management practices, the decision making and contracting processes, the problem framing and the acceptability of the policy model. The results reveal how the representation of different interests in the implementation affects the spreading of BMPs. Results are presented in a diagram which depict the relation, on each watershed and for all tested BMPs, between acceptability and cost / efficiency ratios.

The selection grid for BMPs is represented as synthetic diagram. The produced scheme structures the different cumulative curves. Results are illustrated by data from the Don watershed, concerning efficiency, cost and acceptability for the implementation of reasoned fertilisation.

Integrated catchment modelling of nutrients and instream ecology for diffuse pollution and eutrophication studies

Professor Paul Whitehead

Aquatic Environments Research Centre, University of Reading

Over the past four years a suite of models has been developed for the integrated simulation and management of catchments. These models are process based, capture the main dynamic behaviour patterns, describe the transport mechanisms within catchments and address both terrestrial and aquatic ecosytems. Thus the models are ideal for investigating questions concerning the interactions between land use change, instream water quality, diffuse and point source pollution. The INtegrated Nitrogen in CAtchments model (INCA) is a mechanistic model of plant/soil system and instream nitrogen dynamics. The model has been designed to assess the effects of multiple nitrogen sources (nitrogen deposition and agricultural and sewage inputs) on river water chemistry in large and small catchments. Based on mass balance, the model simulates the principle mechanisms operating, including mineralisation, immobilisation, nitrification and denitrification. The river catchment to which INCA is applied, is sub-divided into reaches and, since land use is one of the most important factors effecting streamwater nitrogen, the landscape is further divided into six land use groups. INCA has been applied to over 10 catchments in the UK and, as part of a large EU project, to 12 catchments across Europe. The EU INCA project was concerned with the development of a generic version of the model for European river systems, thereby providing a tool (a) to aid the scientific understanding of nitrogen transport and retention in catchments and (b) for river-basin management and policy-making. The findings of the study highlight the heterogeneity of the factors and processes controlling nitrogen dynamics in freshwater systems. Nonetheless, the INCA model was able to simulate the in-stream nitrogen concentrations and fluxes observed at annual and seasonal timescales in Arctic, Continental and Maritime-Temperate regimes. This result suggests that the data requirements and structural complexity of the INCA model are appropriate to simulate nitrogen fluxes across a wide range of freshwater environments. This model has now been extended to include organic and inorganic phosphorus transport from catchment land surfaces and groundwaters into streams and has been linked to an instream water quality and ecological model. This component simulates the instream ecology, namely macrophtyes, epiphtyes and phytoplankton, so is ideal for evaluating how change in pollutants and water quality affect instream ecology. INCA-N and INCA-P have both been applied to the upper Kennet River and this river system will be used to illustrate the model and the potential use for assessing relative impacts of point and diffuse polution on the eutrophic status of streams.

Decision support frameworks to assess the risk of phosphorus loss at field to national scales

Louise Heathwaite[1], Andrew Sharpley[2], & Tamie Vieth[2]

[1] University of Sheffield, UK; [2] USDA-ARS Pasture Systems & Watershed Mgt. Res., USA

Decision support frameworks are important in helping to identify agricultural areas or practices vulnerable to diffuse phosphorus (P) loss at various scales in order to aid policy decisions, to provide advice on the selection of appropriate best management practices (BMPs), and to maximise their effect on reducing diffuse P loss. One of the advantages of this type of approach over more advanced deterministic, process-based models is they are based on easily available input data calibrated using empirical research. We will review current decision support frameworks that act as screening tools for the evaluation of the spatial variability and risk of P loss from agricultural land to water. Our evaluation will examine the benefits and limitations of tools developed to operate at the field scale (e.g. The P Index, Gburek et al., 2000), through semi-quantitative approaches operating at hillslope and small catchment scales (e.g. the Nutrient Export Risk Matrix, www.shef.ac.uk/seal), up to national screening tools such as the DEFRA P Indicators Tool (Heathwaite et al., 2003). The P index identifies the risk of P loss from a field based on source and transport-to-stream characteristics. Annual P-index results will be compared with those from a long-term, daily time-step simulation model (SWAT – Soil and Water Assessment Tool, Arnold et al., 1998) for several fields within a small watershed. The objective is to show that, while the P index and simulation model both identify areas of high risk to P loss, the P index provides a much simpler screening tool with a few, easily obtained inputs. Some differences are expected as the P index provides an annual estimation of risk, whereas the simulation model is affected by individual storm events during highly erosive management periods such as tillage and planting. Additionally, distance to the stream is considered by the P index but the simulation model. However, these differences can be used to reassess and perhaps improve prediction capabilities of the P index and/or the simulation model. We will asses the extent to which these various tools meet the needs of end-users such as farmers, advisory bodies and legislators and where further work is needed to improve the predictive capacity of these simple models.

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Measures to reduce phosphorus load from agricultural land in the catchment area of the lake of Sempach

Josef Blum

Fachstelle für Ökologie in der Landwirtschaft, Centralstrasse 21, CH-6210 Sursee, Switzerland

The lake of Sempach, with a surface area of 14.4 km^2, a maximum depth of 87 m and a catchment area of 61.9 km^2, is highly eutrophic. The eutrophic condition of the lake can be fully attributed to antropogenetic impacts, since its water changed from an oligotrophic to an actual eutrophic condition somewhere between 1950 and 1965. Untreated sewage from settlements and industry caused a first phosphorus load. From 1960 intensive farming with high animal stocking (cows and pigs) caused an additional phosphorus input. By 1984 the phosphorus content in the lake reached the maximum level of 160 mg P/m3. At the same time a remarkable fish kill related to eutrophication occurred.

A concerted action to reduce lake phosphorus content was started 1970. First of all the treatment of sewage had priority. Today all households are either connected to a treatment plant or have possibilities to apply sewage together with animal manure on their own agricultural land. Between 1984 and 1996 the hypolimnium was artificially aerated with oxygen during the summertime and in the wintertime by air. Today the oxygenation of deep waters is done by air. Investigations on the tributaries show that after completing the sewage treatment, 85% of the annual phosphorus load originated from agricultural land. Therefore most emphasis must be put on measures in agriculture. In 1985 an office for information and consulting of farmers in ecology (Fachstelle für Ökologie) was installed. In 1993 integrated agricultural production and a direct payment program connected to this production method was introduced by the Swiss Government. One of the main criteria in this direct payment program is equilibrium of the phosphorus and nitrogen balance at the farm level. This criterion provides a clear result about the nutrient surplus or deficit on the farm. It defines how much fertilizer nutrients the farm can import or how much manure has to be exported, respectively how much livestock has to be reduced to reach the nutrient balance. A maximum of 110% of phosphorus input of the requirements of the plants is possible. At present more than 95% of the farmers in the catchment area of the lake of Sempach participate in this program. Although this program limits the application of phosphorus on the farm level, it is not sufficient to reach the goal of less than 30 mg P/m^3 in the lake, mainly because of the high percentage of over fertilized plots in the catchment area. Therefore a Swiss program for regional projects in the catchment area of lakes and ground waters was started. This program makes it possible to pay farmers for additional measures to the integrated production to improve water quality.

Farmers who participate in this program get an additional direct payment of Fr. 300.-/ha and have to realise the following measures:

- Buffer strips of at least 5 m width along all rivers and open drainages
- At least 5% of the farm area is not fertilized
- The nutrient balance is below 100%, for overfertilized plots the limit is by 80%
- Soil samples of all plots are analysed at an interval of 5 years
- No manure is applied during wintertime
- Soils are covered during wintertime and the soil protection index must be at least 70
- Corn on plots with a slope of more than 18% must be sown without tillage

- The percentage of fodder and sugar beets, potatoes and corn in the crop rotation must be less than 20% of all crops on arable land
- The infrastructure on the farm yard has to be as such, that no nutrients are washed off (storage place for manure, washing place for machines, no drainage of the farm yard directly connected to rivers etc.)
- Farmers participate at least once a year in the educational program concerning the lake restoration

Beside this package of several combined measures farmers can also realise the following additional measures:

- Installing ponds as nutrient traps for drainage and runoff water
- Program to shut down pig and poultry units

With the combination of lake external and internal measures, which started in 1970, the concentration of phosphorus in the lake could be reduced to 36 mg P/m^3 in 2003.

Effectiveness of treatments to reduce P runoff losses from grassland soils

[1]Schärer, M., [2]Vollmer, T., [1]Sinaj, S., [3]Stamm, C., [2]Flühler, H., and [1]Frossard, E.

[1] Institute of Plant Sciences, Plant Nutrition, ETH Zurich, Research Experimental Station, Eschikon 33, CH-8315 Lindau, Switzerland
[2] Institute of Terrestrial Ecology, Soil Physics, ETH Zurich, Grabenstrasse 3, CH-8952 Schlieren, Switzerland
[3] Swiss Federal Institute for Environmental Sciences and Technology (EAWAG), Water and Agriculture, Überlandstrasse 133, CH-8600 Dübendorf, Switzerland.

Permanent grassland soils in areas of high animal stock densities are often prone to high P losses due to over-fertilization. The high P inputs and the non-tillage management regime lead to a strong P accumulation in the topsoil. We present results of a field experiment in which we investigate different measures intended to reduce P losses. The studied treatments are a zero-P management, zero-P plus a single tillage operation followed by resowing grass, and zero-P plus tillage plus addition of Fe-(II)-sulfate solution on a calciumhydoxide-soil mixture to increase the sorption capacity of the soil. These treatments have been applied on two field sites in the Greifensee catchment nearby Zurich. The soils of the study sites are rich in total and available P content. These values decrease strongly with depth. The soil at site I is a neutral sandy-clayey loam, whereas at site II it is an acid sandy clay.

On each site, the treatments have been compared in 4 replicates of 65 m^2 to control plots receiving inorganic N,P,K fertilization. In the year 2000, the P losses from all plots were evaluated under the control treatment as a reference value for each plot. The remediation measures were applied at both sites in early summer 2001. The monitoring program includes soil P analyses, sprinkling experiments inducing surface runoff, as well as runoff measurements under natural rainfall conditions.

Comparison of P concentrations in the runoff induced by natural rainfall with those values obtained from sprinkling experiments were similar indicating that the sprinkling experiments could be used as a monitoring tool as long as de-ionized water is used. The concentration of dissolved reactive P (DRP) in the induced runoff was also clearly correlated to available P in the topsoil. Three months after the tillage operation the P availability of the topsoil, as well as DRP concentrations in runoff have been reduced significantly by the tillage and tillage plus Fe-treatment, but not by the zero P treatment. One year after the start of the remediation treatments, the same trends could be observed, with the exception of the tillage treatment, where DRP concentration in surface runoff did not differ significantly from the control plots any more. No treatment effect could be observed on total P concentration in surface runoff one year after the start of the treatments, due to increased particulate P losses from the tilled plots. The runoff behaviour was not affected by the treatments.
The results suggest that on the short term only drastic measures (tillage, chemical amendment) lead to a reduction of runoff P concentrations. Such treatments are applicable only to small areas (e.g. to create buffer zones). Moderate management measures (e.g. reduced P fertilisation) might take much more time, at least several years, in order to reduce runoff P losses from P enriched soils.

Integrated Soil and Water Protection: Risks from Large Scale Diffuse Pollution (SOWA)

Peter Grathwohl

University of Tübingen, Center for Applied Geoscience, Sigwartstrasse 10, 72076 Tübingen, Germany, e-mail: grathwohl@uni-tuebingen.de

SOWA is an Accompanying Measure aiming at the integration of soil and water research in Europe. The thematic focus is set on large scale diffuse pollution of soils from e.g. atmospheric deposition and agricultural practices. Many manmade compounds are persistent, bioactive and accumulative in the environment, some already exceed environmental standards in soils and water bodies at a regional scale and many compounds accumulate continuously in soils and sediments. Polluted soil and sediments finally can become long-term secondary contaminant sources affecting future generations. As largest and most active compartment, soil governs groundwater and surface water quality and has to be recognised as key zone between land surface and groundwater (Fig. 1).

The motivation of the SOWA consortium is therefore the protection of soil as the most active resource in the hydro- and biosphere.
The objective is to pull together the critical mass needed in order to integrate available and emerging scientific knowledge from various disciplines such as soil science, soil chemistry, soil physics, hydrogeology, water resources, agriculture, atmospheric deposition of pollutants, environmental analysis and engineering as well as management and remediation of contaminated soil and groundwater. SOWA provides therefore a multidisciplinary forum for the identification of research needs and strategies for integrated soil and water protection.

The work of SOWA is divided into five thematic working groups which focus on different aspects of integrated soil and water protection: *Inventory* of priority compounds and trends, screening and monitoring *tools* at different scales, chemical and physical *processes* in the unsaturated zone, heterogeneity and *scale issues* in soil and groundwater, and *management* options for diffuse soil and groundwater pollution by agricultural practises.

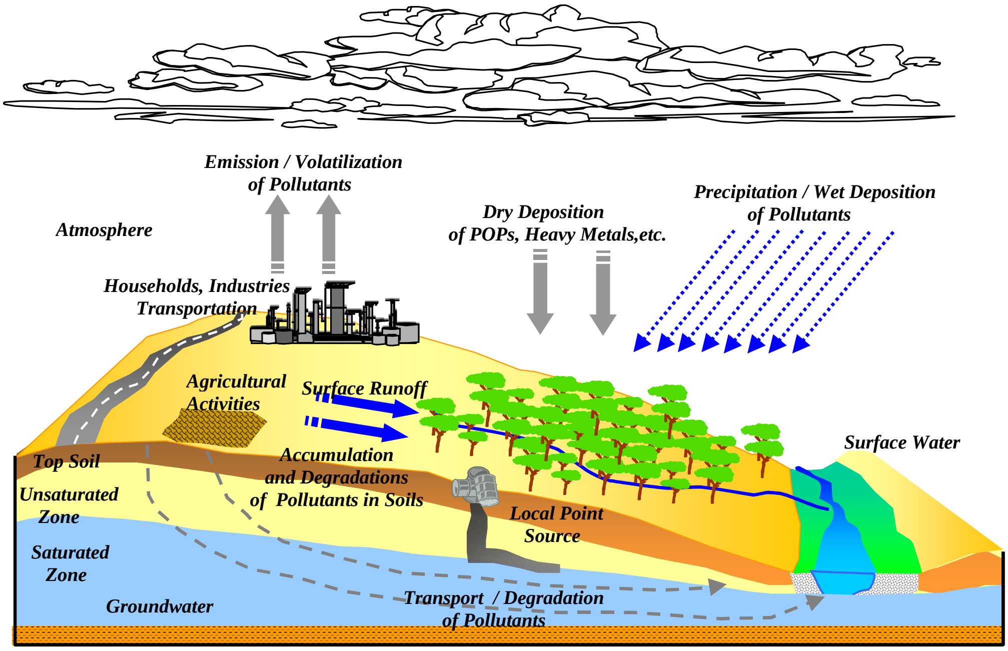


Figure 1: Pollutants in the water cycle: As key zone between land surface and groundwater, soils can act as source (if accumulations or contaminants exceed the “critical load”) and a sink (because of their filter, retention and transformation capacity)

POSTER ABSTRACTS

Quantifying the Agricultural Contribution to Eutrophication in Norway

M. Bechmann[1] and T. Krogstad[2]

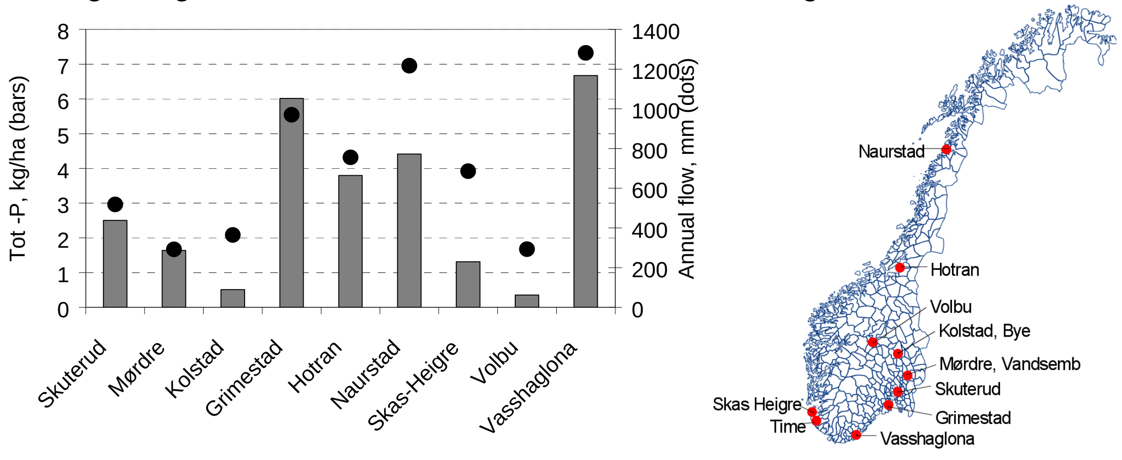
[1]Norwegian Center for Soil and Environmental Research, Fredrik A. Dahl vei 20, N-1432 Aas, Norway. marianne.bechmann@jordforsk.no
[2]Dept. of Soil and Water Sciences, Agricultural University of Norway, N-1432 Aas, Norway. tore.krogstad@ijvf.nlh.no

In the introduction to the EU COST (Co operation in Sciences and Technology) 832 action it is said that the extent of eutrophication in fresh waters is most commonly related to the concentration of phosphorus and that agriculture has been identified as a significant phosphorus source. It is argued that identification of mitigation options to reduce phosphorus inputs to water, in line with EU initiatives (PARCOM), requires a sound knowledge base on the significance of agriculture as an eutrophication source. This poster presents state of the art in Norway.

Pollution from settlements and agriculture effect water quality in Norwegian lakes and rivers, and may result in poor drinking water quality, fish mortality, and reduce the value for bathing and other outdoor recreation. The eutrophication of fresh water tends to occur in lowland areas, particularly near settlements and agricultural land. 45% of the anthropogenic P input to surface waters originate from agricultural areas. Based on studies it is estimated that conditions in 700-900 lakes warrant the classification "bad" (20-50 µg P/l) or "very bad" (>50 µg P/l). Even though this is only 2.5% of all Norwegian lakes, it has to be considered a significant environmental problem.

Causes of phosphorus losses from Norwegian agricultural land follow the farmer's production, e.g. livestock or cereal. In areas with high livestock density (e.g. South-west) the soil P content is the main problem, while cereal production areas have generally greater problems with erosion (e.g. South-east).

P losses from agricultural land were monitored in catchments representing different production, soil, climate and management practice. A normal variation in P runoff in Norwegian agricultural influenced areas is shown in the figure below.



Water monitoring program for a municipality in a cereal dominated area in south-eastern Norway shows that 70% of bioavailable P in runoff originated from agricultural areas. In the most cultivated dominated parts of the municipality about 70% of the waters were classified to have a "very bad" water quality (> 50 µg P/l).

Most P from agricultural catchments comes from only a small but well-defined part of the landscape. To identify these critical source areas a P Index for cultivated fields was developed based on source factors and transport factors. The P Index is a tool to help implement better management practice to mitigate the agricultural contribution to eutrophication of river and lakes.

New, environmentally friendly P fertiliser recommendation system for Hungary: a useful tool for eliminating agricultural P losses to surface and subsurface waters

Péter Csathó[1], Tamás Árendás[2] and Tamás Németh[1]

[1] Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, (RISSAC) H-1022 Budapest, Herman O. út 15, Hungary.
[2] Agricultural Research Institute of the Hungarian Academy of Sciences, (RIA) H-2462 Martonvásár, Brunszvik u. 2. Hungary.

Following the 20-year intensive fertilisation practice in the country, two thirds of Hungarian soils became well or very well supplied with P and K. As a consequence of both political and ecological changes in the late 80's and early 90's, fertiliser subsidies were withdrawn, and N use has dropped to one fifth, one third, P and K use to one twenty fifth, one twentieth of the amounts used in the early or mid- 80's. An enormous demand has risen for a new, cost saving and environmentally friendly fertiliser recommendation system. The new system – based on the evaluation of the results of the published long-term field trial data in the period of 1960 to 2000 – faces the new challenges.

Experts of the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest, (RISSAC) and of the Research Institute for Agronomy of the Hungarian Academy of Sciences, Martonvásár, (RIA) have elaborated an environmentally friendly fertiliser recommendation system, based on the evaluation of the Hungarian long-term field trials published between 1960 and 2000 (Csathó, 1997; Csathó et al., 1998a,b; Csathó, 2002a, 2003a,b,c). The new system gives recommendations for the 32 most important field crops in Hungary (winter wheat, corn, sunflower, alfalfa, sugar beet, potatoes, spring and winter barley, rye, oats, peas, dry beans, soybeans, red clover, flax, hemp, etc.).

Under the present economic conditions — instead of the principle of "fertilisation of the soil" — our aim is the "fertilisation of the crop", supplying the plant nutrients in the given year in accordance to the specific needs of each crop. The new system attempts to estimate the N fertiliser demands more precisely. Instead of good to very good soil PK status, moderate to good soil PK supply is to be maintained.

According to their responses to N, P, and K fertilisation, crops were grouped as either strongly, or slightly N-, P-, or K-demanding, resp. Soil test limit values were elaborated separately for both the slightly, and the strongly demanding groups, similarly to the findings of Várallyay, Sr (1950).

Yield levels guaranteeing the maximum economic yields (about 95% of maximum yields) are to be reached, instead of maximum yields. The joint application of the three macronutrients, N, P, and K for each crop is not obvious any more. Instead, within the rotation, on soils with moderate PK supply, P is applied for the P-demanding cereals (wheat, barley, oats, etc.) and the residual P will supply adequate P for the less demanding row crops (corn, sunflower), resp. In the same way, within the rotation, K is applied to the K-demanding row crops (corn, sugar beet, potatoes, hemp, etc.), and the residual K will supply adequate K for the less demanding cereals (wheat, barley, oats, etc.) and sunflower, resp.

The new, cost saving and environmentally fertiliser recommendation system provides circumstances for reaching safe, high yield levels while recommending much less P fertiliser doses than the previous intensive advisory system did. According to estimations, at the moment Hungarian agriculture contributes in 21% (thousand tonnes N/year) to the total N load to surface waters, and in 15% (thousand tonnes P/year) to the total P loads of surface waters (streams, rivers, lakes etc.) (Németh, Csathó and Molnár, 1994; Ijjas et al., 1994).

Sources of the water surface eutrophication in Romania.

Dorneanu Emilia, Dana Daniela

Research Institute for Soil Science and Agrochemistry, 61 Marasti Street, CP 011464, Bucharest, Romania

In Romania the eutrophication of surface water bodies caused by the nitrates and phosphorus shows a decreasing trend as a consequence of the reduced amount of fertilizers applied in the last ten years in the Romanian agriculture. This fact determined an intensification of the consumption of nutrients from soil reserves and implicitly a nitrogen and phosphorus soil depletion. Under these conditions the agricultural contribution to water pollution is very reduced. But a high eutrophication is accuring only in the water bodies in the Danube Delta, generally due to macronutrients collected by this river from upstream.

The same decreasing trend of eutrophication has been observed in the ground waters, that suffered over time a contaminating process with nitrates (NO_3^-) from different sources, especially from domestic use and from livestock increase.

The ground water pollution caused by nitrates is regionally differentiated. There are areas with more than 45 mg/l NO_3, but also areas with less than 45 mg/l NO_3 (the maximum limit allowed for drinking water).
The main factors which increase the risk of water surface eutrophication in Romania are:

- **Soil acidification** (dystrification) by over-use of nitrates is difficult to assess because often it overlaps natural (genetic) soil acidity. However, the agricultural lands acidified by inadequate use of the nitrogen fertilizers, amounts of about 841 thousand ha.
- **Water soil erosion**
  Water soil erosion is present on 6300 thou. ha - 26.4 per cent of the total country arable area, to which 702 thou. ha - 3 per cent of the total country arable area with land deformation (gully or mass movement) has to be added. The specific soil loss from agricultural land trough water erosion ranges from 3.2 to 41.5 t/ha/year, the nation-wide average being 16.28 t/ha/year, while the allowable economic limit is 4 - 6 t/ha/year.
  The total amount of soil loss in Romania by water erosion reaches about 126 mills. t/year. The humus loss caused by the removal of the topsoil ranges from 45 to 90 percent of the total organic matter reserve. At the country level the total humus loss amount to about 0.5 mill. t/year and the total phosphorus loss to 176.4 thou. t P_2O_5/year
- **Wind soil erosion**
  The obvious wind erosion affects sandy soils on 378 thou. ha - ca. 1.6 percent of the total country area. The area eroded by wind may show a slight increase as consequence of intense deforestation made in the last ten years on sandy soils located in the dry-warm climatic zone of the country.

Characterization of river sediments in the Fonte Espiño basin (Galicia, NW Spain)

Gil-Sotres, F.*; Trasar-Cepeda C., Leirós de la Peña, M.C.***

* Dep. Edafología y Q. Agrícola, Universidad de Santiago de Compostela, E-15782 Santiago de Compostela, Spain.
** Dep. Bioquímica del Suelo, Instituto de Investigaciones Agrobiologicas de Galicia, C.S.I.C., E-15780 Santiago de Compostela, Spain.

The Fonte Espiño basin is a small basin (775 Ha) that flows directly into the Fervenza reservoir (Rio Xallas, Provincia de Coruña, Spain), one of the most widely studied reservoirs in the Buffer project (EU Contract EVK1-CT-1999-00019). The basin is drained by two rivers (Fonte Espiño and Rego de Abellas) which merge 100 metres before flowing into the reservoir. The majority of the soils in the basin are under pasture use, supporting a large amount of cattle, and thus are subjected to a high degree of fertilization with manure and other residual organic products. Given its size and morphological characteristics and soil use, this basin has been the object of detailed study in the aforementioned project, which has included the analysis of water flow, the analysis of soils and the characterization of the sediments on the river bed. This work will place special emphasis on some of the characteristics of these sediments related with the phosphorous dynamics.

Eight sediments were analyzed (particle size distribution, total P and Fe contents): four sediments from the course of the stream Fonte Espiño; 3 in that of Rego de Abellas; and one after the confluence of both rivers, immediately before entering into the reservoir. In all cases these were highly sandy sediments, in which the fraction smaller than 100 µm was only higher than 15% in areas of Gley and Anmoor soils located at the headwaters or source of the rivers. The total P varied between 100 and 15000 µg g^{-1}, and the Fe_2O_3 between 1 and 8 %, in both cases depending on the sampling point and the particle size. For both P and Fe contents, the highest values were found for the 2-1 mm and <100 µm fractions. From the sources to the mouths of both rivers there was a progressive decrease in the contents of fine elements, total P and total Fe_2O_3, as well as in the percentages of P and Fe_2O_3 in the <100 µm fraction. Conversely, from the sources to the mouths of both rivers there was an increase in the enrichment rates of P and Fe for fine particles with respect to the total. This suggests that the fine sediments reaching the reservoir are very rich in P and Fe, capable of giving rise to environmental disturbance in its waters.

Phosphorus content in soil and water of the river's catchments in Poland

Mariusz Fotyma, Janusz Igras, Czesław Pietruch

Institute of Soil Science and Plant Cultivation, Czartoryskich 8, 4-100 Puławy, Poland

Introduction

Poland covers the area of about 31 million ha, of which round 60 % is farmland and 30 % woodland. Almost the whole territory is located in Baltic Sea Basin, with a very small area of the southeastern part of the country in the Black Sea Basin. The rivers Oder and Vistula flow across the whole Polish territory and a number of small rivers discharge directly into the Baltic Sea (Fig. 1). More than half of the coastal inhabitants of the Baltic Sea Basin live in Poland, using 40 % of the arable land situated there; hence the high impact of the country on the pollution of this sea with biogenical substances including phosphorus compounds.

Methods and materials

The phosphorus discharge to waters depends on the combination of source and transport conditions. The measure of source is the content of available P in the soils, according to Egner-DL method estimated on the countrywide scale by Agrochemical Laboratories, as an essential part of fertilizer recommendation scheme. The measure of transport is the concentration of phosphate ions in the drainage waters monitored in about 760 control farms selected in Poland. The average concentration of phosphates for the years 1998 – 2000 from all sites localised in the particular catchment was considered as representing the concentration in the river's water draining this area. On the poster the data concerning both source and transport will be presented for 43 individual catchments covering the whole country's area. Due to a limited space in this abstract the generalised source and transport data for 16 regions are included only.

Results

Table 1 The source and transport data for phosphorus in regions of Poland

	Dln	Kuj	Lub	Lus	Lod	Mal	Maz	Opl	Pdk	Pod	Pom	Sls	Swi	Wrm	Wlk	Zpm	Pol
Source*	58 7	64 2	52 11	60 5	53 10	46 13	59 6	63 3	48 12	48 12	62 4	53 10	46 13	55 8	67 1	54 9	57
Transport**	0,16 11	2,97 1	0,57 6	0,17 10	1,29 4	0,14 11	1,57 3	0,21 9	0,32 7	0,07 13	0,14 11	0,14 11	0,09 12	0,24 8	0,60 5	2,18 2	

* upper value -mg P·kg^{-1} soil, lower value- ranking
**upper value - mg P·dm^{-3} water, lower value – ranking

The lowest content of available phosphorus is recorded in the soils of the regions Mal, Pdk, Pod and Swi (see Fig 1) and the highest in the regions Kuj, Opl, Pom and Wlk. These differences can be attributed to the soil pedogenesis and the level of agriculture intensification. The ranking of the regions with regard to the content of available P in the soil does not entirely coincide with the ranking concerning the average concentration of phosphate ions in the drainage water. Nevertheless the regions Pod and Swi are characterised by the lowest value both for source and transport, while Kuj region takes the first place with respect to both characteristics. Few other regions, Mal, Pod, Sls and Wrn are classified in the same group of the source and transport data. The relation between both characteristics is closer when calculated on the data from 43 catchments (see poster).

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Does raindrop impact influence both sediment and phosphorus transport?

W. Schiettecatte, G. Hofman, D. Gabriels

Department Soil Management and Soil Care, Ghent University, Coupure Links 653, 9000 Ghent, Belgium wouter.schiettecatte@ugent.be, http://soilman.ugent.be/

In areas affected by soil erosion, phosphorus (P) is mainly transported in particulate form. Consequently, reduction of sediment transport can diminish P losses to a large extent. Providing sufficient soil cover is the best way to control erosion on site. However, although soil loss can be reduced drastically by soil cover, the impact on P losses may be less pronounced due to preferential transport of clay-sized particles, especially at low erosion rates. In which way this preferential transport can be attributed to the low erosion rates or the reduction of rainfall impact on the soil surface remains unclear.

By means of rainfall simulations on small soil pans (0.2×0.55 m) different rates of rainfall kinetic energy were applied. Plastic cover was used to simulate different cover percentages (0-100 %). Runoff samples were analysed for total particulate P (TPP) in the eroded sediment and molybdate reactive P (MRP) in solution. All rainfall simulations were done on air dried aggregates (< 8 mm) of a silt loam soil (15.5 % clay, 51.3 % silt and 33.2 % sand) with a total P (TP) content of 693 mg P kg^{-1}. The soil samples were taken at erosion plots, where field rainfall simulations were carried out to verify the laboratory experiments. The field experiments were done on a bare soil and a soil covered by corn residues (70 %).

The results of the laboratory rainfall simulations indicated that enrichment of TPP occurred at unit sediment load values smaller than 0.0002 kg s^{-1} m^{-1}. Based on regression analysis using rainfall kinetic energy classes as dummy variables, it could be concluded that the direct impact of rainfall on the soil surface did not influence the TPP enrichment process. Concerning sediment transport, our results indicated that both stream power of runoff (calculated on the basis of slope and runoff discharge) and raindrop impact have an important influence on sediment transport. The MRP content in runoff was low (< 5% of TP). As for the enrichment ratio, it was also found that the MRP content in the runoff was not influenced by raindrop impact.

The data obtained by field rainfall simulations were in good agreement with the laboratory results. The enrichment ratio (ER) values of TPP were higher for small unit sediment load values (< 0.00001 kg s^{-1} m^{-1}) in case of the field experiments. Because it is more likely that deposition occurs on large field plots compared to small soil pans, the higher ER values may be attributed to the influence of deposition on the selective transport of particulate P. Concerning the MRP concentration in runoff, no direct influence of raindrop impact could be observed, but the MRP concentrations were 3 to 4 times higher than those found in the laboratory experiments. This was not attributed to leaching from the corn residues, because similar MRP concentrations were observed in runoff from the bare field plot, compared to the covered plot. A possible explanation may be a higher bioavailable P content in the field plots due to a higher initial soil moisture content and TP content (804 mg P kg^{-1}), compared to the soil used in the laboratory experiments.

Summarising, it could be concluded that raindrop impact did affect the unit sediment load, which influenced the enrichment process. The raindrop impact did neither influence directly the selective transport of TPP nor the MRP concentration in runoff. The results of the laboratory experiments were confirmed by the results of field rainfall simulation experiments.

PSYCHIC: A pragmatic catchment-based decision support system to reduce transfer of particulates and phosphorus from agricultural land to water.

R.L. Humphrey and P.J.A. Withers

ADAS Gleadthorpe Research Centre, Meden Vale, Mansfeld, Nottinghamshire NG20 9PF
Rebecca.Humphrey@adas.co.uk

Nutrient enrichment of rivers and lakes is undesirable as it can lead to the dysfunction of aquatic ecosystems. An important source of nutrient enrichment is diffuse pollution from agricultural land and phosphorus (P) is the priority concern for freshwaters in the UK. Transfer of soil particles in land runoff is also a major problem causing siltation of fish spawning gravels. Policy, regulatory and conservation bodies in the UK have identified an urgent need for a pragmatic decision support system that will allow measures to control agricultural loads of particulates and phosphorus to be implemented in a strategic way within priority river basins suffering the effects of diffuse pollution.

Using current scientific understanding and available information, together with a cost conscious strategic water quality monitoring and sampling programme, PSYCHIC is designed to locate specific source areas of particulate and P loss and to identify practical and cost-effective options to control the loss in these areas. Operating within a GIS environment, PSYCHIC will use the same technology, datasets and thinking as other on-going projects funded by DEFRA and the EA to ensure that it becomes part of a wider package of management tools that are as compatible as possible in terms of operation and outputs. PSYCHIC will be a beneficial tool in implementing the EC Water Framework Directive, the EC Habitats Directive and the Environment Agency Eutrophication Management Strategy, as well as River Basin Management Planning and minimisation of pollution at a cost-effective level to landowners.

Visit the PSYCHIC project website at www.psychic-project.org.uk

Can the Nitrate Directive really protect all fresh waters from eutrophication?

Lowie van Liere

Netherlands Environmental Assessment Agency, Post-box 1, 3720 BA Bilthoven, The Netherlands.
lowie.van.liere@rivm.nl

The nutrients phosphorus and nitrogen cause severe eutrophication effects in surface waters. In most fresh water lakes of the temperate region phosphorus is the main cause of eutrophication, since it was the principal limiting factor for algal growth in pristine conditions. One of the end stadiums of eutrophication in fresh water lakes is a bloom of cyanobacteria. When this stadium is reached, often light energy of nitrogen concentration are determined as growth limiting factor. However, this is merely a result of high phosphorus input to the system. In recovery of those fresh water ecosystems reduction of phosphorus is more efficient as a restoration tool than reduction of nitrogen. Reduction of nitrogen input, if possible at all because of its diffuse inputs, may lead to blooms of nitrogen-fixing cyanobacteria.

In ditches in the Netherlands *Lemna minor* is often an end stadium of eutrophication. When phosphorus load is high, for example because of high phosphorus concentrations in the input of those ditches we find *Azolla filiculoides* as dominant species. *Azolla* spp. grow in symbiosis with *Anabaena azollae,* a cyanobacterium which is able to fix nitrogen. Nitrogen input reduction to ditches in which *Lemna minor* dominates, may result in dominance of *Azolla* spp. and also not in a recovery of eutrophication.

Reduction of phosphorus is the obvious mean to combat eutrophication in most fresh waters. Nitrogen is important since return of waterplants depend on it, and because its input may lead to extended growth of plants on the shores and in the catchment. After mineralisation the nutrients in these plants may load the water system.

In the most marine environments nitrogen is the main factor limiting algal growth, but with phosphorus as a good second nutrient to control the spring bloom of *Phaeocystis pouchetti.*

The Nitrate Directive wants to protect waterbodies from eutrophication. However, although nitrogen is important to reduce eutrophication in marine environment, it is not to be expected to control eutrophication in most fresh water ecosystems.

Phosphorus enrichment of sediment eroded by overland flow

N. J. Miller[1], J. N. Quinton[2]

[1]National Soil Resources Institute, Cranfield University, Silsoe, Bedfordshire, MK45 4DX, UK
[2]Department of Environmental Science, Institute of Environmental and Natural Sciences, Lancaster University, Lancaster LA1 4YQ, UK

Diffuse sources of P from agricultural land continue to contribute to the eutrophication of water bodies throughout Europe. The strong P sorption ability of soil particles means that soil erosion is an important mechanism for the transport of P from agricultural land and sediment eroded by overland flow is often enriched with P and other nutrients when compared with the soil mass.

The aim of this study was to investigate the P enrichment of sediment eroded by overland flow. With this in mind, 24 arable soils from six European countries were subjected to simulated rainfall in laboratory experiments. The soils had a wide range of total P (TP) from 367 mg kg^{-1} to 1903 mg kg^{-1}. Rainfall was applied to a soil area (0.5 x 0.25 m) from 30 min at an intensity of 60 mm hr^{-1}. Overland was collected and the sediment and $TP_{>0.45}$ concentration determined. Particle size analysis of the soil and eroded sediment was determined by wet sieving and particles <125 µm were measured using the sedigraph.

The results of our study show that the majority of P in overland flow was in the form of $TP_{>0.45}$, accounting for between 65-95% of the TP. The concentrations of $TP_{>0.45}$ in overland flow from the 24 soils ranged from 0.18 to 7.09 mg l^{-1} with a mean of 1.91 mg l^{-1}. The sediment eroded from all soils was P enriched. The TP content of the eroded sediment ranged from 1552 to 2857 mg kg^{-1} with a mean of 2510 mg kg^{-1}. The Enrichment ratio (ER) ranged from 1.3 to 7.5, the mean ER was 3.4. Preliminary analysis of the data indicated that silt size particles were preferentially detached and transported by rainsplash and overland flow and this may have lead to the P enrichment of eroded sediment.

HBV-P: A Catchment Model For Phosphorus Transport

L.Andersson[1], B. Arheimer[1], M. Larsson[2], J. Olsson[1], B.C. Pers[1], J. Rosberg[1], K. Tonderski[3], B. Ulén[2]

[1]Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden
[2]Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden
[3]Department of Biology, Linköping University, Sweden

Several possible measures are available to reduce diffuse (non-point source) nutrient load to surface water and thereby reduce eutrophication. Such measures include changed arable practices and constructions of wetlands and buffer zones in the landscape, as well as managing lake ecosystems. For some measures, there is an intense debate regarding their nutrient reducing capability. Further, the combined effect of several measures in a catchment is not necessarily equal to their sum. It is therefore important to apply a holistic and integrated catchment approach when applying and evaluating different management strategies.

To facilitate such catchment analyses, the Swedish Water Management Research Programme - VASTRA - focuses on the development of modelling tools addressing nutrient transport dynamics in catchments. In Phase 1 of the multidisciplinary programme (1997-2000) focus was on the assessment of nitrogen (N) fluxes, and the catchment N transport model HBV-N was developed. The model is based on the conceptual, semi-distributed hydrological HBV model (Lindström et al., 1997), equipped with routines for N transport and turnover (Arheimer and Brandt, 2000). Within VASTRA Phase 1, HBV-N was coupled with SOIL-N (e.g., Johnsson et al., 2002), a mechanistic field-scale model for N leakage from arable land, and used for scenario analyses of various measures to reduce non-point source N loads.

In Phase 2 of VASTRA (2002-2004) focus is on phosphorus (P), and at present the catchment transport model HBV-P is under development. A number of sub-modules are being added (or modified) to take various features of catchment-scale P transport into account:

- Erosion. Upland: estimated by a GIS-based model for soil loss, surface runoff and sediment delivery. Streambank: approximated as a simple function of discharge with parameters related to catchment characteristics (slope, soil type, land use, etc.) and estimated by GIS.
- Rivers. Main processes: sedimentation/resuspension, biological net uptake, adsorption/dissolution, hyporheic retention. A pool of particulate P in sediment is used for the sedimentation/resuspension.
- Lakes. Main processes: retention/release of dissolved P, sedimentation of particulate P. Variables: area, temperature, eutrophication level, P concentration.
- Wetlands/buffer zones. Wetlands: completely mixed batch reactor. Buffer zones: reduction of surface runoff (%).

Similarly to the coupling of HBV-N and SOIL-N, HBV-P is being coupled with the field-scale model ICECREAM model for P leakage from agricultural land (Tattari et al., 2001), which has been modified to incorporate preferential flow through macropores. Fast and slow transport of dissolved and particulate P through the various pathways (matrix flow, macropore flow, field wells/tile drains) are in the HBV model transferred to water compartments representing direct runoff, shallow or deep groundwater.

Tests of the sub-modules in a pilot catchment in southern Sweden indicate that much of the P dynamics which can be seen in observed concentrations and transports are reasonably well captured. However, there are large uncertainties, and uncertainty analysis is a vital part of the remaining work within VASTRA. HBV-P will be applied for scenario analyses within VASTRA's pilot catchment. The results will be used for evaluation of which remedies that are most efficient, both with regard to acceptance, costs, and their contribution to reducing P loads in accordance to the water framework directive.

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Integrated research for phosphorus in agriculture and river catchments in England and Wales: An overview of the Defra phosphorus research programme.

Phil Haygarth

Soil Science and Environmental Quality Team, Institute of Grassland and Environmental Research, North Wyke Research Station, Okehampton, EX20 2SB,

Agricultural sources of phosphorus (P) are the main components of diffuse P transfer to waters in England and Wales. The UK government, through the Department for Environment, Food and Rural Affairs (Defra), funds a research programme that contains a number of different projects, involving a variety of contractors, including Universities and Research Institutes. It is essential to encompass a wide skill base but it is also of importance that outputs from the different Institutions are aligned in order to integrate the research, develop cost effective and user friendly mitigation options and interface with other international research. This is achieved through co-ordination of communication between the groups of scientists and policy makers and extends the programme to the wider stakeholder community.

The Defra (previously MAFF) research has been running for the last ten years and the programme of work has evolved from the knowledge accumulated of processes in arable and grassland soils in the earlier studies. As a direct result of these investments in knowledge, the research consortium has helped to define the ways in which P is mobilised from agricultural land and thus enable the means to manage water quality. Currently, there is an emphasis on integrated catchment and national scale modelling initiatives that are being created to inform farmers, catchment planners and policy makers. The challenges for the future are to meet strategic requirements for policy, whilst improving the fundamental knowledge base as an investment for the future.

Visit the Defra Phosphorus Web page at:
http://www.iger.bbsrc.ac.uk/igerweb/NWNew/DEFRA_Phosphorus/Index.html

Soil nutrient status and balances (P, K, Cl) as well as leaching estimations in selected groundwater aquifers in Lower Austria.

G. Dersch, H. Hösch and H. Spiegel

In the semiarid plains (Marchfeld, Tullner Feld) in Lower Austria huge pore groundwater aquifers are situated underneath intensively used arable land. The presented results refer to a catchment in the North-East of Austria of approx. 170 000 ha, 120 000 ha are agricultural land. According to the Austrian Water Quality Monitoring System in these areas the concentrations not only for nitrate but also for chloride and sometimes for potassium exceed the guideline limits (Cl: 60 mg l^{-1} and K:12 mg l^{-1}). Enhanced phosphate concentrations (>0.3 mg l^{-1}) only occur sporadically.

If Phosphorus (P) and Potassium (K) are given in surplus of plant needs losses towards the ground water are possible. Chloride (Cl) acts as an attendant to K-fertiliser and is contained in most of organic fertilisers. It isn´t as necessary for plant nutrition as the other nutrients and is not taken up by crops to the same degree. Furthermore these nutrients show a very different behaviour in soils concerning mobilisation/immobilisation as well as plant availability.

The poster will show if and to which extent losses of P, K and Cl are expected by leaching with usual cultivation and regarding good agricultural practice.

Table 1: Utilisation of the catchment (Marchfeld and Tullner Feld)

	Marchfeld and Tullner Feld
Area	170 063 ha
Agricultural area	120 022 ha
thereof pasture	2,2%
thereof permanent crops	5,1%
thereof arable land	92,6%

As can bee seen from table 1, arable land is predominant: the most important crops are cereals, sugar beet and maize. The P and K status of the investigated soils (n=9339) in this region according to the Austrian classification system (5 fertility classes from very low to very high supplied) is given in table 2. The period of analysis is 1998-2002. The majority of samples can be classified as adequately (medium) supplied and above.

Table 2: P- and K-status according to the Austrian classification system

	% of samples (n=9339) in fertility class				
	A (very low)	B (low)	C (medium)	D (high)	E (very high)
P	2	5	59	24	10
K	2	14	54	22	8

Table 3 shows the required P- and K fertiliser amounts for the aspired medium fertility class (C) according to the Austrian Fertilisation Guidelines.

Table 3: P- and K-demand in kg ha^{-1} agricultural area (of Marchfeld and Tullner Feld) for fertility class C

	P	K
Total demand	25,0	103
Delivery through crop residues	5,6	52
Application of manure	5,5	12
Required additional mineral fertiliser	13,9	39
Mineral P fertilisation about 1970	38,4	119
Mineral P fertilisation about 1990	20,5	66
Mineral P fertilisation 2002	approx. 13,7	approx. 35

Mineral fertilisation of 2002 is an estimation on the basis of sales statistics, whereupon quantity of sales were reduced by one third since 1990 with P and by 40-50% with K. The table shows that the total actual P demand may be covered by crop residues and manure each with about ∅ 20 %. To the K demand crop residues contribute with ∅ 50 %. Less attention was paid to chloride, it was generally assumed to be leached. Therefore mineral K fertilisers should be applied in autumn to minimise Cl-concentrations in the soil solution in spring. About 85 – 90% of K-fertilisers are sold as KCl, sulphate containing K fertilisers are rather irrelevant in Austria.
Table 4 shows a Cl-balance for the described area in consideration of the Cl-input with mineral and organic fertilisers, precipitation and Cl-offtake by crops.

Tab. 4: Chloride-balance with appropriate K-fertilisation per ha agricultural area (proportion of Cl containing K fertiliser 85%) and chloride in the leachate depending on the annual amount of leachate

	∅ Marchfeld and Tullner Feld
Cl-Input from mineral K fertiliser	30,3
Cl-Input from manure	4,4
Cl-Input from precipitation	2,0
Cl-Offtake by crops	11,8
Balance	+ 24,9
Chloride concentration with	
25 mm leachate	100 mg l^{-1}
50 mm leachate	50 mg l^{-1}
75 mm leachate	33 mg l^{-1}
100 mm leachate	25 mg l^{-1}

Table 4 reveals a chloride surplus of ∅ about 25 kg ha^{-1} agricultural area in the investigated catchment, even if the guidelines of appropriate fertilisation are complied. The (calculated) chloride concentration in the leachate depends on the formation of seepage water, which is assumed, with 5-10% of the annual precipitation in the Marchfeld and amounts between 50 and 100 mg Cl l^{-1}. In the Tullner Feld, where an annual ground water recharge of 88 mm is assumed these values range between 25 and 33 mg Cl l^{-1}. In this region additional inputs of chloride are caused by the use of road salt which amounts to 1.5 times the input from agriculture and may also lead to chloride in the ground water, exceeding the guideline limit of 60 mg l^{-1}.
As mentioned above, the mineral P and K-fertilisation is given in accordance with the demand nowadays. Thus the Austrian Water Quality Monitoring System in accordance with the Water Quality Monitoring Ordinance (Federal Legal Gazette No 338/91) in general does not show endangered areas in the catchment under investigation.
It has to be stressed that periodic soil analyses are necessary to detect P- and K-supply in excess or deficiency. Field experiments in Lower Austria have revealed that zero P- and K-fertilisation for 20 years is possible without yield reduction if soil contents range in the highest fertility class, and at least for 10 years with medium to high content of soil P and –K.

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DELEGATE LIST

NAME	ORGANISATION & COUNTRY	EMAIL ADDRESS
ALFREDSSON Hakan	Swedish Board of Agriculture, SWEDEN	hakan.alfredsson@sjv.se
BARBERIS Elisabetta	University of Torino, ITALY	elisabetta.barberis@unito.it
BETSON Mark	ADAS, UK	mark.betson@adas.co.uk
BLUM Josef	SWITZERLAND	josef.blum@lu.ch
BORLING Katarina	Swedish University of Agricultural Sciences, SWEDEN	Katarina.Borling@mv.slu.se
BUTLER Patricia	IGER, UK	patricia.butler@bbsrc.ac.uk
CELARDIN Fredi	SWITZERLAND	fredi.celardin@etat.ge.ch
CHARDON Wim	Alterra, THE NETHERLANDS	wim.chardon@wur.nl
CSATHO Peter	HUNGARY	csatho@rissac.hu
DEANS Debbie	Anglian Water, UK	ddeans@anglianwater.co.uk
DILS Rachael	EA, UK	rachel.dils@environment-agency.gov.uk
DJODJIC Faruk	Swedish University of Agricultural Sciences, SWEDEN	Faruk.Djodjic@mv.slu.se
EHLERT Phillip	Alterra, THE NETHERLANDS	phillip.ehlert@wur.nl
EKHOLM Petri	Finnish Environmental Institute, FINLAND	petri.ekholm@ymparisto.fi
FLYNN Nicola	University of Reading, UK	
FOTYAMA Mariusz	POLAND	fot@iung.pulawy.pl
FOY Bob	Department of agriculture and rural development, Northern Ireland, UK	bob.foy@dardni.gov.uk
GALLAGHER Stephen	Environment and Heritage Service, Northern Ireland, UK	stephen.gallagher@doeni.gov.uk
GIL-SOTRES Fernando	SPAIN	edgils@usc.es
GRATHWOHL Peter	University of Tubingen, Germany	grathwohl@uni-tuebingen.dr
HAWKER Keryn	Arup, UK	keryn.hawker@arup.com
HAYGARTH Phil	IGER, UK	phil.haygarth@bbsrc.ac.uk
HEATHWAITE Louise	University of Sheffield, UK	a.l.heathwaite@shef.ac.uk
HEFFRON Lorna	University of Essex, UK	lpheff@essex.ac.uk
HILLMAN Jon	ADAS, UK	jonathan.hillman@adas.co.uk
HILTON John	CEH Dorset, UK	JHI@CEH.AC.UK
HODGKINSON Robin	ADAS, UK	Robin.Hodgkinson@adas.co.uk
HOFMAN Georges	BELGIUM	georges.hofman@UGent.be
HUMPHREY Becky	ADAS, UK	Rebecca.Humphrey@adas.co.uk
IRVINE Kenneth	Trinity College, IRELAND	kirvine@tcd.ie
ISERMANN Klaus	Bureau for Sustainable Agriculture, GERMANY	isermann.bnla@t-online.de
JONCZYK Jennine	University of Newcastle, UK	Jennine.Jonczyk@ncl.ac.uk
LAPLANA Ramon	Cemagref, FRANCE	ramon.laplana@cemagref.fr
LAZZAROTTO Patrick	Institute of Terrestrial Ecology, SWITZERLAND	lazzarotto@ito.umnw.ethz.ch

LINDERHOLM Kersti	SEPA, Sweden	kersti.linderholm@naturvardsverket.se
LISTER Debbie	PhD student, UK	dlister81@hotmail.com
MACDONALD Jannette	SEPA, UK	Jannette.MacDonald@sepa.org.uk
MEISSNER Ralph	Centre for Environmental Research, GERMANY	meissner@lysi.ufz.de
MENARY Wayne	University of Ulster, UK	w.menary@ulster.ac.uk
NÉMERY Julien	FRANCE	nemery@ccr.jussieu.fr
NEYROUD Jean-Auguste	SWITZERLAND	jean-auguste.neyroud@rac.admin.ch
OLSSON Jonas	Swedish Meteorological and Hydrological Institute, SWEDEN	jonas.olsson@smhi.se
PAGE Trevor	University of Lancaster, UK	t.page@lancaster.ac.uk
PETERS Joanne	Anglian Water, UK	jpeters@anglianwater.co.uk
PINHEIRO Jorge	Acores University, PORTUGAL	jpinheiro@angra.uac.pt
QUINN Paul	University of Newcastle, UK	P.F.Quinn@ncl.ac.uk
ROBINSON Steve	University of Reading, UK	j.s.robinson@reading.ac.uk
RYDBERG Ingrid	SEPA, Sweden	ingrid.rydberg@naturvardsverket.se
SCHAERER Michael	SWITZERLAND	michael.schaerer@ipw.agrl.ethz.ch
SCHNEIDER Philipp	SWITZERLAND	Philipp.Schneider@unibas.ch
SCHOUMANS Oscar	Alterra, THE NETHERLANDS	oscar.schoumans@wur.nl
SPIEGEL Heide	Austrian Agency for Health and Food Safety, AUSTRIA	adelheid.spiegel@lwvie.ages.at
STUART Judith	DEFRA, UK	judith.stuart@defra.gsi.gov.uk
TUNNEY Hubert	Teagasc, IRELAND	htunney@johnstown.teagasc.ie
TURNER Jackie	University of Newcastle, UK	lisa.allsopp@ncl.ac.uk
TURPIN Nadine	Cemagref, FRANCE	nadine.turpin@cemagref.fr
ULÉN Barbro	SWEDEN	barbro.ulen@mv.slu.se
UUSI KÄMPPÄ Jaana	MTT, FINLAND	jaana.uusi-kamppa@mtt.fi
VAN LIERE Lowie	RIVM, THE NETHERLANDS	lowie.van.liere@rivm.nl
VOLLMER Tobias	SWITZERLAND	vollmer@ito.umnw.ethz.ch
WHELAN Mick	Unilever Colworth, UK	mick.whelan@unilever.com
WHITEHEAD Paul	University of Reading, UK	p.g.whitehead@reading.ac.uk
WITHERS Paul	ADAS, UK	Paul.Withers@adas.co.uk
WOODWARD Kevin	University of Newcastle, UK	lisa.allsopp@ncl.ac.uk