PROGRAM AND ABSTRACTS

Nutrient Management in Agricultural Watersheds – A Wetlands Solution

A Symposium conducted:
May 24th to 26th 2004

Teagasc Research Centre,
Johnstown Castle,
Co. Wexford, Ireland

Teagasc
Agriculture and Food Development Authority

University of Florida
IFAS

WELCOME LETTER

Welcome to the international symposium on "*Nutrient Management in Agricultural Watersheds: A Wetlands Solution*," organised by Teagasc Research Centre, Johnstown Castle, Wexford, Ireland and the Soil and Water Science Department, University of Florida/IFAS, Gainesville, Florida. This internationally collaborated symposium is co-sponsored by the Department of Agriculture and Food, Ireland; Department of Environment, Heritage and Local Government, Ireland; Environmental Protection Agency, Ireland; and the United States Department of Agriculture.

Internationally, wetlands both constructed and natural are increasingly being used to reduce point and non-point source nutrient and contaminant loss from agricultural practices. This symposium will cover aspects that include: water quality issues in agricultural watersheds; fundamental functions and values of wetlands within agricultural watersheds; overview of nitrogen and phosphorus cycling within wetland ecosystems; present conventional management practices to reduce nutrient loss from agriculture; some policy and regulatory issues relating to water resource management and the use of constructed wetlands to improve water quality; and finally, case studies illustrating the use of wetlands to retain contaminants and nutrients.

During the symposium a total of 23 oral presentations, 3 volunteered papers and 12 poster papers will be presented over the two and a half days. Contributors to this symposium are from several countries (Ireland, Northern Ireland, U.K., Czech Republic, Norway, Spain, and USA). Symposium participants come from a range of disciplines and sectors including state bodies, research centres, universities, consultants, county councils, non-governmental organisations, farmers and individuals. A cheese and wine reception, symposium dinner, and optional field trip will also be held during the symposium.

Special thanks are extended to our sponsors and participants (oral speakers, poster presenters, session moderators and registrants). The assistance of the University of Florida/IFAS, Office of Conferences and Institutes staff, especially Ms. Sharon Borneman and Ms. Eleanor Spillane, Teagasc Research Centre, Johnstown Castle, Wexford who handled most of the symposium arrangements and registration, are also gratefully acknowledged. The significant contribution of Ed Dunne to the organization of the symposium is also acknowledged. Finally, special thanks are extended to the symposium review panel members, who will attempt to summarize and review symposium outcomes.

The Organizing Committee

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Teagasc Research Centre
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Wetland Biogeochemistry Laboratory
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Ireland

United States Department of Agriculture

Department of Environment
Heritage and Local Government
Ireland

Environmental Protection Agency
Ireland

ORGANIZING COMMITTEE

O. T. Carton
Teagasc, Johnstown Castle, Co. Wexford, Ireland
EMAIL: ocarton@johnstown.teagasc.ie

K. R. Reddy
Soil and Water Science Department, University of Florida / IFAS, Gainesville, FL, USA
EMAIL: KRR@ifas.ufl.edu

R. Harrington
National Parks & Wildlife Service, Department of Environment and Local Government, Dublin, Ireland
EMAIL: rharrington@duchas.ie

E. Dunne
Department of Environmental Resource Management, Faculty of Agriculture, Belfield, Dublin 4, and Teagasc, Johnstown Castle, Co. Wexford, Ireland
EMAIL: EJDunne@ifas.ufl.edu *-or-* edunne@johnstown.teagasc.ie

N. Culleton
Teagasc Research Centre, Johnstown Castle, Co. Wexford, Ireland
EMAIL: nculleton@johnstown.teagasc.ie

AGENDA

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Monday, 24 May 2004

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10:30am-11:00am	Symposium Introduction and Address

GENERAL SESSION - AGRICULTURAL WATERSHEDS AND WATER QUALITY

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GENERAL SESSION - AGRICULTURAL WASTEWATERS

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12:40pm-1:00pm	Costing Soiled Water Management in Irish Agriculture – ***Noel Culleton*** and *Ed Dunne*, Teagasc Research Centre, Wexford; *Sean Regan* Teagasc, Galway; *Tom Ryan* Teagasc, Kilkenny; *Rory Harrington*, National Parks and Wildlife, DELG, Waterford; *Colm Ryder*, Office of Public Works, DEHLG, Dublin, Ireland (p. 8)
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GENERAL SESSION - FUNCTIONS AND VALUES OF WETLANDS WITHIN WATERSHEDS

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3:10pm-3:30pm	Watershed Management and Reelfoot Lake – The Role of Wetlands – ***Paula M. Gale***, University of Tennessee, Martin, TN USA (p. 12)
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Tuesday, 25 May 2004 (continued)

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POSTER DIRECTORY

NOTE: Presenting authors appear in **Bold**.
Poster number is listed to the left of the poster title.
Abstract page numbers are in parenthesis at end of listing. (p.)

Poster No.

SPEAKER ABSTRACTS

Presenting authors are **bolded.**
Listed alphabetically by presenting author.

Retention of Soil Particles and Phosphorus in Small Constructed Wetlands in Agricultural Watersheds

Bent C. Braskerud
Jordforsk (Norwegian Centre for soil and Environmental Research), Ås, Norway

Loss of soil particles and nutrients from arable land may degrade stream and lake water quality. Internationally, the use of constructed wetlands (CWs) is regarded as an effective and often the only alternative measure for reduction of diffuse pollution in streams. It is often required that the CW surface area should be large to achieve good water quality results. However, the small Norwegian farms and the hilly landscape, make it impossible to set aside large areas for wetlands. Consequently, small wetlands of approximately 0.1 % of the watershed area have been constructed, even though several models predicted little retention of particles and phosphorus (P), due to their small dimensions.

The objective of this paper is to show how small CWs can contribute to cleaner waterways. The paper presents results from four wetlands, each monitored for 5 to 10 years by water proportional composite sampling on wetland inlets and outlets. In addition, sedimentation traps and sedimentation plates were placed in the wetlands, to study distribution and characteristics of the sediment.

The results showed that the average retention in the different wetlands varied from 45-75 % for soil particles. The clay content in wetland sediment was equivalent to or higher than the topsoil in the watershed. In addition, the clay retention was several times higher than originally assumed. Moreover, retention tends to increase in relative and absolute figures with runoff. This higher than expected effect is probably a consequence of a number of factors including (i) soil aggregates, (ii) shallow water depth, and (iii) wetland vegetation cover. Clay particles enter wetlands as aggregates with higher sedimentation velocity than single particles. As runoff increases, erosion processes in the watershed deliver more and larger particles and aggregates to the wetlands. As a result, retention can increase.

The same effect was observed for particulate phosphorus (PP). The results showed that average retention in the different wetlands varied from 21-44 %. Retention increased with increased wetland size. In addition, factors related to land use influence wetland retention significantly.

Norwegian agricultural authorities sponsor 70 % of the CW building costs. Construction of wetlands seems to be quite popular; as 100 CWs were built in 2002.

Contact Information: Bent C. Braskerud, Jordforsk, Frederik A. Dahls vei 20, NO-1432 Ås, Norway.
Phone: +4764948100, Fax: +4764948110, Email: bent.braskerud@jordforsk.no

Functions and Values of Wetlands in Agricultural Watersheds in the USA

Mark W. Clark
University of Florida, Gainesville, FL, USA

Over fifty percent of the wetlands in the 48 contiguous United States were lost between the 1780's and 1980's. An estimated 80% of those loses were due to converting wetlands to agricultural land. Many of these impacts were in the pursuit of fertile land and more desirable soil moisture conditions. During this period, the value of a wetland was its soil and this was drained and made productive. Since that time, the Green Revolution has promoted inorganic fertilizers and soil amendments to enhance soil fertility and used intensive irrigation to turn even the most arid landscapes into productive fields. During the last few decades our perception of wetlands has changed, as we began to relate the loss of wetlands to the loss of habitat, increased flooding, declining fisheries and degraded environmental quality. Due to the successes of the Green Revolution, United States agriculture is now rarely challenged to meet demand, instead it is challenged to meet regulatory water quality standards, compete in global markets and struggles to make economic viability under increasing capital and production costs. In this environment, wetlands are becoming far more valuable to agriculture than just moist fertile soil. From the Southeast to the Midwest, wetlands are becoming an integral part of water and nutrient management programmes on ranches and farms. In Florida, previously drained wetlands are being restored and considered a Best Management Practice (BMP) to reduce phosphorus runoff. In the Midwest, wetlands lost for decades are being restored and evaluated for their ability to improve water quality from underground tile drains thought to be a significant contributor of nitrogen to the Mississippi River watershed. The added benefit of using wetlands to improve water quality is often wildlife habitat and landscape biodiversity. Numerous federal, state and local incentive programs exist to assist farmers and ranchers to implement wetland BMP's in certain regions.

Contact Information: Mark W. Clark, University of Florida, PO Box 110510, 106 Newell Hall, Gainesville, FL USA, 32611-0510, Phone: (352) 392-1804 ex 319, Fax: (352) 392-3399, Email: clarkmw@ifas.ufl.edu

Constructed Wetlands for Wastewater Treatment in Rural Communities

Frank Clinton and *Margaret Keegan*
Environmental Protection, Agency, Wexford, Ireland

The potential role of constructed wetlands (CWs) in treating municipal wastewater from small rural populations has been recognised in Ireland. Clusters of houses have built up around a nucleus, where secondary municipal wastewater treatment plants have not been provided. Primary treated effluents may conceivably be further treated by passing these through constructed wetlands. A guidance manual was published by the Irish EPA in 2000 setting out best practice for the treatment of sanitary wastewater from small population centres (less than 50 population equivalent). The approaches suggested include the provision of primary wastewater treatment such as septic tanks followed by CWs for further treatment prior to discharge to surface water, or to groundwater. A characterisation on the basis of flow-path is given for types of constructed wetland and these are subdivided into horizontal flow, vertical flow, free-water surface and sub-surface horizontal flow. A detailed site assessment is required in advance of wetland construction. The methodology for this site assessment is outlined in the guidance note. It is recommended that the specified procedure should be followed in order to determine the suitability of a given site for the establishment of a constructed wetland. The site assessment includes; local planning restrictions, current legislation, hydrogeological and hydrological aspects, soil and subsoil on the site, other activities in the locality and engineering challenges presented by the proposal to locate the CW. Issues related to the licensing of discharges from CWs are also addressed. Where discharges are to surface waters a licence to discharge to waters is required under section 4 of the Water Pollution Acts (1977) and (1990) and where volumes in excess of $5m^3\ d^{-1}$ are to be discharged to groundwater a license is a specified requirement under separate national regulations.

Contact Information: Frank Clinton, EPA, P.O.Box 3000, Johnstown Castle Estate, Co. Wexford, Ireland, Phone: 00 353 53 60600, Fax: 00 353 53 60699, Email: f.clinton@epa.ie

Constructed Wetlands for the Treatment of Farmyard Dirty Water: Questions from a Farmer

Robert J. B. Cochrane
Coleraine, Co. L'Derry, Northern Ireland

A farmer's priority is the generation of income to support the farm family. To achieve this objective, farmers have adopted production systems based on scientific research to produce food and fibre, cost effectively. Our success is easily measured in terms of the output achieved, increased production per labour unit and the associated use of mechanisation.

However, in terms of water quality, the determination of our success in achieving these is difficult to measure at farm scale. This is because low levels of nutrient losses from our individual fields and their impact on water cannot be easily quantified. Quite often, the only measure we have is when water quality reports are periodically published or poor farm management practices reported. Water quality statistics continue to highlight the contribution of nutrient loss from agriculture to water as a major source/cause of pollution. The intensification of agriculture has contributed to eutrophication and can be expressed by a negative statistical relationship between water quality and cattle numbers. This is very frustrating for us as in many cases we have responded to the advice provided, by changing our management accordingly. For example, reducing fertiliser inputs, the construction of slurry storage facilities and spreading slurry during the growing season.

Nutrient loss from farmyards, is something we, as farmers are acutely aware of, especially in areas of high winter rainfall, where most animals are over-wintered indoors, in open yards or in corrals. Farmyard dirty water is a major problem because of large volumes generated. There are a range of possible and sometimes expensive solutions.

In recent years the use of constructed wetlands to treat this waste has been promoted. It is an old and proven technology. The fact that it can increase biodiversity on the farm is a fundamental benefit. However, from the farmer's perspective there is confusion about their potential. On one hand they have been promoted and indeed installed on farms. On the other, Local Authorities and some researchers raise questions about them in relation to the efficacy to treat farmyard dirty water, their sizing and construction, their longevity and their planning requirements. Farmers will look to this symposium to provide clarity in relation to the use of constructed wetlands to treat farmyard runoff water. Answers to questions like, if they are used to treat this effluent, what are the site selection and constructions guidelines and what management practices are required? Farmers can then evaluate these and decide whether or not they are appropriate to their farming system.

Contact Information: Robert J. B. Cochrane, 65 Ballinteer Road, Coleraine, Co. L'Derry, N. Ireland, BT51 4LZ, Phone: Home, 028 703 52571, Mobile: 07802 232141, Email: rjbcochrane@hotmail.com

Design and Performance of the Glenstal Abbey Wastewater Management System

Ciaran J. Costello
Maxpro Consultants, Kinsale, Co. Cork, Ireland

Glenstal Abbey, Murroe, Co. Limerick is a Benedictine monastery, boarding school and guesthouse with a population varying between 200 and 400. There is 100-head dairy farm associated with the monastery. The drains from the buildings and yards are collected in a combined sewer and the farm has a large concrete open yard with an open dungstead and silage pits. Domestic effluent was initially discharging untreated to a small lake and the farm effluent was discharging to a lagoon. The peak dry weather flow (DWF) is estimated at $80m^3 d^{-1}$ and the peak flow at 1400 $m^{-3} d^{-1}$. The Murroe Public Supply is recharged from the Glenstal lands and the Geological Survey of Ireland prepared a draft report on Murroe Public Supply Groundwater Protection Zone for Limerick County Council in 1995. The Council was very concerned with the situation, as the water supply had been contaminated.

In 1987 the Abbey's Consultant Engineers proposed the installation of a wastewater treatment plant to treat the domestic wastewater but did not address the issues of the combined sewers or the final disposal of the effluent. No solution to the farm effluent problem was proposed. A preliminary examination showed that without any engineering improvements, a nearby natural wetland system was remediating the effluent. However, there had been a number of reported pollution incidents. The farm had a number of low-lying areas with poor drainage, as indicated by the growth of rushes, and a constructed wetland solution to the problems was therefore indicated. A hydrogeological survey, involving the drilling of nine boreholes and a site assessment were carried out and the flow in a nearby stream, planned to be used as the receiving water, was measured. Planning permission and a discharge licence was granted for a constructed wetland treatment system. The basis of the design calculations together with final effluent analysis and logged effluent flow as required by the discharge licence are given and discussed. The system was commissioned in November 1997 and the system performance and analysis of the monitoring borehole will be presented.

Contact Information: Ciaran J. Costello, Maxpro Consultants, 2 Harbour Heights, Kinsale, Co. Cork, Ireland, Phone: +353 21 4702085, Fax: +353 214702084, Email: maxpro@eircom.net

Costing Soiled Water Management in Irish Agriculture

N. Culleton
Teagasc, Johnstown Castle, Co. Wexford

S. Regan
Teagasc, Athenry, Co. Galway

T. Ryan
Teagasc, Kildalton, Piltown, Co. Kilkenny

E. Dunne
Teagasc, Johnstown Castle, Co. Wexford and University College Dublin, Belfield, Dublin 4, Ireland

R. Harrington
National Parks and Wildlife, Dept. of Environment, Heritage and Local Government, The Quay, Co. Waterford, Ireland

C. Ryder
Office of Public Works, Dept. of Environment, Heritage and Local Government, Dublin, Ireland

In Irish grassland based agriculture, about 90% of the animals' diet is composed of grass, silage and hay. Animal manure and slurry that is stored during wintering periods is generally returned to agricultural land. Following codes of good farming practice can reduce the potential impact of these systems on water quality. However, during over wintering periods, large volumes of dirty water can be produced in farmyard areas. It is generated by rain falling on yards areas contaminated by dung/urine and silage, washings from milking parlours and washings from collection yard areas. Conventional management of dirty water is by land spreading. Management practices can be labour intensive, costly and may cause soil structure damage resulting in reduced agronomic performance.

We have outlined and costed some conventional and alternative methods for dirty water management. These methods are: automatic pump and self travelling irrigator systems; earthen bank tank storage and vacuum tanker spreading; umbilical spreading system; and constructed wetlands. Methods were costed in terms of capital, operating and external costs. Constructed wetland systems can be a cost effective option on some farms.

Contact Information: Noel Culleton, Teagasc Research Centre, Johnstown Castle, Co. Wexford, Ireland
Phone: 011-353-53-71200, Fax: 00-353-53-42004, Email: nculleton@johnstown.teagasc.ie

Phosphorus Removal in Treatment Wetlands

Thomas A. DeBusk, *Forrest E. Dierberg* and *John Juston*
DB Environmental, Inc., Rockledge, FL, USA

Constructed wetlands (CWs) are becoming increasingly popular as a technology for removing nutrients from point and non-point source flows. Phosphorus (P) removal in wetlands has proven to be particularly challenging, because soils are the only long-term sink for this element. In order to improve P removal performance and sustainability by wetlands, a number of design approaches and management practices have been evaluated. These include encouragement of selected vegetation types through water depth control, periodic vegetation harvest and removal of accumulated sediments.

Despite the challenges in achieving long-term P removal, some wetland systems have proven to be effective, with outflow total P concentrations equalling or exceeding the capability of conventional chemical treatment technologies. For example, several Stormwater Treatment Areas, large (> 1,000 ha), which are large CWs in south Florida are being used to treat "low strength" agricultural runoff. They have produced outflow total P concentrations in the range of 15-20 µg l^{-1}. The wetlands that achieve these low outflow concentrations receive runoff with inflow total P concentrations of 60 - 120 µg l^{-1}, at mass P loadings of 1 - 2 g P m^{-2} yr^{-1}.

Constructed wetlands also have been utilized for "higher strength" agricultural effluents, such as treating dairy and food processing wastewaters. Under such circumstances, the P loadings are typically high, which also leads to higher wetland outflow P concentrations. In this presentation, we describe some of the design and management approaches for enhancing P removal performance and sustainability of constructed wetlands used to treat low and high-strength flows from agricultural operations.

Contact Information: Thomas A. DeBusk, DB Environmental, Inc., 365 Gus Hipp Blvd., Rockledge, FL, 32955, USA, Phone: 321-631-0610, Fax: 321-631-3169, Email: azureainc@aol.com

A Farm Scale Integrated Constructed Wetland in Ireland

E. J. Dunne
Teagasc Research Centre, Johnstown Castle, Co. Wexford and University College of Dublin, Ireland

N. Culleton
Teagasc Research Centre, Johnstown Castle, Co. Wexford, Ireland

G. O'Donovan
University College of Dublin, Ireland

R. Harrington
National Parks and Wildlife, Department of Environment, Heritage and Local Government, Co. Waterford, Ireland

Nutrient loss from agricultural practices to surface waters can cause point source pollution. Point source pollution (PSP) from agriculture can include inappropriately managed agricultural dirty waters such as dairy farmyard dirty water (FDW). In Ireland, FDW is commonly composed of farmyard runoff, dairy parlour washings, silage/farmyard manure effluents and general yard washings. Irish dairy farms applied 18 million tonnes of FDW to agricultural land in 1998. The objective of this study was to monitor the performance of an integrated constructed wetland (ICW) to manage FDW. The ICW was situated at the Teagasc Research Centre, Wexford and the wetland monitoring period was from April 2001 to September, 2003. It treated FDW from a 42 cow organic dairy unit that had an open concrete yard area of 2,031 m^2. The wetland system comprised three treatment cells and one final monitoring pond with a total area of 4,800 m^2. Flow proportional composite water samples and flow rates were taken biweekly. Within system water quality was sampled every fortnight. Monthly wetland inlet flow rates and rainfall were variable. There was a weak, but significant relationship between measured FDW wetland inflow rate and rainfall ($r = 0.55$; $P < 0.01$; $n = 27$). There was no significant seasonal difference in FDW inflow and wetland surface outflow rates. Thus, mean daily wetland inflow and outflow rates were 7.5 ± 0.8 and 30.9 ± 7.6 m^3 d^{-1}, respectively for the complete monitoring period. The discrepancy in flows suggests that other waters were entering the ICW during the monitoring period. Mass input loading rate to the ICW during the monitoring period were 36, 98, 4,238 and 1,105 kg yr^{-1} for soluble reactive phosphorus (SRP), NH_4^+, BOD_5 and total suspended solids (TSS), respectively. Percent mass retention by the ICW was 59, 74, 93 and 95% for SRP, NH_4^+, BOD_5 and TSS, respectively for the same period. However, after periods of heavy rainfall (October and November, 2002) the ICW also released P at a rate of 42% of incoming P loads.

Contact Information: Ed. J. Dunne, Teagasc Research Centre, Johnstown Castle, Co. Wexford and University of College of Dublin, Ireland, Phone: 00-353-53-42888, Fax: 00-353-53-42213, Email: edunne@johnstown.teagasc.ie

Agriculture and Water Quality Issues in Northern Ireland – Potential Mitigation Roles for Wetlands

R. H. Foy
Department of Agriculture and Rural Development, Northern Ireland

The agricultural industry in Northern Ireland depends on animals, both grass-based and, increasingly, from imported animal feedstuffs. The industry has major detrimental impacts on water quality from point source discharges from farms and high phosphorus (P) losses from fields that has resulted in widespread eutrophication of lakes. The most visible problem is fish kills caused by illegal discharges of animal manures and silage effluents. In fact small lowland headwater streams typically have a degraded biological fauna that is indicative of no fish life. Marked improvements in chemical water quality data in these chronically polluted streams have reflected a decline in recorded farm pollution incidents. There is no evidence of improvement in biological water quality status. This disparity between water chemistry and biology reflects a reduction in frequency of pollution events rather than their elimination. A secondary factor may be that the emphasis on controlling manures and silage discharges, with BOD_5 in excess of 20000 mg l^{-1}, may have led to a relative neglect of dirty water as a pollutant. The latter, while having only a fraction of the polluting power of organic wastes, remains highly polluting, with BOD_5 of up to 1000 mg l^{-1}, which, as a category of pollution incidents, has increased.

Costly standards for constructing farm waste facilities apply in Northern Ireland. However, on many farms these standards remain an aspiration rather than a reality that can be accommodated into farm economics. Therefore, there is an interest in the use of constructed wetlands as a low cost mitigation measure, but there are scientific and institutional barriers to their adoption in Northern Ireland. The most critical relate to appropriate specification, likely effectiveness in reducing BOD_5, ammonium, and their capacity to retain P, for which the literature evidence appears inconclusive. There is a concern that, while they may reduce BOD, they may remain as significant or enhanced sources of P, especially if they receive large organic loadings, which would be simply a case of pollution displacement.

If they are to be regarded as waste treatment facilities on farm, potentially they are subject to the same consent and monitoring requirements as any other industrial discharge. This not only presents costs to the farmer but also problems to the environmental regulator, not least what should be the standard of treatment. Given the scale of the agricultural industry in small catchments, it is difficult to see how standards more stringent than the typical 20:20 BOD_5:suspended solids standard could be justified. Finally, the location of wetlands is also subject to an environmental audit to avoid the loss of protected habitats of which, unimproved pasture is one.

Contact Information: Bob Foy, Agricultural and Environmental Science Division, Department of Agriculture and Rural Development, Newforge Lane, Belfast, BT9 5PX, Northern Ireland, Phone: +44 (0)2890255512, Fax: +44 (0)2890255004, Email: bob.foy@dardni.gov.uk

Watershed Management and Reelfoot Lake - The Role of Wetlands

Paula M. Gale
University of Tennessee, Martin, TN USA

Reelfoot Lake is considered one of the premier natural resources in West Tennessee and is Tennessee's largest natural lake. Located on the floodplain of the Mississippi River in NW Tennessee it's drainage area encompasses a total of 62,200 ha in both Kentucky and Tennessee. Thought to have formed during the New Madrid earthquake of 1811-12, the lake is shallow (average depth 1.6 m) and has a surface area of approximately 6,000 ha. It is important not only to the economy of the region, but also as a significant natural area for wildlife. The water quality of Reelfoot Lake has been of concern to resource managers for quite some time. Agricultural and residential runoff in the watershed have added excess nutrients and metals into the lake and subsequently have contributed to anthropogenic eutrophication of this aquatic system.

The natural ebb and flow of water in the lake has been inhibited by the construction of the Mississippi River levee system (1920) that isolated the lake from the river and the construction of a spillway at the lake outfall in 1931. Modifications to the spillway in 1959 have resulted in relatively stable water levels in the lake since that time. Although strides have been made in changes in land use within the watershed (purchases of property by state and national park programs and implementation of soil conservation practices) water quality in the lake has not improved. It is surmised that the wetland sediments continue to be a source of nutrient enrichment to the lake. The wetlands of Reelfoot Lake while functioning as physical filters, are also behaving as nutrient sources to the lake. This study looks at the role of these wetlands in the watershed and their implications for water quality in the lake.

Contact Information: Paula M. Gale, University of Tennessee, 256 Brehm Hall, Martin, TN 38238, USA, Phone: 731-587-7326, Fax: 731-587-7968, Email: pgale@utm.edu

Phosphorus Dynamics in Depressional Wetlands in Beef Cattle Pastures in South Florida

Donald A. Graetz and *Carla M. Sperry*
University of Florida, Gainesville, FL, USA

Patrick J. Bohlen and *Stanley M. Gathumbi*
Archbold Biological Station, Lake Placid, FL, USA

The Lake Okeechobee watershed in south Florida is characterized by extensive beef cattle ranching operations. Within these grazing lands, depressional seasonal wetlands are common and the extent to which, they are influenced by cattle grazing activities is an increasing concern. A study was conducted at the MacArthur Agro-Ecology Centre, a division of Archbold Biological Station in south central Florida, to assess the effect of cattle stocking density on parameters such as runoff water quality, soil phosphorus (P) loading, and effects on embedded wetlands, in two land-use scenarios (improved and semi-native pastures). Within each pasture type, there were two replicates of four cattle stocking densities (0, 0.74, 0.99 and 1.73 cow-calf units in the improved pastures and 0, 0.46, 0.62, and 1.08 cow-calf units in the semi-native pastures). This presentation will address the degree of nutrient enrichment in seasonal wetlands within the two pasture types.

Vegetation was sampled in the wetlands during fall 2000, spring 2001 and summer 2001. Plant materials were separated into live and dead/litter and analyzed for total carbon (C), nitrogen (N), and P. Soils were sampled by depth (surface detritus, 0-15, 15-30, and 30-45 cm) once during the study period. Soils were analyzed for total phosphorus (TP), water extractable phosphorus (WSP), Mehlich 1 extractable P (MP) and resin-extractable P. Soils were further characterized for P forms, P adsorption parameters and degree of P saturation (DPS).

Phosphorus concentrations in wetland plants were greater in improved pasture wetlands than semi-native pasture. Nutrient ratios (N:P and C:P) determined in live and dead/litter plant materials and soils were lower in wetlands surrounded by improved pastures than those surrounded by semi-native pastures implying greater enrichment of P in the improved pasture wetlands. Concentrations of TP, WSP, MP, and resin P were highest in the detrital layer and decreased with soil depth. Organic P and labile inorganic P_i (WSP plus $NaHCO_3$-P_i) were the dominant forms of P in the detrital and soil layers. Degree of P saturation values in the detrital layers were above the commonly used threshold value of 30% while the mineral soil layers were below this threshold. Conversion of native rangelands into more intensively managed pasture systems increases plant and soil nutrient concentrations and also alters seasonal plant production patterns in the wetlands.

Contact Information: Donald A. Graetz, University of Florida, PO Box 110510, Gainesville, Florida 32611, USA, Phone: 352-392-1804, Ext. 318; Fax: 352-392-3399, E-mail: dag@ifas.ufl.edu

The Concept, Design and Performance of Integrated Constructed Wetlands

R. Harrington
National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, The Quay, Waterford, Ireland

P. Carroll
Adamstown Laboratory, Waterford County Council, Kilmeaden, Waterford, Ireland

E. Dunne
Teagasc, Johnstown Castle, Co. Wexford, Ireland

J. Keohane
Geotechnical and Environmental Services, Innovation Centre, Carlow Institute of Technology, Carlow, Ireland

C. Ryder
Engineering Services, Office of Public Works, Dublin, Ireland

Integrated Constructed Wetlands (ICWs) are a specific wetland design approach to water resource management. The approach adopts the "small watershed technique". The concept and its design arose from the need for improved sustainable environmental infrastructure in the adjacent rural communities of Annestown and Dunhill, Co. Waterford, Ireland. The ICW concept incorporates water quality management with "landscape fit" and biodiversity along with, social and economic considerations. Taken together, these additional considerations require larger wetland land areas in comparison to conventional surface flow (FWS) constructed wetlands. As a surface flow wetland system, the cleansing capacity of ICWs is largely dependent upon the ratio of water volume inflow to wetland area. Precipitation-derived wetland influent fluxes are critical in determining required wetland area for water quality improvement. The composition of wetland influent is of lower importance, however high ammonium concentrations impact wetland vegetation survival. Results for phosphorus, nitrogen and faecal coliforms will be presented for 13 individual ICWs that discharge waters to the stream of Annestown/Dunhill catchment.

Contact Information: Rory Harrington, National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, 106 The Quay, Waterford, Ireland, Phone: 00353-51-854329,
Email: rharrington@duchas.ie

Nitrogen Cycling in Wetland Systems

Patrick G. Hunt, *Matthew A. Poach* and *Sarah K. Liehr*
USDA-ARS, Florence, SC, USA

The nitrogen (N) transforming and assimilating processes of wetland systems have attracted great interest over the last several decades, as the importance of wetlands in the landscape has been more clearly understood. The N processes have been particularly appreciated as functional components of treatment wetlands. In the early development of our understanding of wetlands N cycling, there was considerable excitement, as the roles of closely associated aerobic and anaerobic zones were delineated; and the simultaneous occurrences of nitrification and denitrification were explained. These concepts allowed for better management of N for crop production in agricultural systems such as rice, and they allowed for a better appreciation of the function of riparian wetlands as stream buffers against nonpoint source N pollution from agricultural lands. Furthermore, the advanced understanding of wetland N processes was used to enhance wetland wastewater treatment systems such as overland flow, surface flow, and subsurface flow systems. When these wetlands were impacted or loaded at relatively low rates, there was significant distribution of the N in the soil/organic matrix, plant uptake, and microbial denitrification. However, as constructed wetlands were used for treatment of high strength wastewaters such as swine and dairy effluents, it has become apparent that denitrification is by far the most important process. It has become clear that our understanding of wetland nitrification and denitrification processes is not complete. In particular, there often appears to be more nitrification than can be readily explained by current concepts of oxygen inputs from water surfaces or plant root systems. Thus, new concepts and discoveries are needed to completely explain observed differences in wetland N cycling. One of the most tantalizing is the discovery of the anaerobic ammonia oxidation (anammox) bacteria which function with less precursor oxygen and without carbon energy. There is also substantial debate on the possibility of chemical denitrification as well as consideration of undiscovered N transforming microbes and extracellular enzymatic processes. Thus, we are at a very interesting time in both our understanding of wetland N processes and our appreciation of their potential in agricultural and natural systems.

Contact Information: Patrick G. Hunt, USDA-ARS, 2611 West Lucas Street, Florence, SC, 29501, USA, Phone: 843-669-5203, Fax: 843-669-6970, Email: hunt@florence.ars.usda.gov

Water and Nutrient Budgets in Isolated Wetlands

James W. Jawitz and *Daniel B. Perkins*
Soil and Water Science Department, University of Florida, USA

The ability of natural wetlands such as isolated wetlands distributed throughout watersheds to provide hydrologic buffering and contaminant assimilation capacity is well recognized. Landscape-scale restoration of wetlands that have been drained or otherwise altered is an area of emerging interest. Currently, most wetlands (constructed or natural) that are managed for contaminant removal receive waste waters discharged from point sources; the use of managed wetlands for reduction of contaminant export from nonpoint sources is a fairly recent development. Performance evaluation for treatment wetlands is predicated on contaminant removal effectiveness–usually determined by comparing imported and exported contaminant loads at well-defined surface inflows and outflows. Comparing imported and exported contaminant loads requires quantification of both wetland water and nutrient budgets, which are not simple to calculate because of the transient nature of most water and solute inflows/outflows. Performance evaluation for isolated wetlands is further confounded by the lack of a well-defined inflow, outflow, or both. This study addresses the challenges associated with measurement of both water and nutrient budgets in isolated wetlands, and the associated landscape-scale impacts of wetland restoration. An innovative approach for measurement of subsurface water and solute fluxes is highlighted, with an emphasis on current field work at isolated wetlands in the Okeechobee basin, Florida, USA.

Contact Information: James W. Jawitz, Soil and Water Science Department, University of Florida, 2169 McCarty Hall, Gainesville, FL 32611 USA, Phone: 352.392.1951 x 203, Fax: 352.392.3902, Email: jawitz@ufl.edu

Constructed Wetlands to Remove Nitrate

Robert H. Kadlec
Wetland Management Services, Chelsea, MI, USA

Applied agricultural fertilizer nitrogen (N) often contributes to elevated nitrate levels in leachates that reach receiving waters. Nitrogen compounds are among the principal pollutants of concern in fresh and marine waters because of their role in eutrophication, their effect on the oxygen content of receiving waters, and their potential toxicity to aquatic invertebrate and vertebrate species. Nitrate removal is an efficient process in treatment wetlands, creating the possibility of reducing pollution with modest wetland landscape features. Fully vegetated marshes with either emergent or submergent communities are the preferred option for nitrate reduction.

Treatment wetlands are an attractive option for addressing a portion of the nitrate pollution problems of agricultural watersheds. The process of operating reconfigured agricultural lands for the purpose of nitrate removal is a new application for wetland technology. A large experience base is now available that has been used to calibrate first generation models, and designs can go forward within a rather narrow uncertainty band.

Contact Information: Robert H. Kadlec, Wetland Management Services, 6995 Westbourne Drive, Chelsea, MI 48118, USA, Phone: 734-475-7256, Fax: 734-475-3516, Email: rhkadlec@chartermi.net

Integrated Constructed Wetlands – Site Suitability Assessment

Jerome Keohane
Geotechnical & Environmental Services Ltd, Carlow, Ireland

Paul Carroll
Waterford County Council, Adamstown, Co Waterford, Ireland

Rory Harrington
National Parks & Wildlife, DEHLG, Waterford, Ireland

Colm Ryder
Heritage Engineering & Safety, OPW, Dublin, Ireland

Constructed wetlands and Integrated Constructed Wetlands (ICWs) in particular are a relatively new phenomenon in Ireland. An approach for the assessment of the suitability of the site for the construction of an ICW is described. This will form part of a nationally agreed protocol on the design and construction of ICW's. The approach is based on a combination of desk study and site works and uses a risk based approach to address the potential impact on receptors such as groundwater and surface water, flora, fauna, landscape and material assets.

Contact Information: Jerome Keohane, Geotechnical and Environmental Services Limited, Green Road, CARLOW, Ireland, Phone: 00353-59-9130314, Fax: 00353-59-9140499,
Email: keohane@eircom.net

Water Quality in Ireland – Diffuse Agricultural Eutrophication, a Key Problem

Martin McGarrigle
Environmental Protection Agency, Ireland

The Irish Environmental Protection Agency (EPA) and its predecessor organisations have monitored Irish river water quality since the early 1970s. Over 3,200 separate locations on Irish rivers are routinely monitored, covering some 13,200 km of main-stem river channel. This enables the extent of river pollution to be quantified and the causes of pollution to be determined. Serious organic pollution has declined over time to approximately one percent of river channel surveyed at present. Eutrophication has increased, however, and almost 30 percent of river channel suffers from eutrophication. Almost half of all observed river pollution is now attributable to agricultural sources. Recent studies provide strong evidence that elevated soil phosphorus (P) levels greatly increase the risk of P loss. Reducing the diffuse losses of P is now regarded as an essential element of programmes aimed at controlling river eutrophication.

Of 304 lakes assessed in the 1998-2000 period, 44 were eutrophic. The eutrophication of Lough Sheelin in County Cavan provides an important example of the decline of a large wild brown trout population resulting from pig slurry runoff in a catchment dominated by impermeable gley soils. Many smaller lakes have become eutrophic in the relatively recent past.

Recent evidence also demonstrates that P can reach groundwater directly, in addition to ammonia and nitrate in vulnerable zones. Some 38 percent of aquifer samples taken by the EPA were contaminated by faecal coliform bacteria further indicating direct gross organic contamination occurs.

Estuarine and coastal waters are also affected by eutrophication due to P and nitrogen (N) with some 13 of 47 Irish estuaries and bays examined found to be eutrophic.

If eutrophication is to be brought under control it is crucial to balance inputs and outputs of P on farms. Nutrient management planning on all farms is essential in order to reduce the unnecessary P loss to water. Control of farmyard pollution is also critical, but there is a growing body of evidence to suggest that diffuse sources contribute even more P to water than do farmyard losses. An integrated strategy requires control of both. Irish lakes and rivers are naturally salmonid. Sustainable populations of salmon, trout and arctic char, however, require high water quality. Thus, eutrophication control is a high priority in Ireland. Ongoing reductions in agricultural P and N losses are required if the target of good or high ecological status for all Irish waters is to be achieved by 2015 as required by the EU Water Framework Directive.

Contact Information: Martin McGarrigle, Environmental Protection Agency, John Moore Road, Castlebar, Co. Mayo, Ireland, Phone: +353 94 9048430, Email: m.mcgarrigle@epa.ie

Wetlands of Ireland - An Overview

Marinus L. Otte
University College Dublin, Dublin, Ireland

Ireland is the eighth richest country in the world in terms of water, and it is therefore no surprise that it is also rich in wetlands. The wide variety of wetland habitats includes salt marshes, lagoons, swamps, wooded wetlands, bogs, fens, floodplains (callows) and a wetland type turloughs or dry lakes. Despite, or perhaps because, of the richness in wetlands, these ecosystems are still not highly valued in Ireland. Restoration and utilization of existing wetlands and (re-) creation of new wetland systems for applications such as flood control and wastewater treatment are only now being developed. In a way, Ireland is in an enviable position, because past wetland destruction and alterations in many cases are still reversible. Much can be learned from the experiences in other countries because wetland management and development in Ireland is in its infancy. The construction of wetlands for quality improvement of contaminated water, both from point and diffuse sources, is of particular interest. At present, about 75 constructed wetlands are in operation around the country, treating a wide variety of wastewaters. Most of these are no more than ten years old. Many were built on an ad-hoc basis, without proper considerations regarding design. This is partly because the initiatives by wetland enthusiasts were not supported, or even opposed, by local authorities and government organizations, and the construction could thus not be vetted and overseen via official channels. Recent developments have lead to a better understanding and appreciation of wetlands in Ireland and abroad. In order to construct and restore wetlands, we must learn from existing, natural wetlands. It does not take a wetland scientist to observe that larger and more biodiverse wetlands are more stable and effective in supplying ‘ecosystem services’, such as water quality improvement.

Contact Information: Marinus L Otte, Wetland Ecology Research Group, Department of Botany, University College Dublin, Belfield, Dublin 4, Ireland, Phone: 353-1-716-2019, Email: marinus.otte@ucd.ie

Treatment of Atrazine in Wetland Macrocosms

G. B. Reddy, *Phani C. Madida* and *Vestel Shirley*
North Carolina A & T State University, Greensboro, NC, USA

Atrazine is one of the most widely used herbicides to control annual grasses and broad leaf weeds in various crops. Because of it's vast usage, atrazine has been detected in surface waters. Therefore, atrazine in runoff water from agricultural fields needs to be treated before entering into surface waters. Constructed wetlands provide a simple and effective way to treat the agricultural runoff.

Wetland macrocosms (2.4 m by 0.75 m) were treated with 3.5 or 7.0 ppm of atrazine for 30 days. Half of the macrocosms were planted with bulrushes (*Scirpus americanus*) and other microcosms without the bulrushes. Water level in macrocosms was maintained at 15 cm above the soil surface. Water samples were taken at random on a weekly basis for atrazine analysis. At the end of 30 days, water, soil and plant samples were taken for atrazine analysis and it's metabolites. Batch equilibrium sorption and desorption experiments were conducted using the same soil that was used in the wetland macrocosms. The soil samples from macrocosms were used to count bacterial populations. Bacteria were isolated to study the biodegradation of atrazine in the laboratory.

Diffusion of atrazine from water phase to soil occurred in all macrocosms. On an average, macrocosms with bulrushes showed a 70% mass diffusion in comparison to 58% mass diffusion in macrocosms without bulrushes. Diffusion increased with the increase in concentration. The sorption–desorption isotherms were calculated. Microbial populations were determined by plate count and MPN methods.

Contact Information: G. B. Reddy, Dept. of Natural Resources and Environmental Design, North Carolina A& T State University, Greensboro, NC 27411, USA, Phone: 336-334-7543, Fax: 336-334-7844, Email:reddyg@ncat.edu

Phosphorus Cycling in Wetlands Associated with Agricultural Watersheds

K. R. Reddy
Wetland Biogeochemistry Laboratory, Soil and Water Science Department, University of Florida/IFAS, Gainesville, Florida, USA

Wetlands can function as sources or sinks for phosphorus (P), depending on the type of wetland and the loading rates. Most of the P added is retained within the system, resulting in accumulation of large reserves of P. Phosphorus retention capacity of wetlands is regulated by a series of abiotic and biotic factors including: physical, chemical and biological processes. Ultimately, a significant portion is retained in a form not readily released under normal conditions Phosphorus retention by wetland soils includes surface adsorption on minerals, precipitation, microbial immobilization, and plant uptake, and these processes may be combined into two distinct P retention pathways: sorption and burial. Phosphorus sorption in soils is defined as the removal of phosphate from soil solutions to the solid phase, and includes both adsorption and precipitation reactions. Phosphorus immobilization through microbial and plant uptake is also a significant pathway for P removal. However, when plants and microbes die off, the P contained in cellular tissue may either recycle within the wetland, or may be buried with refractory organic compounds.

Accretion of organic matter has been reported as a major mechanistic sink for P in wetlands. Wetland soils tend to accumulate organic matter due to the production of detrital material from biota and the suppressed rates of decomposition. The genesis of this new soil is a relatively slow process, which may affect P sorption characteristics of the wetland. With time, productive wetland systems will accumulate organic matter (which ultimately forms peat) that has different physical and biological characteristics than the underlying soil. Eventually, this new material settles and compacts to form new soil with perhaps different P sorption characteristics than the original soil. As the wetland ages, steady accumulation of organic matter can potentially decrease the efficiency of the wetland to assimilate additional P and alter the hydraulic flow paths, as organic accretion is spatially variable. These conditions can result in elevated effluent P concentrations. However, management of newly accreted material by consolidation or removal can improve the overall P retention capacity of the wetland. In this paper, we present an overview of key biogeochemical processes regulating P retention in wetlands associated with agricultural watersheds.

Contact Information: K. R. Reddy, University of Florida/IFAS, Soil & Water Science Dept.-Wetland Biogeochemistry Lab, 106 Newell Hall, P.O. Box 110510, Gainesville, Florida, USA, 32611-0510, Phone: 352-392-1804, FAX: 352-392-3399, Email: krr@ifas.ufl.edu

Wetland Restoration within Agricultural Watersheds: Balancing Water Quality Protection with Habitat Conservation

Steve Robinson and *Albert Niedermeier*
The University of Reading, UK

David Reid
The Somerset Wildlife Trust, Bridgewater, UK

In the UK, most wetland restoration schemes in lowland catchments are limited to small-scale blocking of drains and the damming and pumping of ditches to control water levels in individual fields. The potential for balancing wetland habitat restoration with improvement of agricultural runoff quality also remains limited, since many wetland habitats in UK agricultural catchments need protecting themselves. On the other hand, there is evidence to suggest that small, eutrophic wetlands can be loaded with substantial quantities of nitrogen (N) and phosphorus (P) without drastically impacting their structure or functioning. However, eutrophic wetland soils have the potential to act as long term nutrient sources, particularly of P, to adjoining watercourses.

The study reported here focuses on the dynamics and losses of soil P in a recently re-wetted, eutrophic fen peat developed on alluvium in south west England. The 52 ha site has a history of agricultural use and is now managed as a seasonal wetland under permanent pasture, specifically to attract wetland birds. During the 2-year study (2001 - 2002), piezometric head data and soil water tensiometry revealed that the field water table (fluctuating annually between +20 cm and –60 cm relative to ground level) was strongly influenced by the management of the adjacent ditch water levels using pumps and sluices. This prescribed water balance was facilitated by the high hydraulic conductivity of the peat (4×10^{-6} m s^{-1}) at approximately 90cm depth. During only a four day period of water table drawdown by intermittent pump drainage, as much as 300 g dissolved P (DP) entered the pumped ditch via subsurface flow from a eight ha area. Summer rainfall events > 35 mm d^{-1} also coincided with significant peaks in ditch water P concentration (up to 200 µg l^{-1} DP). Even larger peaks (up to 700 µg l^{-1} DP) occurred with the annual onset of autumn reflooding. Periodic flooding and draining of the 0-30 cm soil layer triggered the dissolution of redox-sensitive Fe bound soil P, with subsequent leaching of the dissolved species to the permanently reduced 90 cm layer. Indeed, the concentration of soil solution P consistently increased with soil depth, corresponding to a decrease in Langmuir-derived, soil P sorption maxima and P binding energies. In conclusion, the permanently flooded, peat layer at around 90 cm depth probably provided a mass flow pathway for P to the pump drained ditch, owing to the low P affinity at this depth coupled with the high, lateral hydraulic conductivity.

Contact Information: Steve Robinson, Department of Soil Science, The University of Reading, Whiteknights, PO Box 233, Reading RG6 6DW, UK, Phone: +44 118 9316075, Fax: +44 118 9316660, Email: j.s.robinson@reading.ac.uk

Wetlands for the Management of Agricultural Wastewater: A Perspective from the Department of Agriculture and Food

Christopher Robson
Department of Agriculture and Food, Dublin, Ireland

The Department of Agriculture and Food has responsibilities for a variety of direct grant-aid schemes for farmers. These include Area Aid, On-Farm Investments, and the Rural Environment Protection Scheme. It also has direct involvement in the "Nitrates Action Programme" and the programme for "Good Farming Practice," both of which will be in cross-compliance with the grant-aid schemes. These responsibilities result in a tension between welcome and caution when initiatives are suggested which impact Irish Governmental schemes and programmes. Solutions must be environmentally sustainable and economically sound.

Constructed wetlands (CWs) are to be welcomed for their ecological value, and for their potential increase in biodiversity. When they are correctly constructed and performing as designed, they are also a useful addition in treating wastewaters. Whether they provide a viable solution for the wide range of Irish farms remains to be proven.

Doubts arise, firstly, from the limited range of waste waters that they can accommodate. These include animal slurries, silage effluents, leachates from stored manures, soiled-water runoff from contaminated yards, and washings from dairies. The Specialist Unit of our Department has spent much of the last 25 years grant-aiding structures to eliminate the production of soiled water, primarily by the use of covered or external slatted easy-feeding areas. Thus, the only source of soiled water that remains is the washings from dairies, and using CWs to treat these seems a complicated solution. Properly constructed wetlands are relatively expensive to construct and monitor. The elimination of soiled water sources may make more sense.

There are also apprehensions that wetlands may be used for the entire range of farm wastes, and that intermittent checks by local authorities may not pick up the consequent damage to water-courses. Evidence is now being evaluated in a range of farms where such misuse appears to have occurred. It is clear, at least, that planning permission for wetland construction must be fully enforced, together with a design by a registered contractor, and a signed “completion certificate” of compliance.

Other remaining doubts focus on the collection and disposal of the stored nutrients in decaying plants and soiled pond liners after some 15 years. There may be simple management options, but they have not been made clear to us.

Contact Information: Christopher Robson, Department of Agriculture and Food, Kildare St., Dublin 2, Ireland, Phone 353-(0)1-4963762, Fax 353-(0)1-6767126, Email Christopher.robson@agriculture.gov.ie

Integrated Constructed Wetlands – Regulatory Policy and Practical Experience in the Irish Planning Context

Colm Ryder
Heritage Engineering & Safety, OPW, Dublin, Ireland

Paul Carroll
Waterford County Council, Adamstown, Co Waterford, Ireland

Rory Harrington
National Parks & Wildlife, DEHLG, Waterford, Ireland

Jerome Keohane
Geotechnical & Environmental Services Ltd, Carlow, Ireland

Constructed wetlands, and Integrated Constructed Wetlands (ICWs) in particular are a relatively new phenomenon on the Irish planning landscape. The authors have developed the concept of ICWs for treatment of farmyard dirty water in particular. The background to Irish regulatory requirements is outlined, defining the general requirements of planning authorities. The actual experience with different local authorities is described, with specific reference to required supporting material and planning conditions. Finally the authors describe the proposal for a nationally agreed protocol for design and construction of ICWs to treat farmyard dirty water.

Contact Information: Colm Ryder, Heritage Engineering, OPW, 17/19 Hatch St, Dublin 2, Ireland, Phone: 00353-1-6472537, Fax: 00353-1-6761714, Email: cryder@duchas.ie

Nutrient Transfer from Soil to Water - Catchment Based Approach for Phosphorus

***H. Tunney**, K. Daly* and *I. Kurz*
Teagasc, Johnstown Castle, Wexford, Ireland

G. Kiely and *G. Morgan,*
University College, Cork, Ireland

P. Jordan
University of Ulster, Coleraine, UK

R. Moles and *P. Byrne*
University of Limerick, Ireland

In Ireland about half or more of nutrients such as nitrogen (N) and phosphorus (P) loss to water is from agricultural sources and has increased significantly over the past 50 years. National and European Union policy and legislation aim at reducing P loss to water in order to address eutrophication. In Ireland, the average soil test P has increased ten fold, from less than 1 to over 8 mg Morgan P l^{-1} soil, over the past 50 years (1950-2000), reflecting increased fertiliser use.

Recently a number of research projects on the loss of N and P to water have been funded through EPA, Teagasc and other agencies. This paper deals mainly with projects, started in 2001 that will finish in 2004, on P loss from agriculture to water in three catchments, one in the north (shale soil, Oona, Co. Tyrone), centre (limestone soil, Clarianna, Co. Tipperary) and south (old red sandstone soil, Dripsey, Co Cork) of the island. The main objective of this research was to investigate P loss from soil to water in grassland catchments, the main influencing factors and appropriate amelioration options. This involved setting up field stations for the collection of hydrological and water chemistry data in the nested catchments at scales from 17 to 1524 ha, to investigate P dynamics in the river water under various seasonal, meteorological and hydrological conditions. This paper will bring together the main outcomes and recommendations from the results from the study of these three catchments. There were important differences between rainfall, soil type and farming system between the three catchments and this was reflected in the P export to water. The Dripsey and Oona catchments were broadly similar with total P exports up to 3 kg P ha^{-1} yr^{-1} in some sub-catchments. The Clarianna had an almost ten fold lower P export per unit land area despite having similar or higher soil P levels and agricultural intensity as the Dripsey and Oona. The Clarianna catchment has mainly thick calcareous Quaternary deposits with little overland flow, which potentially provides considerable buffering capacity that helps prevent entry of P from soils to surface water. It can not be assumed that this buffering action operates in all limestone catchments, and that it will be maintained indefinitely into the future.

Contact Information: Hubert Tunney, Teagasc, Johnstown Castle Research Centre, Wexford, Ireland.
Phone: +353.53.71200, Fax: +353.53.42213, Email: htunney@johnstown.teagasc.ie

Constructed Wetlands for Wastewater Treatment in Europe

Jan Vymazal
ENKI o.p.s., Trebon, Czech Republic

Constructed wetlands (CWs) are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters. They are designed to take advantage of many of the processes that occur in natural wetlands but do so within a more controlled environment. The basic CW classification is based on type of macrophytic growth; further classification is usually based on the water flow regime. The most commonly used types of constructed wetlands in Europe are those with free water surface (FWS) and with sub-surface horizontal flow (HF) or vertical flow (VF). Recently, the combinations of various types of CWs (so called hybrid systems) have been used to enhance the treatment effect, especially for nitrogen (N).

The first attempts to use wetland vegetation to remove various pollutants from water were conducted by K. Seidel in Germany in early 1950s. The first full scale FWS CW was built in The Netherlands to treat wastewaters from a camping site during the period 1967-1969. Within several years, there were about 20 FWS CWs built in the Netherlands. However, FWS CWs did not spread throughout Europe. Horizontal flow CWs became the dominant type of CW in Europe. The first full scale HF CW was built in 1974 in Othfresen in Germany. The early HF CWs in Germany and Denmark used predominantly heavy clay soils. These systems had a very high treatment effect but because of low hydraulic permeability clogging occurred and the systems began to resemble more or less FWS system. In late 1980s in United Kingdom soil was replaced with coarse materials (washed gravel) and this approach has been successfully used since then. In 1990s, increased demand of N removal from wastewaters lead to more frequent use of vertical flow CWs. These systems provide higher degree of filtration bed oxygenation and consequent removal of ammonia via nitrification. In late 1990s, the inability to produce simultaneously nitrification and denitrification in a single HF or VF CWs and thus remove total N lead to the use of hybrid systems, which combine various types of CWs. The concept of combination of various types of filtration beds was actually suggested by Seidel in 1960s, but only a few systems were built (e.g. Saint Bohaire in France or Oaklands Park in U.K.) in 1980s and early 1990s. At present, hybrid CWs are commonly used throughout Europe with VF-HF combination is the dominant type. Free water surface CWs are also used in hybrid systems.

In 1970s and 1980s, constructed wetlands in Europe were nearly exclusively built to treat domestic or municipal sewage. Since 1990s, CWs have been used for all kinds of wastewaters including landfill leachate, runoff (urban, highway, airport, and agricultural), food processing (winery, cheese, and milk), industrial (chemicals, paper mill, and oil refineries), mine drainage and sludge dewatering.

Contact Information: Jan Vymazal, ENKI o.p.s., Dukelská 145, 379 01 Trebon, Czech Republic,
Phone: +420 2 3335 0180, Email: vymazal@yahoo.com

Agricultural Runoff Treatment by a Large Constructed Wetland for the Protection of The Everglades Ecosystem, South Florida, USA

John R. White and *Marco A. Belmont*
Wetland Biogeochemistry Laboratory, University of Florida, Gainesville, FL, USA

Recent inputs of phosphorus (P) into the Florida Everglades from agricultural drainage waters have led to increased soil total P and associated ecological impacts. Stormwater Treatment Area 1-West (STA1-W) is a constructed wetland (CW) built on former agricultural land in South Florida, USA and is designed to remove nutrients from incoming agricultural runoff from the Everglades Agricultural Area. This wetland is part of a larger Federal and state program to reduce the input of nutrients to the Everglades ecosystem. Cell 5 of STA 1-W is an 800 ha constructed wetland containing primarily submerged aquatic vegetation (SAV). Although different species were present after initial construction, *Hydrilla* sp. has become the dominant (~ 80 %) submerged plant in the wetland. One hundred and twenty five stations were sampled for surface water quality including nutrients, dissolved oxygen (D.O), colour and plant biomass, twice over 4 months. Cell 5 has proven to be efficient in removing suspended solids, inorganic nitrogen, soluble reactive P and total P from the 14 inflow to the 12 outflow stations. Total suspended solids decreased from 6.0 ± 1.03 (mean ± standard error) to 1.0 ± 0.43 mg l^{-1}. Soluble reactive P concentrations were reduced from 0.08 ± 0.01 to 0.02 ± 0.005 mg l^{-1} and total P from 0.14 ± 0.007 to 0.05 ± 0.007 mg l^{-1}. Nitrogen removal was greater than 80% for ammonium from and influent mean of 0.46 ± 0.03 to 0.08 ± 0.014 mg l^{-1} while nitrate removal was ~ 33% from 0.48 ± 0.07 to 0.16 ± 0.05 mg l^{-1}. This CW is reducing nutrient concentrations in the agricultural drainage waters, thus reducing nutrient inputs to the Florida Everglades.

Contact Information: John R. White, University of Florida, Box 110510, Gainesville, FL 32611, USA, Phone: 352-392-1804, Fax: 352-392-3399. Email: jrwhite@ufl.edu, ORAL, Constructed Wetlands

POSTER ABSTRACTS

Presenting authors are **bolded.**
Listed alphabetically by presenting author.

Flow Effects on Phosphorus Loss in Overland Flow

Donnacha Doody, *Hubert Tunney* and *Isabelle Kurz*
Teagasc, Johnstown Castle, Wexford, Ireland

Richard Moles
Department of Chemical and Environmental Science, University of Limerick, Ireland

Recent studies show that concentrations of phosphorus (P) in overland flow increases with flow rate. Contrary to dilution principles, this relationship has been reported at both field and catchment scale. Investigations on grassland soils have examined the chemical and physical processes that result in P loss in overland flow but they have not explained the relationship between P concentration increases with overland flow. This study determines the relationship between flow and P concentration at three different scales so that the factors controlling this relationship at field scale could be elucidated. Continuous flow methods were used to demonstrate the impacts of flow on P desorption. The impacts of flow on desorption/dissolution varied during the experiment depending on the processes controlling the rate of desorption. Flow had a significant impact on P desorption during the early stages of the experiment when film diffusion was rate limiting. However, in latter stages of the experiment when dissolution controlled the rate of desorption, an increase in flow resulted in a decrease in P concentration due to dilution. A simulated overland flow experiment was carried out on intact soil sods to investigate the impact of flow volume, area of saturation and time between events on P concentration in overland flow. Area of saturation and time between events had a significant positive impact on P concentration, while flow volume had a significant negative impact. When an increase in area of saturation was combined with an increase in flow volume, P concentration in overland flow increased despite the impact of dilution. A 10m x 1m hydrologically isolated site was instrumented for soil moisture, flow and water quality sampling, to examine the impact of changes in soil moisture of P concentration in overland flow. Results suggest an increase in P concentration during overland flow events in summer and autumn, while there was a gradual decrease in concentration during winter months.

Contact Information: Donnacha Doody, Teagasc Johnstown Castle, Wexford, Ireland, Phone: 00-353-53-71275, Fax: 00-353-53-42213, Email: ddoody@johnstown.teagasc.ie

Phosphorous Retention and Sorption by Two Constructed Wetland Soils in Ireland

Ed J. Dunne and *Noel Culleton*
Teagasc Research Centre, Johnstown Castle, Co. Wexford, Ireland

Grace O'Donovan
University College of Dublin, Ireland

Rory Harrington
National Parks and Wildlife, Department of Environment, Heritage and Local Government, Co. Waterford, Ireland

Best management practices (BMPs) within agricultural watersheds may not be adequate to help meet phosphorus (P) surface water quality criteria in Ireland. It maybe necessary to consider additional management practices such as constructed wetlands (CWs) to improve water quality. The objectives of this study were to determine the ability of two CW soils to retain P, determine P sorption capacities of the CW soils, and investigate the influence of soil physiochemical properties on P sorption. Two site soils were chosen (a CW soil from Johnstown Castle, Co. Wexford and one from Dunhill, Co. Waterford). Soils were characterized for physiochemical properties. Soil cores were also taken for incubation studies. Within the incubation studies, cores were reflooded and spiked with 0, 1, 5, and 15 mg soluble reactive P (SRP) l^{-1} and placed outside under environmental conditions. Floodwaters remained in cores for a predetermined hydraulic residence time (HRT) of 30 days.

When soil columns were flooded with 0 mg P l^{-1}, there was an initial increase in floodwater P concentrations indicating a net release from soil to overlying water. After this initial increase, P concentrations typically decreased. As P load increased, P retention also increased ($P < 0.05$). Soils under 0 and 1 mg P l^{-1} spiked floodwaters had similar amounts of release and retention, while cores spiked at 5 and 15 mg P l^{-1} typically retained P. Phosphorus adsorption isotherms were also undertaken. Soils were incubated with 20 ml of 0.01 *M* KCl containing 0, 0.1, 0.5, 1, 5, 10, 50, and 100 mg P l^{-1} as KH_2PO_4. Phosphorus sorption parameters such as maximum P sorption capacities (S_{max}), ammonium oxalate extractable P, iron (Fe) and aluminium (Al) were greater in Dunhill than in Johnstown Castle CW soils ($P < 0.05$). Phosphorus sorption maximum values indicated that soils sorbed between 814 and 2,266 mg P kg^{-1}. Equilibrium P concentrations correlated best with oxalate extractable Fe ($P < 0.05$; r = 0.74). Equilibrium P concentration values were similarly low between and within site soils. The most significant relationship was between oxalate extractable Al and S_{max} values ($P < 0.05$; $R^2 = 0.91$). This indicates that P sorption maximums in these soils are mostly controlled by amorphous forms of Al.

Contact Information: Ed J. Dunne, Teagasc Research Centre, Johnstown Castle, Co. Wexford, Phone: 00-353-53-42888, Fax: 00-353-53-42213, Email: edunne@johnstown.teagasc.ie

Assessment of Landscape Efficiency in Matter Retention in Submontane Agricultural Catchments of the Czech Republic

Libor Pechar, Jan Procházka and *Martin Hais*
Applied Ecology Laboratory, University of South Bohemia, Ceske Budejovice, Czech Republic

***Martina Eiseltová**, Lubomír Bodlák, Jana Šulcová* and *Lenka Kröpfelová*
ENKI public benefit corporation, Trebon, Czech Republic

The evaluation of landscape functions is a crucial problem of landscape management and as such is an important aspect of ecological research. A new ecological concept of landscape efficiency (based on the Energy-Transport-Reaction Model), has been used to study and understand the processes and system functioning within selected submontane agricultural catchments in the Czech Republic. The concept of landscape efficiency measures, the interrelation of energy dissipation, water, and matter flow. The characteristic features of good landscape efficiency and sustainability are closed nutrient cycling, balanced water budget and low losses of nutrients and base cations with discharge waters.

The suitability of this approach has been tested in three small catchments (each ca. 200 ha) which differ in land use (drained agricultural land, wet meadow, and forestry). Precipitation, nutrient budget, solar energy distribution and biomass production have been monitored since 1996. The drained catchment shows a lower performance of landscape functions in terms of reduced water-retention capacity and quality of surface waters leaving the catchment.

The concept of landscape efficiency is used in a proposed restoration plan for the Stropnice river catchment. During the 1970s and 1980s, over 35 % of agricultural land in the upper part of the Stropnice catchment (112 km^2) was drained, a six km-long stretch of river straightened and deepened and its floodplain reclaimed for agricultural production. Expected ecological and economic benefits from the restored floodplain are evaluated in terms of enhanced water retention, improved stream water quality, amelioration of local climate, sequestration of carbon dioxide, and renewable energy production. A monitoring programme designed to assess the catchment's sustainability before and after restoration is presented.

Contact Information: Martina Eiseltova, U krizku 9, 140 00 Praha 4, Czech Republic, Phone: +420 61 21 79 74, Email: m.eiseltova@volny.cz

Investigating the Rhizosphere Microbiology of Constructed Wetlands

David Dowling and ***Guiomar Garcia-Cabellos***
Institute of Technology Carlow, Kilkenny Road, Carlow, Ireland

Constructed wetlands (CWs) are man-made systems, which can be used to treat polluted water. They are increasingly used in Ireland for the cost effective treatment of wastewater from agriculture and the leisure industry. One of the main mechanisms of decontamination is considered to be the high microbial activity in the nutrient and oxygen rich environment surrounding the roots of wetland plants. Nevertheless, the microbiology of wetlands is poorly understood. A study of the bacteria population of soil, rhizosphere and water from seven CWs at Kilmeaden, Co. Waterford was undertaken. The objective was to establish a profile of microbial populations from spring through to winter seasonal periods. A simple model system (microcosm) was developed to evaluate bacterial strains and plants under a range of ecological conditions. The plants species used were *Iris* sp., *Glyceria* sp., *Rannunculus* sp., *Typha latifolia* and *Myrophyllum aquaticum*. This microcosm was loaded with artificial organic waste. Parameters such as pH, PO_4^-, NO_3^-, SO_4^{2-}, suspended solids, turbidity, conductivity and BOD were measured. Microbial analysis included enumeration of the total cultivable heterotrophs, extracellular protease producers, fluorescent psuedomonads and coliforms from soil, rhizosphere and water column microcosm components. Most variation was in microcosm water columns.

Contact Information: Guiomar Garcia-Cabellos, Department of Applied Biology and Chemistry, Institute of Technology Carlow, Kilkenny Road, Carlow. Phone 059-9170400 ext 220. Fax: 059-9141349,
E-mail: guio_g @hotmail.com

The Relationship between Plant Vigour and Ammonia Concentrations in Surface Waters of Constructed Wetlands Used to Treat Meat Industry Wastewaters

Aila Harrington
Environmental Consultant, Grange, Douglas, Cork, Ireland

Constructed wetlands (CWs) are designed to treat various wastewaters through a combination of physical, chemical and biological processes. Free water surface (FWS) flow CW treatment systems are often densely planted with helophytic plant species. Helophytes are emergent wetland plants. The ability of helophyte species to assimilate nutrients and create favourable conditions for microbial decomposition of organic matter are used in CWs to improve water quality. Although plants require ammonium for growth, studies have shown that there is a threshold level of ammonia. Previous studies have indicated that ammonium concentrations in excess of 100 mg l^{-1} can be toxic to helophyte species. Ammonium can be a substantial component in water polluted with organic waste. It is transformed to nitrate under aerobic conditions (nitrification) and can then be denitrified to N_2 and N_2O under anaerobic conditions (denitrification). Helophyte plants have the ability to transfer oxygen from plant shoots to the immediate surrounding environment facilitating an oxidized micro-environment (plant rhizosphere). This oxidized environment stimulates decomposition and the growth of nitrifying bacteria. Nitrifying bacteria can convert ammonium to nitrate. A study was undertaken at a CW system at Ballon Meats Ltd., Co. Carlow to determine relationships between concentrations of ammonia in wetland surface waters and plant vigour of *Carex riparia*. The 8000 m^2 CW treatment system built in 2002 was designed to treat 150 m^3 of effluent a day. Influent ammonium concentrations are often in excess of 400 mg l^{-1}.

The CW is comprised of four wetland cells, all of which cover a similar area of about 2000 m^2. Ponds one to three were used in the study. A number of sample sites were used within each cell to measure plant vigour and concentration of ammonium. Results suggest that as ammonium concentrations decrease down through the wetland system there is an improvement in plant vigour. This is represented by an increase in plant density, plant height, diameter and the number of new shoots per plant. The concentration of ammonium in wastewaters to be treated by CWs consistently appears as an important limiting factor in wetland design.

Contact Information: Aila Harrington, Environmental Consultant, 13 Ard Field View, Grange, Douglas, Cork, Ireland, Phone: +353 (0)86 8092003, E-mail: aharrington@operamail.com

Effect of Moisture Content on 'Bioavailable' P Loss to Water in Irish Soil

P. Louisor and *K. Daly*
Teagasc, Johnstown Castle Research Centre, Wexford, Ireland

P. Dowding
Trinity College Dublin, Department of Botany, Dublin 2, Ireland

Agricultural enrichment of surface waters caused by phosphorus (P) loss to overland flow is one form of pollution in Ireland. Soil physical characteristics such as moisture content can affect P loss from soil to water. Chemical and biological soil characteristics can also affect P loss from soil to water. Previous studies highlight the impact of drying-rewetting on P loss from soil to water.

The objectives of this study were to determine the impact of soil moisture content on P mineralization under laboratory-incubated conditions and also the effect of drying and re-wetting soils on P loss from soil to water. Four experimental field sites with different soil test P (STP) levels were randomly sampled to a soil depth of 10 cm during August 2003. Samples were divided into two sets. One set was stored at room temperature and used for an incubation experiment. The second set was further sub-divided in two, one oven-dried at 40°C overnight and the other stored at room temperature. Analyses performed were total P (TP), inorganic P (P_i), percentage organic matter (% OM), water extractable P (P_w), iron oxide extractable P using (P_i test), and soil microbial biomass P (SMB-P). For the incubation experiment, three moisture contents were chosen, air-dry (4%), field capacity (75%) and medium moisture content (40%). Soil samples of air-dried soil were adjusted gravimetrically to the three moisture contents with deionised water and incubated for 42 days at 10°C to replicate field conditions. During this period, samples were removed weekly for aeration and deionised water added to compensate for water lost due to evaporation. At day 14, P_w, P_i test and SMB-P were determined. At day 42, only TP, P_i and P_w were determined.

Preliminary results suggest that the concentration of P_w increases when (i) soil is dried at 40°C and re-wetted and (ii) with increasing moisture content under incubated conditions. Furthermore, the maximum mineralization rate of water extractable P in soil solution was reached after 14 days followed by a decrease in rate with time. Further investigation is ongoing in order to confirm these initial results.

Contact Information: Patricia Louisor, Teagasc Johnstown Castle, Wexford, Ireland, Phone: +353 87 7627929, E-mail: plouisor@johnstown.teagasc.ie

Anthropic Changes in Littoral Wetlands of the Plana Baixa (Castellón, Spain): Effects on Water Quality

Esther Martí, *Silvia Falco* and *Miguel Rodilla*
Polytechnic University of Valencia, Grao de Gandia, Valencia, Spain

Inma Romero and *Marino Puricelli*
Polytechnic University of Valencia, Valencia, Spain

Along Mediterranean coasts large littoral wetlands represent transitions between aquatic and terrestrial ecosystems. These provide valuable and productive habitat and play an important role in regulating peak flows from landscapes during storm events. Substantial anthropogenic impacts such as land drainage for agriculture have transformed littoral wetlands. We have studied two littoral wetlands, the Almenara and the Nules wetland.

The hydrogeology of the Almenara wetland is very complex. The levels and flow path of the groundwater are modified by drainage. Intensive farming occupies about 90 % of its land surface area. Nules wetland is reclaimed for agricultural practices that include citrus and vegetable growing. Water regimes are maintained by drainage channels and crops are irrigated. In this area, vegetable growing lands are flooded during the winter to prevent soil salinization.

We have studied the impact of different agricultural systems (citrus, vegetable growing and rice production) on the water quality in the Almenara and Nules wetlands. Furthermore, we have analyzed the function of wetlands as protective barriers for saline intrusion. We present a water balance (inputs and outputs) of both systems. The main inputs are rain, return irrigation water, groundwater and superficial water and the outputs are evapotranspiration, pumping and sea output.

Contact Information: Esther Martí, Hydraulic Engineering and Environmental Department, Polytechnic University of Valencia, Ctra. Nazaret-Oliva, S/N, Grao de Gandia, Valencia, 46730, SPAIN,
Phone: 34-96-2849393, Fax: 34-96-2849309, Email: esmarma1@upv.doctor.es

Microbiological Studies on an Integrated Constructed Wetland Used for Treatment of Agricultural Wastewaters

Sharon McHugh and *Vincent O'Flaherty*
National University of Ireland, Galway, Ireland

Karl Richards and *Ed Dunne*
Teagasc, Johnstown Castle, Wexford, Ireland

Rory Harrington
National Parks and Wildlife, Department of Environment, Heritage and Local Government, The Quay, Co. Waterford, Ireland

Microbial diversity is critical for effective functioning of both natural and constructed wetland (CW) systems. Microbial transformations are responsible for most of the processes involved in water quality improvement. However, research into the structure and function of the microbial populations present in wetland environments is limited. Furthermore, the anaerobic conditions in the wetland are likely to result in the release of N_2O and CH_4 to the atmosphere through microbial activity, and these emissions must be quantified in order to determine the impact of widespread use of CWs on greenhouse gas emissions in Ireland. This research details the microbial community structure and dynamics in an integrated constructed wetlands (ICW), used to treat agricultural wastewaters. The ICW was constructed during the summer of 2000 on an organic dairy farm in the Teagasc Research Centre at Johnstown Castle, Co. Wexford. The wetland, which treats farmyard effluent from a 45 cow unit, is comprised of three treatment cells and one final monitoring pond. No information is available on the microbiological processes that are occurring in this wetland, which we are using as a case study to identify the diversity of microbial populations and determine the fate of nitrogen (N) and carbon (C) in the context of green house gas emissions. In this study, replicate samples were removed from sediments and water columns in each of the wetland cells. An extraction protocol for total nucleic acids extraction was optimized for each sample. Clone library analysis and 16S rRNA gene sequencing were used to obtain phylogenetic information on the populations present. In some cases supposition of function, and terminal restriction fragment length polymorphism (TRFLP) and denaturing gradient gel electrophoresis (DGGE) were used to generate nucleic acid 'fingerprints' for each sample. The study hopes to provide an increased insight into microbial populations and the microbial transformations occurring in wetland ecosystems.

Contact Information: Sharon McHugh, Microbial Ecology Laboratory, Department of Microbiology, National University of Ireland, Galway, Ireland, Phone: + 00 353 91 524411 ext. 2979, Fax: + 00 353 91 525700, Email: sharon.mchugh@nuigalway.ie

Phosphorus Balance in Louth

Padraic Mulroy
TES Consulting Engineers, Dublin, Ireland

Phosphorus (P) is now recognised as one of the primary contributors to eutrophication of Irish waterways. Both the Water Framework Directive (WFD) and Statutory Instrument No. 258 of 1998 support management of nutrients on a catchment basis. To examine the sustainability of current land spreading practices in Louth, the county was divided into 17 river catchments. Assuming that agricultural practices within each rural district are distributed evenly across that rural district, the characteristics of agriculture within every river catchment are known and can be used to determine nutrient requirements of crops within that river catchment.

The nutrient content of sludges currently land spread in Louth was obtained, either from standard analyses, as in the case of livestock slurries, or, for industrial sludges, from data provided in Integrated Pollution Control licences and planning permissions.
In the case of a pig and poultry production for which spreading listings were not available, it was assumed that slurry arising from those units was land spread within the immediate vicinity of that unit. All cattle and sheep slurry was also assumed to be spread within a relatively small radius of the farm on which it was produced. A P balancing exercise was performed for the 17 catchments comparing P spread as a result of over wintering of cattle, P excreted by ewes, P arising from intensive pig production, P spread as a result of land spreading from intensive poultry production units and spent mushroom compost (SMC), P in sludge generated by industry and P required for nutrition by primary agricultural crops. The conclusions of this nutrient balancing exercise are that total nutrients supplied by all sludges currently spread in Louth are less than the nutrient requirements of crops grown. On a countywide basis, P supplied from all organic sources is 0.55 times the crop demand. Although the P balance for the county as a whole is negative, examination indicates that surplus P is provided in just one catchment, the River Fane.

Based on data obtained from Teagasc, P supplied from artificial sources in Louth during 1995 was calculated as 0.45 million kilograms. This was approximately 0.132 million kilograms more than that necessary to achieve a P balance. Total nutrients supplied from both organic and artificial sources in Louth can therefore be calculated to be almost 1.19 times crop nutrient requirements. This indicates that the current practice in Louth may be to apply artificial fertiliser as recommended, without taking account of the nutrients provided in slurries and sludges. The nutrient balance highlights the need to draw up and implement a complete plan for management of all fertilisers in Louth, focusing on developing complementary use of both organic and artificial fertilisers.

Contact Information: Padraic Mulroy, TES Consulting Engineers, Block 4B, Unit 5, Blanchardstown Corporate Park, Dublin 15, Tel: 00353-01-8030401, Fax: 00353-01-8030410, E-mail: padraic.mulroy@tesltd.ie

Soil Hydrology as a Factor in Diffuse Phosphorus Pollution

Colin O'Reilly
Teagasc, Johnstown Castle, Wexford and University College Dublin, Rep. of Ireland

William L. Magette
University College Dublin, Rep. of Ireland

Karen Daly and *Owen T. Carton*
Teagasc, Johnstown Castle, Wexford, Rep. of Ireland

It has been shown that nutrient loss from agriculture is now a large source of diffuse phosphorus (P) pollution in Irish rivers, and thus a contributor to eutrophication. The hydrological pathways responsible for transporting P from soil to waterways are overland flow, subsurface flow and groundwater flow. The extent to which these pathways occur is primarily dependent upon precipitation, soil physical and chemical characteristics, soil moisture status and land management practices.

A field method using a rainfall simulator has been developed and subsequently constructed and calibrated to mimic the characteristics of natural rainfall in south east Ireland. This tool applies simulated rainfall to a hydrologically isolated test plot measuring 9 m by 1.5 m at four discrete rainfall intensities. It allows for the analysis of overland flow and shallow subsurface flow in terms of quality and quantity. Precipitation, using the rainfall simulator, will be applied to contrasting soil types at four different intensities over a range of soil moisture levels.

This research should illustrate the difference in hydrologic responses of contrasting soil types and resulting quantities of P transport. It will also provide important information on how influential soil type, soil moisture status and climatic factors are in regulating P transport potential.

Contact Information: Colin O'Reilly, Teagasc, Johnstown Castle, Wexford, County Wexford, Rep. of Ireland, Phone: 00353 5371210, Fax: 00353 5342213, Email: coreilly@johnstown.teagasc.ie

Effects of Runoff from Agricultural Catchments on Fishpond Water Chemistry. A Long-Term Study from Třeboň Fishponds

Libor Pechar*, Jan Bastl, Martin Hais* and *Jana Štíchová*
University of South Bohemia, České Budějovice, CZ

Lenka Kröpfelová, Jan Pokorný and *Jana Šulcová*
ENKI, public benefit corporation, Třeboň, CZ

The complex of fishponds in the Třeboň Basin (UNESCO Biosphere Reserve) represents a unique system of artificial water reservoirs and adjacent wetlands which have become over the centuries an integral part of the landscape. Fishponds, as the important component of the hydrological system of the Třeboň Basin, integrate all outputs of human activities in catchments. At the same time, fishpond management has an important feedback to the overall hydrological regime and water quality of surface waters. Long-term water chemistry data of fishponds in the Třeboň Basin, which are related to changes in fishery and agricultural practices, provide a tool for description of important causal relationships. During intensification of agriculture and fish production between the 1950s and 1980s, concentrations of ions and compounds of nitrogen (N) and phosphorus (P) increased considerably in fishpond waters. After 1989, political and socio-economic reform in Czechoslovakia initiated rapid changes in land ownership and the structure of agriculture. Also the intensity and structure of agricultural production has changed markedly, and more extensive management practices have been introduced during the last decade.

Results from the years 2000-01 show considerable decrease in conductivity and concentrations of main ions. In comparison to the 1990s, concentrations of total dissolved solids and conductivity reached 64 and 61 %, respectively. The more pronounced decrease in total dissolved solids was found in fishponds where there were more agricultural catchments. In the past ten years, concentrations of total N and P did not change and amount of chlorophyll a seems to be slightly higher. There is no significant relationship between effect of agricultural runoff and trophic level of the fishpond. The decrease in total dissolved solids during the last ten years especially in fishponds with even more agricultural catchments reflects the high sensitivity of fishpond water chemistry to changes in the management practices of the landscape.

<u>Contact Information</u>: Libor Pechar, University of South Bohemia, Faculty of Agriculture, Applied Ecology Laboratory, Ceske Budejovice, Czech Republic, Phone:+42 03855 310 567, Fax:+42 0385 310 567, Email:lpechar@zf.jcu.cz

The Use of Constructed Wetlands with Horizontal Sub-surface Flow for Treatment of Agricultural Drainage Waters

Jan Vymazal
ENKI o.p.s., Trebon, Czech Republic

Constructed wetlands with horizontal sub-surface flow (HSF CWs) provide suitable conditions for removal of nitrate via denitrification due to anaerobic conditions. At present, the majority of HSF CWs are used to treat domestic or municipal sewage, which contains relatively low concentrations of nitrate, organic-N and ammonia-N. These are the predominant forms of nitrogen (N) in this type of wastewater. Agricultural field drainage can contain high concentration of nitrate, but these waters are often low in dissolved organic matter necessary for denitrification. The combination of municipal sewage high in organics and agriculture drainage waters high in nitrate is a possible solution for treatment of both types of wastewater in one constructed wetland. This approach is relatively novel.

In the Czech Republic, there are two HSF CWs, which have been designed to treat such a mixture. A CW at Chmelná was built in 1992 to treat municipal sewage from 150 people together with stormwater runoff and agriculture drainage waters. As a result, the treatment effect in the period 1993-1995 was high for both organics (90.4% for BOD_5 with outflow concentration 2.4 mg l^{-1}) and oxidized nitrogen (71.0%, outflow oxidized N concentration of 6.3 mg l^{-1}). It is possible that the complete denitrification did not occur because of organic matter limitation. On the other hand, the removal of ammonia-N was low (40%, outflow concentration 7.5 mg l^{-1}). These results indicate that the filtration bed is predominantly anaerobic; therefore aerobic nitrification does not proceed. Despite low inflow concentrations the loading of the wetland was very high (1755 g N m^{-2} yr^{-1}) due to high hydraulic loading rate (12.6 cm d^{-1}), which is about twice the rate usually applied to sewage treatment HSF CWs. The resulting hydraulic retention time of 1.6 days was very short, compared with usual values of about four to six days. The CW at Onsov was designed in a similar way but the input of drainage waters was small compared to Chmelná wetland. Mean inflow - outflow concentrations of BOD_5 and oxidized-N were 21.3 mg l^{-1} and 4.8 mg l^{-1}, and 11.7 mg l^{-1} and 2.1 mg l^{-1}, respectively. The hydraulic loading rate was 4.5 cm d^{-1} resulting in hydraulic retention time of 2.4 days. The results from CWs Chmelná and Onsov proved that the agriculture drainage waters with high concentrations of nitrate could be successfully treated in CWs with horizontal sub-surface flow.

Contact Information: Jan Vymazal, ENKI o.p.s., Dukelská 145, 379 01 Trebon, Czech Republic,
Phone: +420 2 3335 0180, Email: vymazal@yahoo.com

AUTHOR INDEX

Bold numbers indicate presenting authors.

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