Cost Action 869 "Mitigation options for Nutrient Reduction in Surface Water and Groundwaters"

Workshop WG4

Hotel "DAS SCHLOSS an der Eisenstrasse" Waidhofen/Ybbs, Austria, 18-21 May 2008

REPORT

PRESENT

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Austria	Alexander EDER	Lithuania	Antanas Sigitas SILEIKA
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Germany	Klaus ISERMANN	Switzerland	Josef BLUM
Germany	Margarete FINCK	UK	Marc STUTTER
Germany	Horst BEHRENDT	UK	David HARRIS
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1 AGENDA

The meeting was organized by Peter Strauss (AT) and Brian Kronvang (DK). It was attended by 40 persons from 16 countries, and consisted of 4 parts:

- Presentations on the Evaluation of Projects in Example Areas across Europe (1.5 days).
- Field trip to Institute for Land and Water Management Research, Petzenkirchen (0.5 day).
- Discussion about conceptual framework of P losses to groundwater and surface water, and the database with mitigation options (0.5 day).
- Workshop on Trend analysis of long-term datasets of N and P concentrations in watersheds (0.5 day).

2 PRESENTATIONS ON THE EVALUATION OF PROJECTS

A list of authors and the titles of the 20 presentations given presentations can be found in Appendix 1 and on the website. On the website a pdf-version of most of the abstracts and of all presentations is available via this list.
Buffer zones are now widely applied in Europe, at least partly due to EU regulations prescribing these zones along water courses. The management of the zones strongly differs: in some zones cattle is allowed, which may cause loss of DRP and faecal organisms. Mowing grass often takes place in the zones, but the mowed grass is not always removed. A gradual build-up of P probably takes place in the buffer zones, the risk of future increased P loss is acknowledged and studied in a number of countries. Mining of soil (removing crops like grass) and the application of P binding compounds could reduce the risk.
In a number of large-scale studies on nitrogen loss to rivers the topic of ammonia deposition as a main source is mentioned. Since the ammonia often originates from other countries this source is difficult to reduce. Techniques for reducing ammonia emission from manure storage or application are available but not yet widely used, so improvement of water quality is possible but will probably take much time.

3 FIELD TRIP to Institute for Land and Water Management Research

During a field trip the institute of the local organizer was visited. A demonstration was given by Peter Strauss of a rainfall simulator. It was shown how reducing the kinetic energy of raindrops, by putting a net over the surface of a clay soil, strongly increased water infiltration in the soil and drastically reduced overland flow of the water. Another example of the use of this simulator can be found on the website (pdf of poster). Three posters containing different examples for application of the rainfall simulator were presented. An outline was given of the Petzenkirchen catchment where studies on the influence of the water regime on soil and nutrient losses are done. Presently continuous monitoring of flow, sediment concentration, electric conductivity and temperature is done. Additionally flow proportional sampling is used to collect information on nutrient contents of the flow. Using isotopic measurements (O^{18}/O^{16}) a realistic separation of various flow paths for water within the catchment are evaluated. Equipment for this analysis was presented during the filed trip. A poster was presented by Alexander Eder on " Evaluation of a discharge-sediment hysteresis model to calculate catchment sediment load". Demonstrations were also given of the lysimeter station and of the weather station where different forms of rainfall (e.g. rain, hail, snow) can be separated. At the lysimeter station results for various experimental periods were presented which clearly demonstrated the capacity of extensive grassland to reduce nitrate loading of groundwater as compared to intensively used arable land.

4 DISCUSSION ABOUT CONCEPTUAL FRAMEWORK AND DATABASE

A presentation was given by Oscar Schoumans (NL), chairman of WG3, about the activities of WG3 so far. At the meeting in Devon (2007) it was decided that factsheets should be written about the different mitigation options (n > 100) with information about results from different countries. Furthermore, we discussed the need / importance to set up a framework where mitigation options could fit in. There are some major advantages in summarizing this information in factsheets and put it together in a European framework:

- Reduce duplication of work.
- Data mining and sharing information and methodologies.
- Transferable information within EU.
- Get evidence about effectiveness in relation to geographical conditions and scale issues.

During the meeting in Rome (April 2008) the first drafts of 64 factsheets were discussed. This was possible due to the contribution of many participants during the period February – March 2008. All factsheets contain the same type of information:

- Description, incl. if effect is aimed on N / P / .. emission
- Rationale, mechanism of action
- Relevance, applicability & potential for targeting
- Effectiveness, including certainty
- Time frame
- Environmental side-effects
- Administrative handling and control
- Costs
- References

During the meeting of WG4 in Waidhofen a session on this ongoing WG3 action was organized. The major topic was to discuss a proposal of the conceptual framework. Since at this meeting other participants were present than in Rome, also some attention was paid to the factsheets, mainly to ask people to review factsheets. Some additional persons volunteered during the meeting.

For the discussion on the conceptual framework a first draft of a document was written with the ideas of the chair of WG3. It was sent to the participants before the meeting. From France a reaction was received already before the meeting, and it was presented during the meeting. Both approaches are complementary: the French approach is more or less based on a spatial discretisation, while the other approach is more based on chemical-physical mechanisms and hydrological connectivity. The field/plot block in the French approach is in the other approach split up into sources (mobilization) and transport (pathways) at field scale. The hydrological system block (French) seems to be the same as the connectivity block in the other approach. There was some discussion regarding the farm scale in the French approach: is it necessary to include it? However, the farm scale has two objectives: first to include point source pollution (directly from the farm to the river) and or mitigation options that can be applied on the farm (practical objective). Secondly, when the farm balance for N and P is calculated, it is not necessary to look at the field or the catchment scale, the first thing to do is to change the budget of the farm. Furthermore, the ecological system block in the French approach should also be implemented in the other approach. Finally, everybody was enthusiastic about the table that was presented that directly shows the influence of the measures on different aspects of the P loss (sources, mobilization, transport, pathways etc). However, it should be kept simple. It was concluded that a small group will contribute to the discussion on this conceptual framework. Maybe in September an updated version can be presented in Greece.

5 WORKSHOP ON TREND ANALYSIS

On Wednesday the 22nd of April 2008 a trend analysis session was held. Water flow, nitrogen and phosphorus concentration data from nine countries (The Netherlands, Denmark, Sweden, Norway, Scotland, Czech Republic, Germany, Lithuania and Austria) covering a total of 21 agricultural catchments were submitted to NERI, Denmark before the meeting, for statistical analysis of trend. The statistical trend analysis was undertaken using Kendall's seasonal trend test with correction for serial correlation. This test is a robust non-parametric site-specific statistical test for monotone trends, and is described in Appendix 2.
The outcome of the trend analysis was delivered to the delegates from each country before the workshop. Each delegate presented the results at the trend workshop for his/her catchments and discussed why the datasets showed either upward or downward trends linking to information from the catchment on development in point sources or non-point sources and catchment management.. Furthermore, the problems associated with utilising different trend test methods were discussed. The workshop agreed upon that there was a need of testing different existing trend methods on sample datasets. Working Group 4 will try to initiate such work. The main outcome of the trend analysis on water flow (daily discharge), nitrogen concentrations and phosphorus concentrations is shown in Table 1.

Table 1: Number of catchments experiencing a significant ($P<0.05$) trend or no trend.

Trend	**Discharge**	**Total N**	**Nitrate-N**	**Total P**	**SRP**
Upward	**2**	**4**	**4**	**4**	**5**
Downward	**2**	**6**	**8**	**5**	**2**
No trend	**17**	**3**	**8**	**11**	**8**

6 PLACE AND DATE OF NEXT MEETING

A proposal from Switzerland for a WG4 meeting was presented by Josef Blum. The topic of the meeting would be: Evaluation of projects in example areas: The Swiss Midland Lakes. The location of the workshop would be Seminarzentrum Nottwil at the border of the Lake Sempach close to Luzern. Two possible dates were given, of which 24 - 26 June 2009 was preferred both by the organisers and by the participants of the workshop. The program presented was accepted, but it was preferred to continue the workshop on Friday afternoon in order to increase the input from other COST countries.

Appendix 1 Authors and titles of presentations and posters

Author	Title
Marc Stutter - UK	Retention and cycling of P in field edge buffer strips
Brian Kronvang - DK	Danish experiences with buffer zones to capture sediment and phosphorus
Jana Uusi-Kämppä - FI	The effects of vegetated buffer zones on erosion and nutrients in surface runoff
Carl Hoffmann - DK	Restoration of wetlands and their nutrient removal potential: Danish experiences
Per Stålnacke - NO	Effects of mitigation measures on nutrient loads in agricultural catchments in Norway
Josef Blum - CH	10 years experience with mitigation measures on the lake of Sempach
Anitas Sileika - LT	Influence of natural and agricultural factors on nitrogen leaching in catchments of small streams
Jeroen de Klein - NL	Retention of phosphorus and nitrogen in lowland river floodplains
Peter Strauss - AT	Influence of slurry application technique on P and N loading of drainage tiles
Josef Hejzlar - CZ	Inferred effect of soil drainage on nitrate concentration in streams in the Zelivka basin, Czech Republic
Gabrielle Weigelhofer - AT	PROFOR (Austria): Integrating the effects of stream structure on nutrient loading patterns in restoration concepts for heavily modified streams
Margarete Finck - DE	Prognosis of groundwater nitrate pollution in the upper Rhine valley aquifer for land use scenarios and remedial actions
Klaus Isermann - DE	Sustainable mitigation and land use options for human health and environ-mental quality in respect to the nutrition system and the nutrients C, N, P, S
Heide Spiegel - AT	The relevance of P-soil analyses on combating P-losses
Daniela Dana - RO	Research on nutrient losses by runoff to various crops in Tarina Vale experimental polygon, Perieni
Michael Rode - DE	Impact of selected agricultural management options on the reduction of nitrogen loads in three representative meso scale catchments in Central Germany
Horst Behrendt - DE	Sources of diffuse N and P loads in the transboundary river systems of Danube and Odra and possible effects of mitigation measures to research the good ecological status
Sarah de Bolle - BE	The Manure decree as large scale measure to reduce nutrient loads in Flanders
Aurore Degré - BE	Walloon action plan for nitrogen sustainable management in agriculture: Prospective modelling of nutrient transfer in surface water and groundwater
Philippe Merot - FR	Innovative tools for the assessment and management of rural basins to recover the water quality

Posters

Alexander Eder	Evaluation of a discharge-sediment hysteresis model to calculate catchment sediment load
Peter Strauss	Temporal effects of rainfall on P-transport of an heavily eroded Hungarian soil - A field rainfall simulation study
Peter Strauss	Effect of compost application on surface runoff and erosion
Alexander Eder	Petzenkirchen - catchment
A. Scheidl	Field lysimeter Petzenkirchen
F. Feichtinger	Lowering management intensity in agriculture - Groundwater protection

Appendix 2 Method for trend analysis

Trend analysis of time series of nutrient concentrations and runoff at river stations in catchments was undertaken using Kendall’s seasonal trend test with correction for serial correlation. This test is robust non-parametric site-specific statistical tests for monotone trends. It is robust towards missing values, values reported as “< detection limit”, seasonal effects, autocorrelated measurements and non-normality (i.e. non-Gaussian data). The test was introduced in the papers Hirsch et al. (1982) and Hirsch and Slack (1984) and has become a very popular and effective method for trend analysis of water quality data. The statistical trend method can analyse both seasonal and annual data and provide a trend statistic, *P*-value and an estimate of the annual increase or decrease in nutrient concentrations.

A trend analysis starts out with a time series plot (a graph showing observed concentrations versus time of observation) and a Box-Whisker plot (a graph showing the distribution of data for each calendar month). Such plots can give hints on possible trends, seasonality and extreme values.

Both total nitrogen and total phosphorus concentrations are highly depending on runoff. This substance-specific relationship can be modelled by the non-parametric and robust curve fitting method LOWESS (Locally Weighted Scatterplot Smoothing, Cleveland, 1979). The nutrient concentrations must be adjusted for runoff in order to minimise the impact from climate and to prevent a deterioration of the trend detection thereby increasing the power of the test. To remove the effects of runoff calculate residuals, i.e.

$$r = x - \hat{x}_{(LOWESS)},$$

where $\hat{x}_{(LOWESS)}$ is the estimated concentration from LOWESS and x is the observed concentration. A time series plot of the residuals will reveal if the trend is still present in the adjusted values (residuals).

The trend method only operates with one value for each combination of season and year. Therefore an average value for the seasons with more than one observation is used. Let r_{ij} denote the average value of all adjusted measurements in year *i* and season *j*. It is assumed that there have been measurement in *n* years and *p* seasons, i.e. $i = 1,2\ldots,n$ and $j = 1,2,\ldots,p$. In normal applications the number of seasons *p* per year was set to 12 one for each month of the year. Some of the r_{ij} ’s can be missing if no measurement have been done in the relevant month and year.

The null hypothesis of the trend analysis is: for each of the *p* seasons the *n* data values are randomly ordered. The null hypothesis is tested against the alternative hypothesis: one or more of the seasons have a monotone trend. The trend test is done by calculating

$$S_g = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sgn}\left(r_{jg} - r_{ig}\right),$$

for $g = 1,2\ldots,p$, and where

$$\text{sgn}(x) = \begin{cases} 1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases}.$$

If r_{jg} and/or r_{ig} is a missing value, then $\text{sgn}(r_{jg} - r_{ig}) = 0$ per definition.

A combined test for all seasons (months) is done by first calculating

$$S = \sum_{g=1}^{p} S_g ,$$

and

$$\text{var}(S) = \sum_{g=1}^{p} \text{var}(S_g) + \sum_{g,h:g \neq h} \text{cov}(S_g, S_h).$$

The variance for S_g under the null hypothesis can be calculated exactly by

$$\text{var}(S_g) = \frac{n_g(n_g - 1)(2n_g + 5) - \sum_{j=1}^{m} t_j(t_j - 1)(2t_j + 5)}{18},$$

where n_g is the number of non-missing observations in season g. In the formula for the variance of S_g it is assumed that there are groups of observations with completely equal values, m groups in total and in the j'th group there is t_j equal values.

It is not possible under the null hypothesis to calculate the covariance between S_g and S_h exactly, but it can be estimated by (Hirsch and Slack, 1984)

$$\text{cov}(S_g, S_h) = \frac{K_{gh} + 4\sum_{i=1}^{n} R_{ig} R_{ih} - n(n_g + 1)(n_h + 1)}{3},$$

where

$$K_{gh} = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sgn}[(r_{jg} - r_{ig})(r_{jh} - r_{ih})],$$

and

$$R_{ig} = \frac{n_g + 1 + \sum_{j=1}^{n} \text{sgn}(r_{ig} - r_{jg})}{2}.$$

The term R_{ig} is the ranking of x_{ig} amongst all observations in season g, and all the missing values get the value $(n_g + 1)/2$ as ranking.

The test statistic for the aggregate test is

$$Z = \begin{cases} \dfrac{S-1}{(\mathrm{var}(S))^{\frac{1}{2}}}, & S > 0 \\ 0, & S = 0 \\ \dfrac{S+1}{(\mathrm{var}(S))^{\frac{1}{2}}}, & S < 0 \end{cases}.$$

The sign of Z indicates an increasing (+) or decreasing (-) trend. Both increasing and decreasing trends are interesting. The null hypothesis must be rejected if the numerical value of Z is greater than the $(\alpha/2)$-percentile in the Gaussian distribution with mean 0 and variance 1. Here α stands for the significance level, which typically is 5%. At the 5%-level all Z-values numerically greater than 1.96 are significant. The reason for evaluating Z in a Gaussian distribution is that under the null hypothesis, S has a Gaussian distribution with mean 0 and variance $\mathrm{var}(S)$ for $n \to \infty$. The Gaussian approximation is good if $n \geq 10$ (Hirsch and Slack, 1984). This means 10 years of data with one concentration measurement for each month.

The trend in each season can be tested by calculating

$$Z_g = \begin{cases} \dfrac{S_g - 1}{(\mathrm{var}(S_g))^{\frac{1}{2}}}, & S_g > 0 \\ 0, & S_g = 0 \\ \dfrac{S_g + 1}{(\mathrm{var}(S_g))^{\frac{1}{2}}}, & S_g < 0 \end{cases}.$$

The null hypothesis of no trend is rejected if the numerical value of Z_g is greater than the $(\alpha/2)$-percentile in the Gaussian distribution with mean 0 and variance 1.

It is possible to calculate an estimate for the trend (a slope estimate) if one assumes that the trend is constant (linear) during the period and the estimate is given as change per unit time (year). Hirsch et al. (1982) introduced Kendall's seasonal slope estimator, which can be computed in the following way. For all pair of residuals (r_{ij}, r_{kj}) with $j = 1,2\ldots, p$ and $1 \leq k < i \leq n$ calculate

$$d_{ijk} = \frac{r_{ij} - r_{kj}}{i - k}.$$

The slope estimator is then the median of all d_{ijk} -values and is robust, if the time series has serial correlation, seasonality and non-Gaussian data (Hirsch et al., 1982). A slope estimate for each season can be calculated in the same way.

A $100(1-\alpha)$ % confidence interval for the slope can be obtained by the following calculations

- Choose the wanted confidence level α (1, 5 or 10%) and use

$$Z_{1-\alpha/2} = \begin{cases} 2{,}576, & \alpha = 0{,}01 \\ 1{,}960, & \alpha = 0{,}05 \\ 1{,}645, & \alpha = 0{,}10 \end{cases}$$

  in the following calculations. For a normal application we use a confidence level of 5%.

- Calculate

$$C_\alpha = Z_{1-\alpha/2} \cdot \left(\text{var}(S)\right)^{\frac{1}{2}}.$$

- Calculate

$$M_1 = \frac{N - C_\alpha}{2},$$
$$M_2 = \frac{N + C_\alpha}{2},$$

  where

$$N = \frac{1}{2}\sum_{g=1}^{p} n_g\left(n_g - 1\right).$$

- Lower and upper confidence limits are the M_1th largest and $\left(M_2 + 1\right)$'th largest value of the N ranked slope estimates d_{ijk} .

Using the modified Van Belle and Hughes test for homogeneity (1984) one can test the homogeneity of the separate season trend test. This homogeneity test must be non-significant in order to use the combined trend test.

Time series of daily runoff values also has to be tested for trends. The same trend test as described above can be used on the measured runoff values. Slope estimates and confidence intervals are computed following the methods described above. If no significant trends are detected in the runoff time series, any significant trend in the concentration time series is said to be anthropogenic in origin.

References

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