Information about the project LIFE ENVD/D/000337

Remotely controlled monitoring of eutrophicating substances from diffuse sources in the region Saar-Lor-Lux

LAYMAN REPORT

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The project is part of the so-called EU-LIFE-Programme (the official term for the project is LIFE00 ENV/D/000337). This programme serves the EU as a financing instrument for the realisation and application of the European environmental politics and their legislation and it allows the demonstration and the development of new methods for the protection and improvement of the environment.

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Introduction

In many cases, rivers are forming the borderline between different states. Nevertheless all these rivers as well as their catchment areas are completely independent from political borders. That is why any evaluation as well as the protection of waters cannot be geared to these borders.

In order to meet the requirements of this fact the EU established the *Water Framework Directive* [WFD] in December 2000 which requests all member states to pursue a common international water policy. The national thinking is replaced by a cross-national approach by defining so-called international *River Basin Districts.*

For the first time discharges from so-called diffuse sources belong to the criteria established in the *Water Framework Directive* which are to be considered when controlling the water quality. That means that besides the punctual discharge sources (such as sewage plant drains etc.) attention is also turned to ecologically effective substances reaching the surface waters by drain from the surroundings or wash-out from the atmosphere (diffuse pollution).

The described project with the title „*Remotely controlled monitoring of eutrophicating substances from diffuse sources in the region SAAR-LOR-LUX*" tried to make allowance for these two new aspects (international approach and diffuse sources). The aim was to develop a tool for registering and interpreting diffuse impacts into surface waters by installing a mobile measuring net. To this end commercialised analysers were combined in mobile trailers which were positioned at different locations along a river.

In addition, a cross-national characterisation of the total catchment area of the river considering different aspects was achieved by the participation of institutes and authorities from Germany, Luxembourg and France.

What does “diffuse pollution of waters” mean?

Pollutants can enter a river by diverse pathways and at many different places in a catchment area. A discharge like an effluent pipe is called a point source. In contrast, diffuse pollution is mainly caused by wash-out processes from the surroundins or also by atmospheric deposition and therefore it can not be localised. So the identification of diffuse inputs poses a challenge to the supervising authorities and to the measurement technology. The diffuse pollutants entering into the water are diverse in nature, depending on rural and urban land use activities. They include for example:

- **nutrients such as nitrogen and phosphorus** coming from the application of fertilisers and manures,
- faecal and other pathogens from livestock farming or from leaks of canalisations,
- pesticides, pharmaceuticals and biocides from industrial or agricultural use,
- metals from industrial processes, former land use or disposals.

Diffuse water pollution can have significant effects on wildlife and our use of water.

These effects implicate for example:

- contamination of groundwater and surface water,
- toxication of fish spawn,
- **nutrient enrichment and eutrophication**,
- oxygen depletion,
- toxicity to plant and animal life.

Eutrophication endangers the quality of water bodies. Eutrophicating substances (like phosphorus and nitrogen compounds) stimulate an excessive growth of plants (such as algae and nuisance plant weeds) which leads to a reduction of dissolved oxygen when dead plant material decomposes. By the decrease of the dissolved oxygen level fish and other animals in the water may suffocate. As the degradation of aquatic ecosystems caused by this phenomenon are hardly to reverse the reduction of eutrophication and the monitoring of the impacts of such substances are of particular importance.

The German *Federal Environmental Agency* (*Umweltbundesamt*) has been estimating the extent of diffuse pollution by phosphorus- and nitrogen-parameters for a long time (see fig. 1). During the last decades a decline of the total pollution by nitrogen and phosphorus could be noticed. This decline was mainly caused by the reduction of emissions coming from point sources (sewage plants and industrial discharges). Meanwhile the quantity of diffuse pollution of both nitrogen and phosphorus is unmodified so that their percentage is increasing.

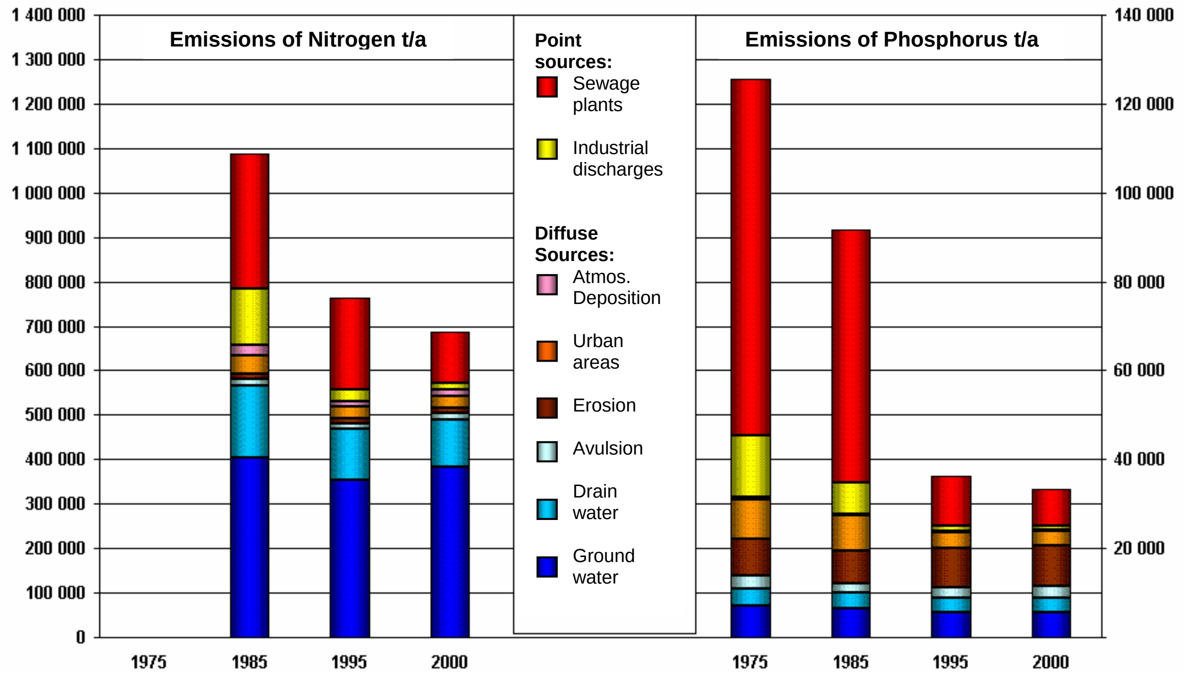

fig. 1: Point and diffuse pollution of surface waters by nutrients in Germany [UBA]

As diffuse discharges occur unpredictable and very quickly, the estimation and the monitoring of pollution coming from diffuse sources are very complicated compared with the measurement and supervision of – well known – point sources, so that they can only be detected by dint of continuous measurements. Manual sampling with a frequency of two weeks or even less could never fulfil these requirements.

The project EUTROPH MONITOR aimed at the creation and examination of a continuously working system for the remotely controlled monitoring of eutrophicating substances coming from diffuse sources. Therefore commercial sensors and online-analysers were installed in mobile measuring stations (trailers) to monitor certain parameters continuously.

Besides the eutrophicating substances like phosphorus and nitrogen containing compounds, the chlorophyll concentrations were determined as indicators for eutrophication. The continuous recording of the substances in the water and the immediate transfer of the measured data allowed the monitoring of current changes and their interpretation. The measured data were transferred to the central computer of the partners and to the supervising authorities.

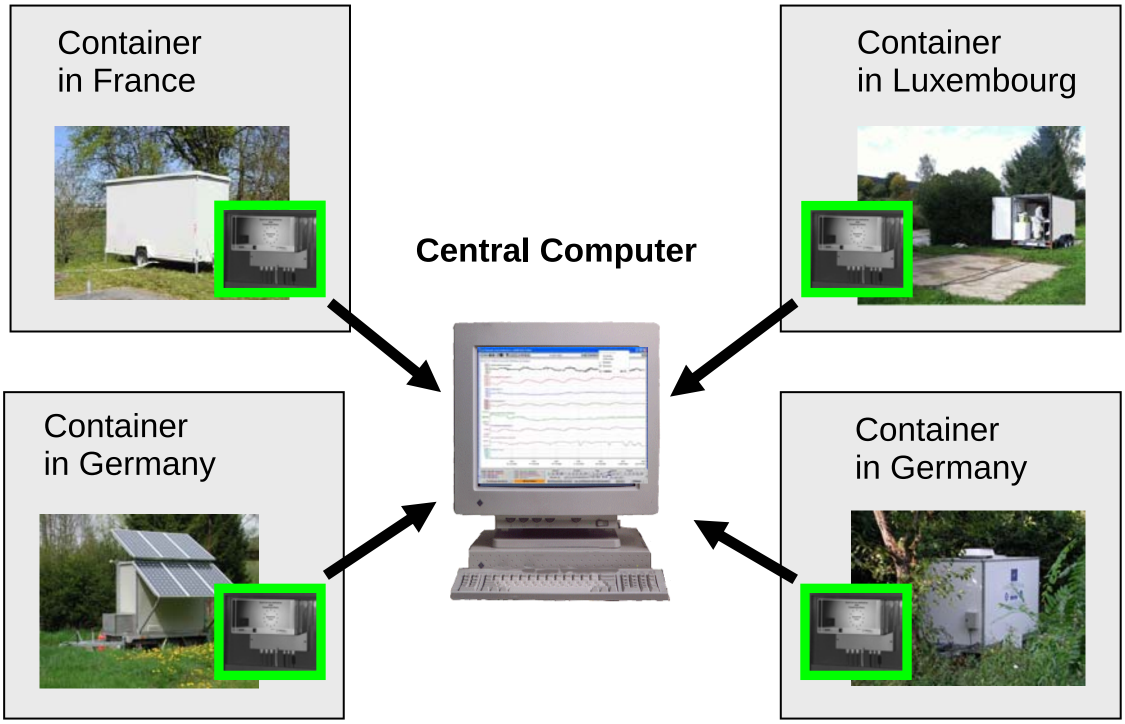

fig. 2: The monitoring network of the project EUTROPH MONITOR

Partners

Partners from the region Saar-Lor-Lux participated in this project. Figure 3 gives a detailed survey of the partners and their tasks:

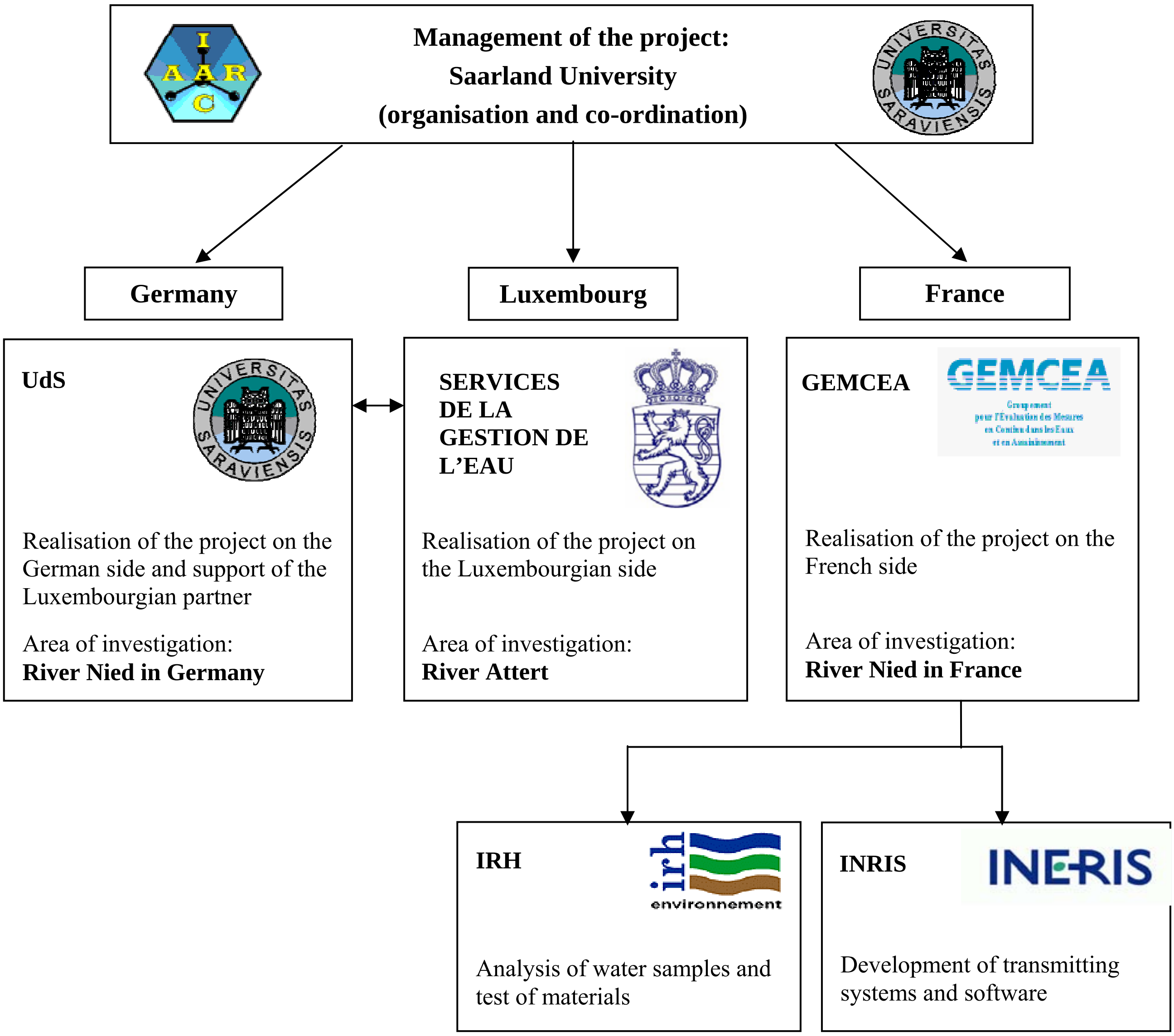

fig. 3: Project partners and their tasks

The project EUTROPH MONITOR was co-financed by:

Ministerium für Umwelt des Saarlandes,

Agence de l'Eau Rhin-Meuse

Administration de l'Environnement de Luxembourg

Catchment areas

River Nied as a cross-border river in Germany and France and River Attert (Luxembourg) was chosen as investigation area (see fig. 4).

Both rivers are very natural and well structured surface waters and they are characterised by rural catchment areas. Therefore these rivers are of considerable importance for recreation and tourism.

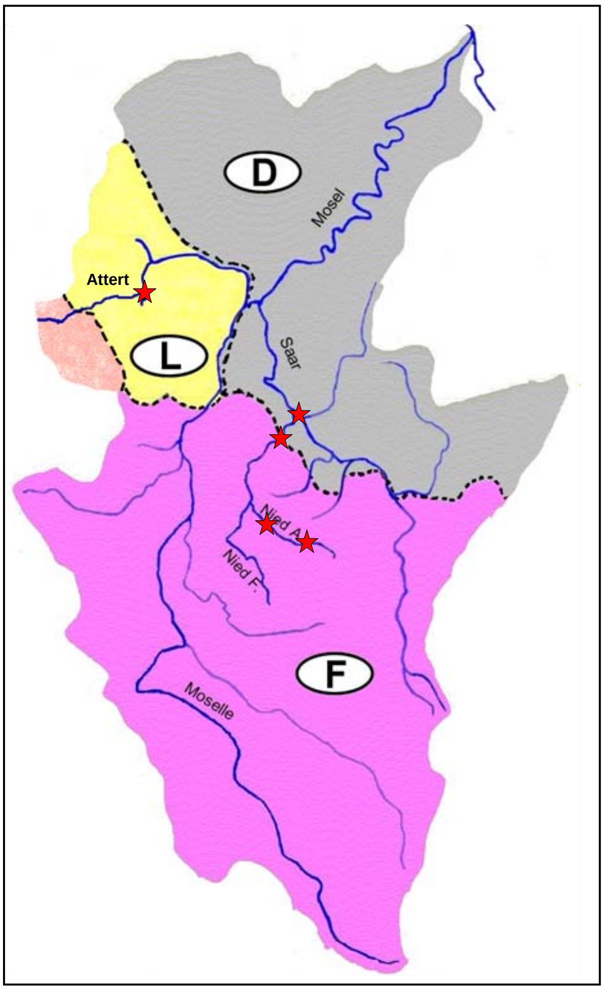

fig. 4: Investigation area and sites

Nied:

River Nied is the second largest tributary of River Saar. It emerges from the confluence of the Nied Allemande and the Nied Française near *Condé-Nothen* (France).

The sources of the Nied Allemande are near *St. Avold*, the river flows in west-southwestern direction. The Nied Française has its source in *Marthil* and flows at first in a western direction towards *Oron* but changes its direction to the north and northwest, later on to the northeast.

Near *Condé-Nothen*, the two river parts unite. After 34 more km, the Nied crosses the German border and mouths below *Rehlingen* into the Saar.

The total length of the Nied is 106 km. The catchment area comprises about 1377 km^2 (73 km^2 on the German side) and it is mainly characterised by agricultural use (meadows, pastureland and farming) and forests.

At the river Nied four measuring stations were installed (see fig. 4): two stations on the German side - *Niedaltdorf* (NAD) and *Fremersdorf* (FD) - and two stations at the French sites *Bionville* (BV) and *Crehange* (CH).

Attert:

River Attert has its source in Belgium near the Luxembourgian border and flows in western direction to Luxembourg. The catchment area of river Attert comprises about 310 km^2 and is also characterised by agriculture and forests. After 38 km, the river flows into the Alzette near *Colmarberg* which - via the Sauer (Sûre) - in the end meets river Mosel.
In Luxembourg a supplement station at the river Attert was installed as reference measuring site near *Everlange* (EL) (see fig. 4).

Conception of the mobile measuring stations

In order to ensure the spatial flexibility of the stations they were constructed as trailers with one or two axes (mobile containers). At first, so-called prototypes were built to test the function of the instruments. The experience gained with these prototypes led to numerous improvements in the construction of the following trailers.

The water was pumped into the so-called sample basin within a trailer and the superfluous water was drained back into the river by an outlet on the opposite side. The mud deposit could be drained by a valve on the bottom of the conical sample basin at any time. In all stations substances representative for nutrients were registered: ammonia (NH_4^+), nitrate (as NO_x^-), ortho- and total phosphate ($o\text{-}PO_4^{3-}$ and $\sum$-P), TOC (Total Organic Carbon) and SAC (Spectral Absorption Coefficient), which in some matrices can replace the complex measurement of TOC. Additionally, parameters giving hints on chemical reactions in the river were measured such as oxygen, conductivity, pH-value and redox-potential. As a measure for the impact of the above-mentioned eutrophicating parameters, the biological activity of the plants was determined by measuring the content of different chlorophyll-species. An automatic sampler allowed a time-controlled sampling for the frequent control of the values as well as an occurrence-controlled sampling in case of unusual events.

The following scheme shows the conception of the mobile measuring stations:

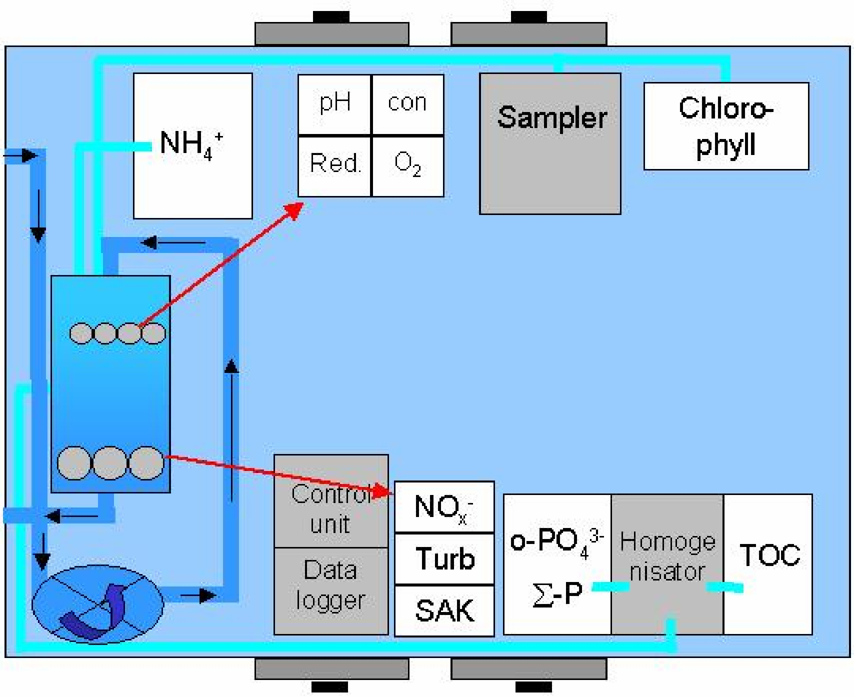

fig. 5: Scheme of the measuring stations

The sensors for the registration of turbidity, SAC and nitrate were installed in the sample basin, as well as the electrochemical sensors for pH-value, conductivity, oxygen and redox-potential. The extraction devices for all other instruments (ammonia, TOC, ortho- and total phosphate and chlorophyll) were also installed in the sample basin. A homogeniser prepared the samples for the TOC- and the phosphate-analyser by controlled crushing of the existing particulate material by ultrasonic digestion.

All values measured in the stations were stored in a data logger and could be retrieved from a central computer via telephone. This central computer was installed at the responsible authorities in order to allow a transmission of all collected data and to receive a current survey of the surface water quality.

Data transfer

In every measuring station all devices were connected to the so-called data loggers by an analogue output of 4 – 20 mA. They recorded the registered values in intervals of 5 minutes and transferred them to the central computer via telephone (see fig. 6) where they were stored in a data base by dint of a special software programme.

fig. 6: First page of the transfer programme

This programme allowed also to plot or tabulate the data and to process them.

In addition, information of the accessory devices like e.g. level indicators could be transferred as binary signals, allowing the remote control of the whole system at any time. It was possible to insert additional alert-functions into the transfer programme in order to receive an alert for the measuring instruments (e.g. water levels exceeding or falling below a certain value) and for the accessory devices (e.g. water inleakage) via the central computer, a fax or a mobile phone (see fig. 6 and fig. 7).

The connection of all stations to the transfer system provided an insight into the data of each measuring station at any time for the responsible authorities and persons in charge and enabled them to register variations in time and to compare different sites (see fig. 7).

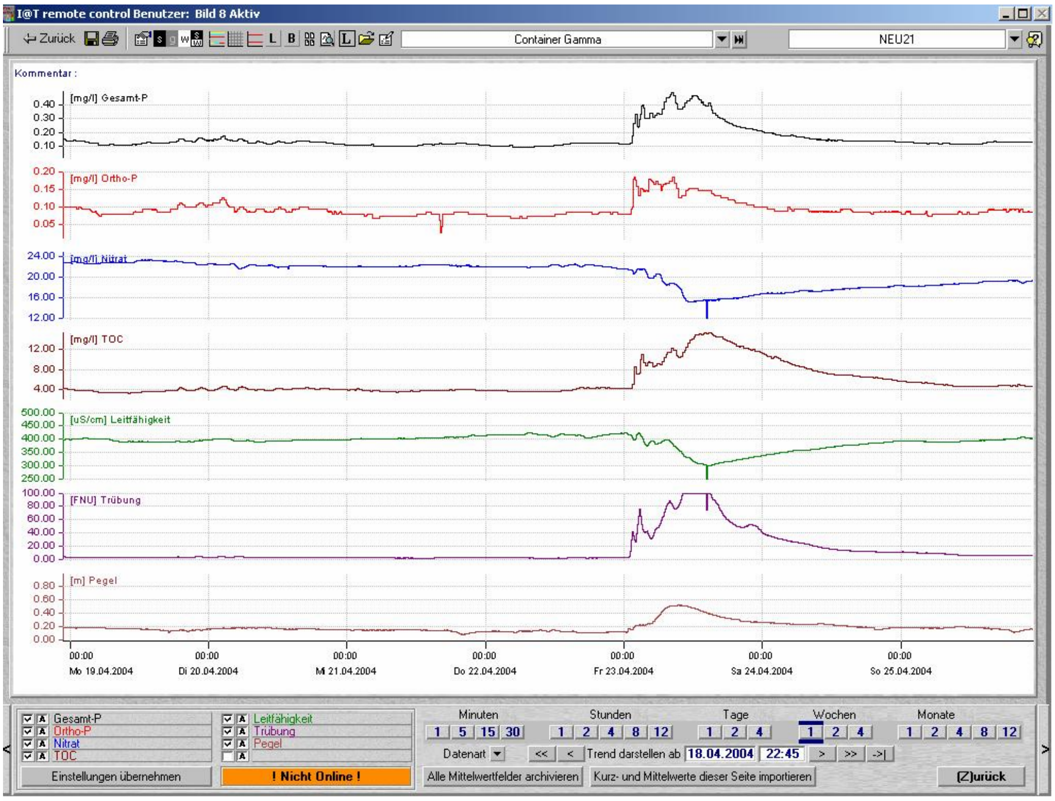

fig. 7: Graph of the measuring results (station in Luxembourg, 10th to 25th April 2004)

The registered data were transferred to a programme for statistic processing which allowed their evaluation by plausibility control and by consideration of statistic fluctuations. The evaluated data of all stations can also be visualised on the project web site [EUM]. Here, they can be displayed as curve (measured trend, see fig. 8), histogram (classification of the selected measurements compared with the classification of all evaluated measurements for the sensor contained in the data base, see fig. 9), and as time statistics (curve of minima, maxima, averages and standard deviations for each day of measurement, see fig. 10). Furthermore the selected measurements can be downloaded in text files for treatment in commercial programmes.

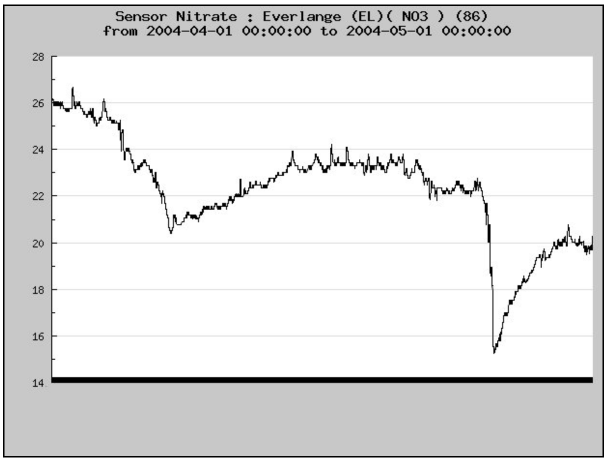

fig. 8: Concentration trend of nitrate (Attert, April 04)

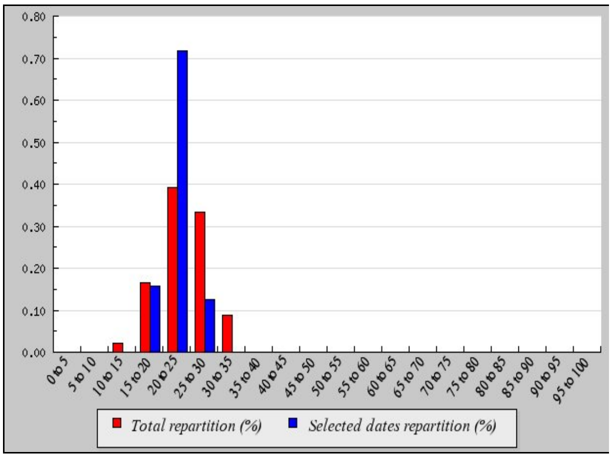

fig. 9: Histogram of the selected data file (Attert, April 04)

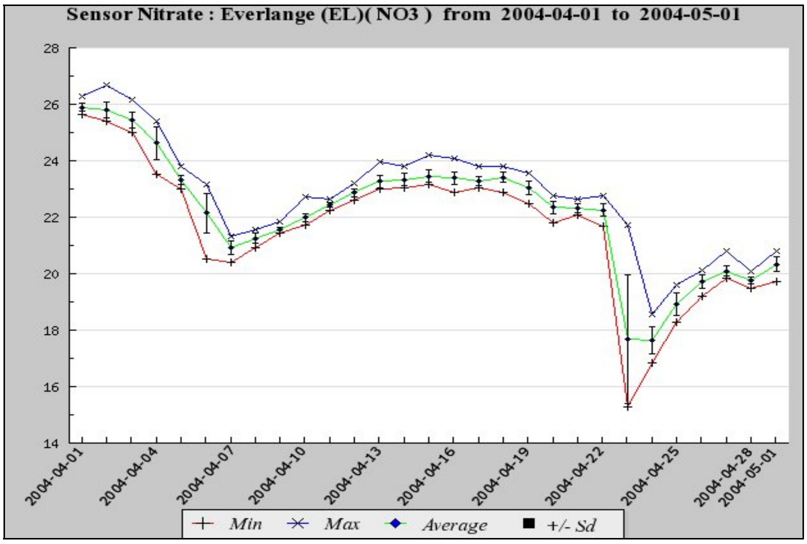

fig. 10: Time statistic of the selected data (Attert, April 04)

Evaluation and interpretation of the data

The first measuring station was put into operation in May 2002. Since April 2003, four more stations in Germany, France and Luxembourg were installed.

Some of the observations made during this time are described as examples in the following.

In order to interpret the measured data as a whole, a lot of additional background information was necessary. Concentration data and correlations between the parameters can be compared, but they give no hints on the total pollution of the river as it depends considerably its aquifer system. In order to determine the total pollution of the river, these data were to be related to runoff measurements (amount of water) so that the load of the different parameters could be calculated.

An observation of the runoff was required with regard to diffuse discharges as well, as only rainfalls can wash out certain substances from the soil.

As described in literature [HEL], the overall flow of a surface water is composed of three different parts: the surface flow, the interflow and the groundwater flow (see fig. 11). During heavy rainfalls only the surface flow increases considerably. This causes soil erosion and flushes soil particles into the rivers. The other parts of the water enter the soil. This soil water partially reaches the river as so-called interflow. This component occurs with a time delay compared with the surface flow and slows down the decrease of the overall flow. The deeper permeating water approaches the groundwater and in the end gains importance in the course of this event. The interdigitation of the different parts of flow determines the total trend of the flow curve after rain falls.

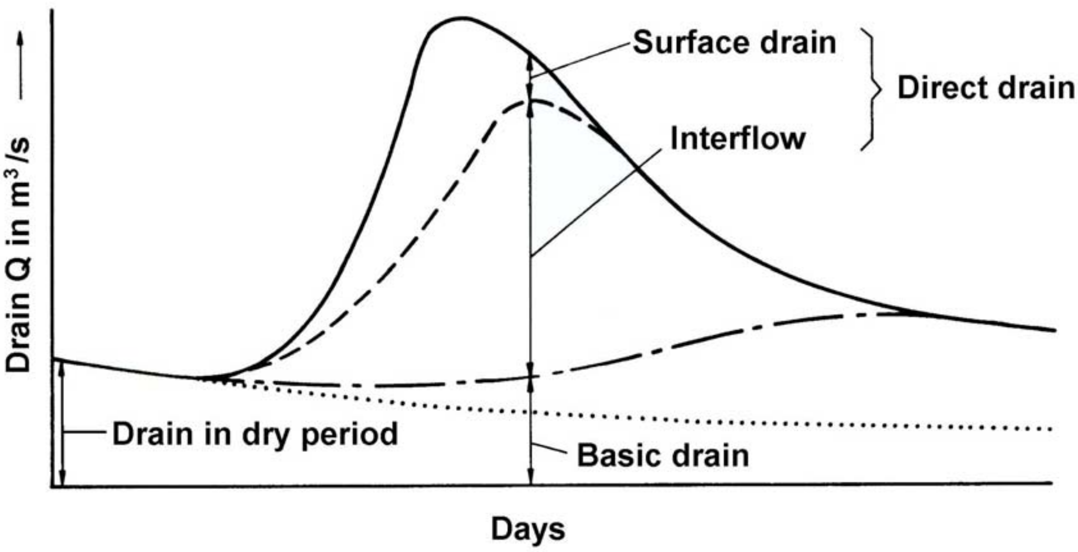

fig. 11: Composition of the overall flow [HEL]

The origin of diffuse discharges is certainly of special interest. In order to trace back the pathways of diffuse pollution more precisely, manual samplings were taken at the influents in addition to the continuously registered data. Determining the pollution of these influents and regarding their catchment areas allowed a differentiated localisation of the diffuse sources.
Apart from the above-mentioned hydrological data, factors like pedology, geology and land use (e.g. sandy soils facilitate the wash out of different parameters) as well as seasonal aspects were considered for interpretation.

Detection of diffuse pollution

Comparing the development of the nitrate concentration (measured at the German station near the French border) with the development of the water amount in River Nied, it can be shown that the nitrate value increases parallel to the runoff increase with a time difference of about 1,5 days (see fig. 12). This leads to the conclusion that the main part of the nitrate comes from diffuse sources and is washed out from the surroundings during rainfalls. The time difference indicates that a part of the discharge is transported via interflow when the rain water at first runs through several soil layers before reaching the river.

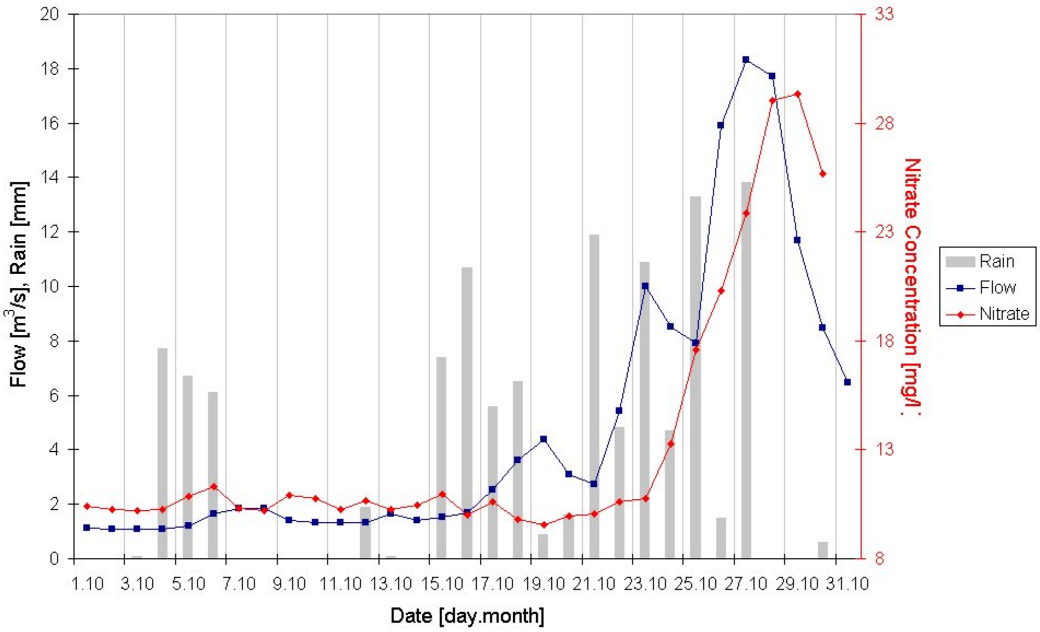

fig. 12: Comparison between nitrate concentration, runoff and rain at station *Niedaltdorf* during one month (daily mean values, October 2002)

When plotting the nitrate concentrations shown in figure 12 (measured in October 2002 in mg per litre) against the runoff of the river Nied (in m^3 per second), different mechanisms can be made out in periods with many rainfalls (see fig. 13). At first the nitrate concentration is constant with an increasing amount of water (about 1 to app. 9 m^3/s) (old content of the river accelerated like a bow wave, marked with a blue box in the graph). A phase of intense wash-out follows while an increase of the nitrate concentration is registered despite a decreasing amount of water (marked with a green box). These phases repeat until finally only little nitrate is left in the soil and the amount of nitrate in the water decreases (dilution, marked with the yellow box in the graph).

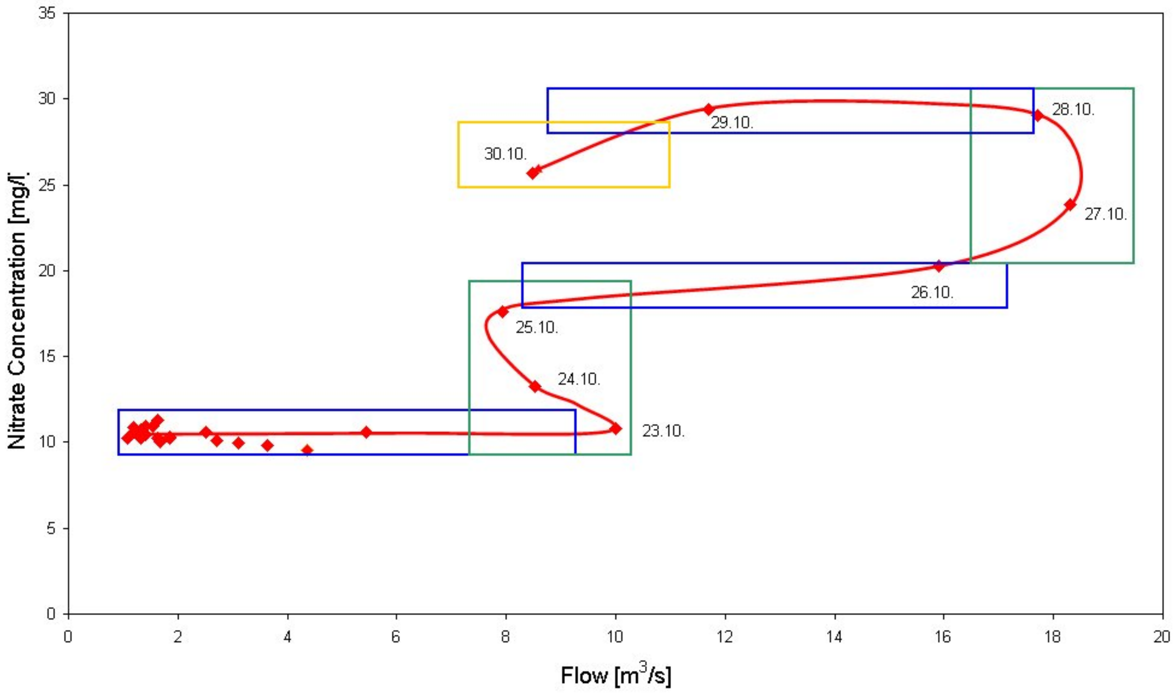

fig. 13: Graph of the nitrate concentration related to the runoff at station *Niedaltdorf* during one month (daily mean values, October 2002)

In contrast to the parameter nitrate the particle-bonded substances show a differing behaviour. They are transported mainly by surface flow. Therefore the concentrations quickly increase with rising flow.

Looking at the phosphorus concentrations and the flow curve in October 2002 (see fig. 14), both curves for ortho-phosphorus (red line) and total-phosphorus (green line) are parallel, when the flow is low (blue line). When the water runoff increases the concentration of total phosphorus and especially the difference of the two parameters (the phosphorus bonded to soil particles, purple line) rises and then rapidly decreases again.

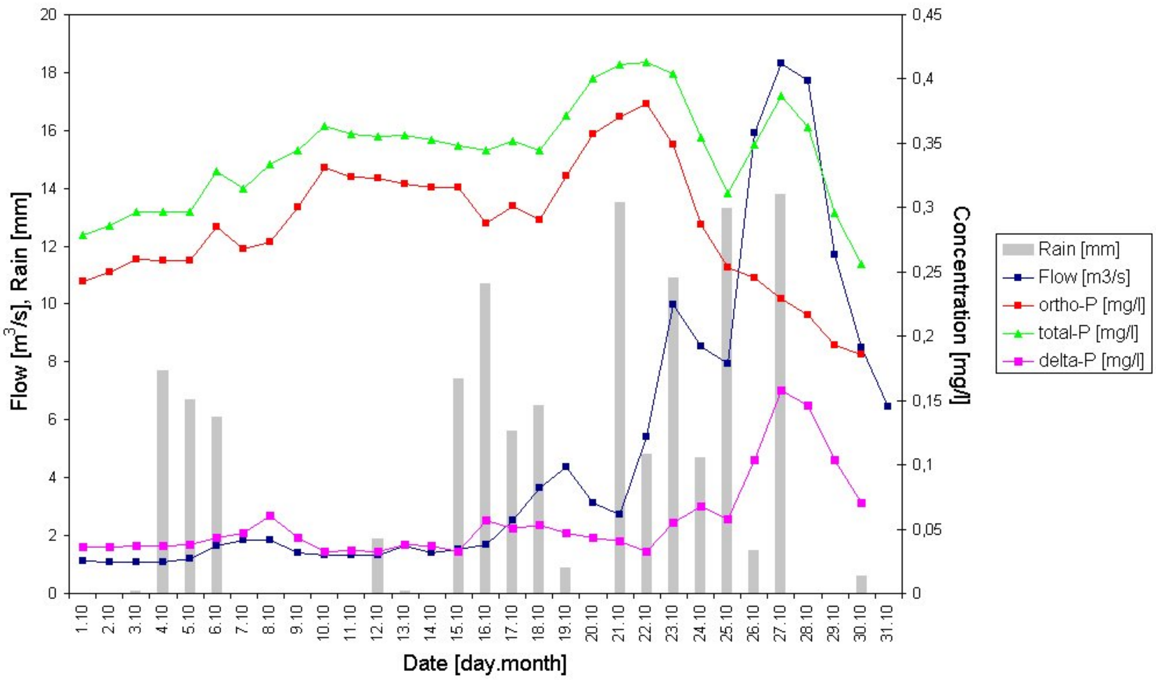

fig. 14: Comparison between the phosphorus concentrations and runoff at station *Niedaltdorf* for one month (daily mean values, October 2002)

The parameter TOC (the total organic carbon) is also correlated with the particle-bonded substances (e.g. humic acids or dead plant material) and the transport mechanism of input is the same like the mechanism of delta P (as it is shown in fig. 14).

In November 2002, several rain events occurred. In the following figure the concentration curves of several parameters are compared with the flow curve (hourly values measured at the German station in *Niedaltdorf*) (see fig. 15). The flow curve shows three main maxima (①,②,③) caused by the rain events. The rainfalls of the 3rd, the 11th and the 17th of November resulted in abrupt rises of the flow. As a consequence, the surface flow started and the concentrations of particle-bonded phosphorus and of TOC strongly increased at the same time.

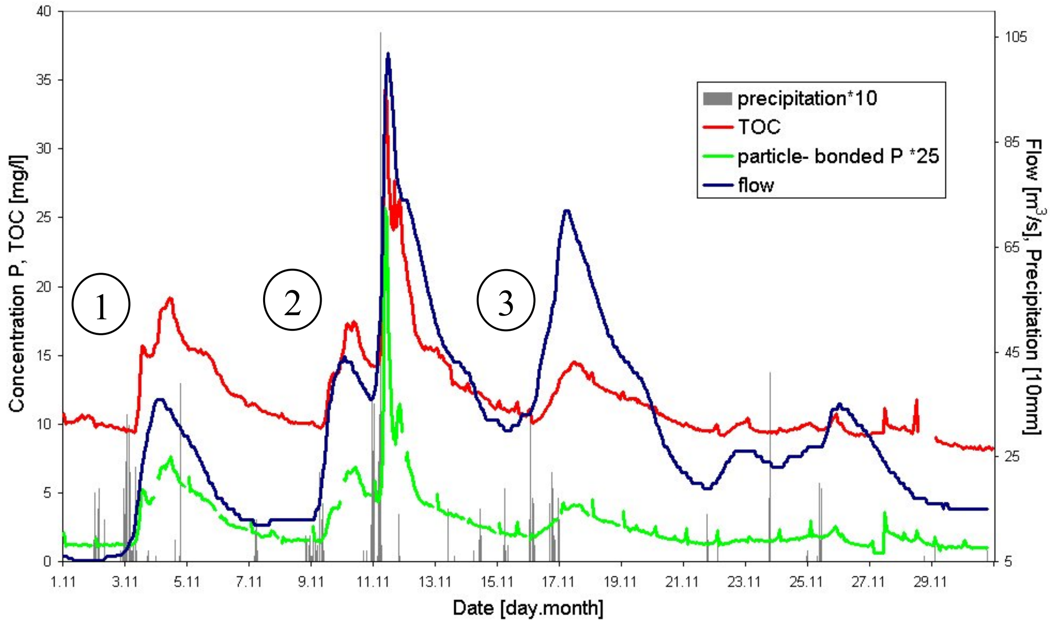

fig. 15: Comparison between the concentration of particle-bonded phosphorus and TOC and runoff at station *Niedaltdorf* for one month (hourly mean values, November 2002)

Looking at the concentrations of particle-bonded phosphorus and TOC related to the flow it could be observed, that every event of the flow and concentration curve was marked by a typical curve progression (fig. 16 “loop curves”). Different from the curve of nitrate (fig. 13) the particle dependent parameters show a quick rise of concentration simultaneously with the flow caused by surface drain (within hours).

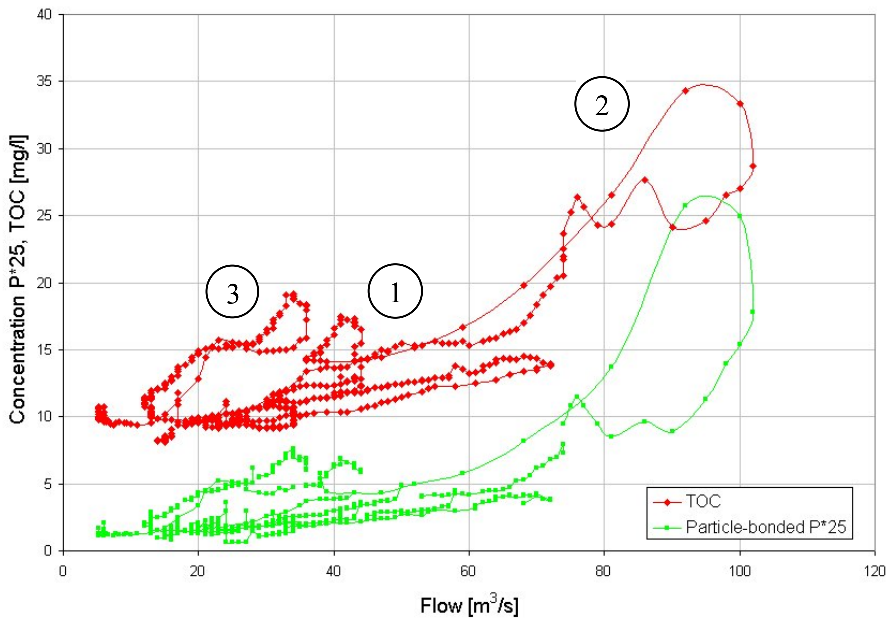

fig. 16: Graph of the concentrations of phosphorus and TOC (compare fig. 15) related to the runoff at station *Niedaltdorf* during one month (hourly mean values, November 2002)

The sources of diffuse pollution

In addition to the continuously registered data manual samplings were taken from the influents of River Nied and River Attert to trace back the pathways of diffuse pollution - which of course were of special interest. The determination of the pollution in these influents and the examination of their catchment areas allowed a more differentiated localisation of the diffuse sources.

These samplings were carried out from November 2002 until June 2004 at nine tributaries and four Nied sites at the same time. It could be shown that several influents were strongly polluted on one hand by punctual discharges and on the other hand by diffuse sources. The following figure illustrates the nitrate concentration trends of all tributaries over one year (see fig. 17).

The nitrate concentration of all tributaries increases during periods with many rainfalls. Thereby highly polluted streams usually drain intensively cultivated agricultural areas. In order to draw conclusions on the influence of these streams on the main river, the water amounts of the streams and thus the loads of the referring substances are to be taken into consideration. The concentration trends of all sampling locations were very similar. During heavy rain falls the nitrate concentration of almost all streams increased caused by the leaching of nitrate from the surrounding areas which are intensively used by agricultural activities. Although the highly polluted Schoppach flows into the Nied between the two German measuring sites, its general influence is small on account of its low flow and, as a consequence, on account of the small load. Generally all Nied sites (blue lines, fig. 17) showed the same trend at a low concentration level. It could be shown that the Nied can buffer these pollution input coming from its tributaries due to its high water quantity and flow.

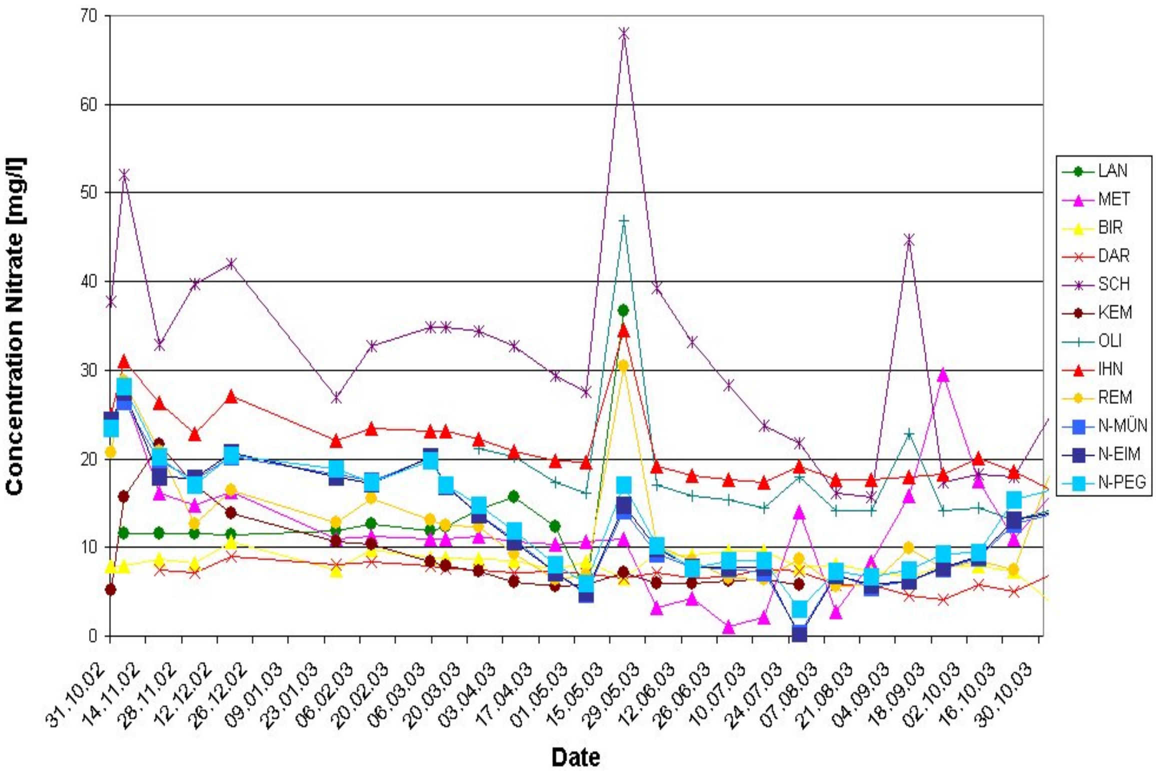

fig. 17: Nitrate concentrations in the tributaries (30.10.2002 - 30.10.2003)

Since spring 2004 four containers were installed at River Nied on the German and French side so that the measured concentrations could be compared along the river.

In summer and spring 2004 many rain events occurred and especially in May interesting observations could be made at all four locations along the river Nied (see fig. 18). At the 8th of May a steady rain began, which resulted in a strong rise of the flow. Consequently the nitrate concentrations rose at all sites along the river. At the locations *Crehange* and *Bionville* we observed a sharp concentration maximum. Downstream, behind the confluence point of Nied Allemande and Nied Française the concentration maximum was broadened (at *Niedaltdorf* yellow line) and at *Fremersdorf* (light blue line). The nitrate was washed out upstream and the concentration was diluted by the confluence of Nied Allemande.

At the 11th of May there was a local heavy rainfall leading to a sharp small signal in the flow curve (dark blue line, NAD). With a time delay, a concentration increase at the locations *Niedaltdorf* (delay of 1,5 days) and *Fremersdorf* (delay of about 2 days) could be noticed caused by discharge from the surroundings of the Nied between *Bionville* and *Niedaltdorf*. Thereby, the sharpness of the concentration maximum indicated, that the input happened not far away from the location of measurement. Discharges into the Nied Allemande or into the Nied Française would have been diluted by the confluence of the two creeks and would have resulted in a broadened peak.

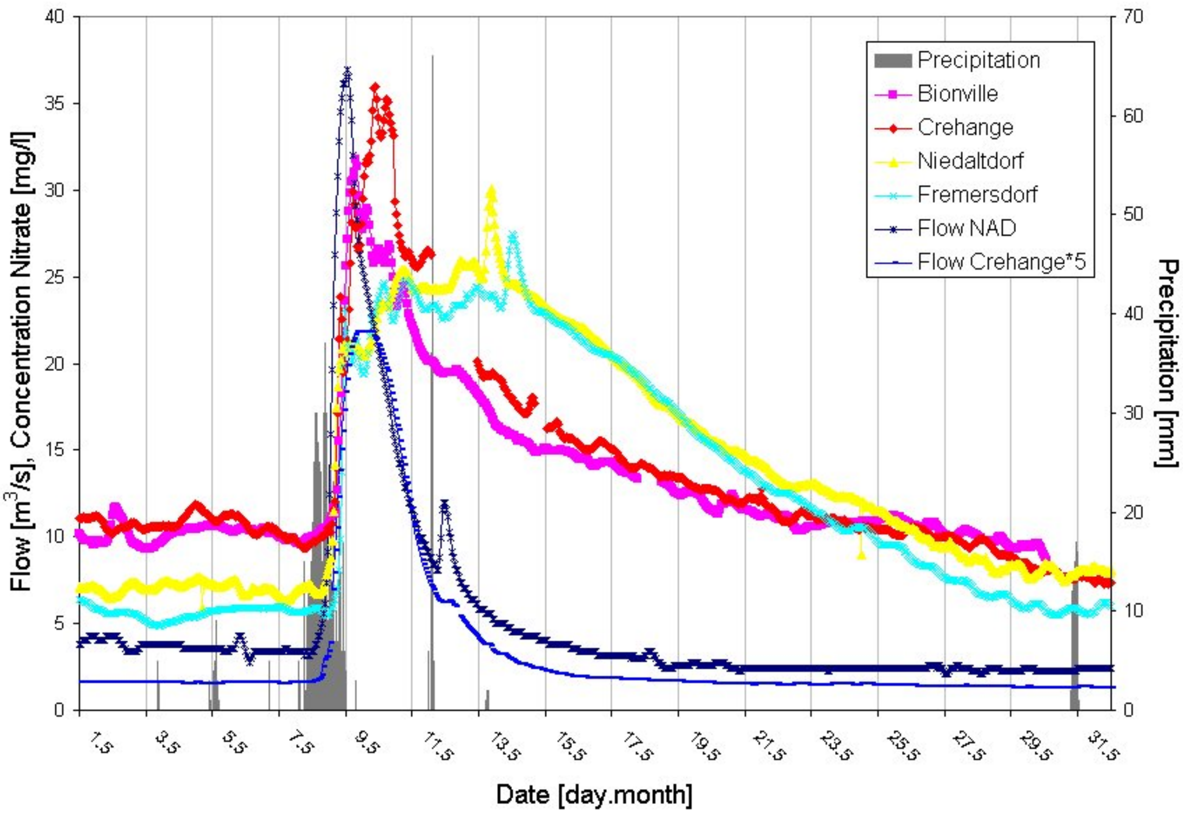

fig. 18: Precipitation, flow curves and nitrate concentration in the river Nied at all four sites in May 2004

Detection of eutrophicating substances

Looking at the concentrations of phosphorus the over all trend was similar to the nitrogen trends with a broadened increase of phosphorus. Especially the ortho-phosphate content showed a broaden maximum and the concentration remained at a high level for several days. The concentration of particle-bonded phosphorus increased at the beginning of the flow event (probably caused by surface drain). The heavy rain of 11th of May had no significant influence.

The nearly constantly elevated content of ortho-phosphate during about a week initiated an increase of the chlorophyll concentration (see fig. 19).

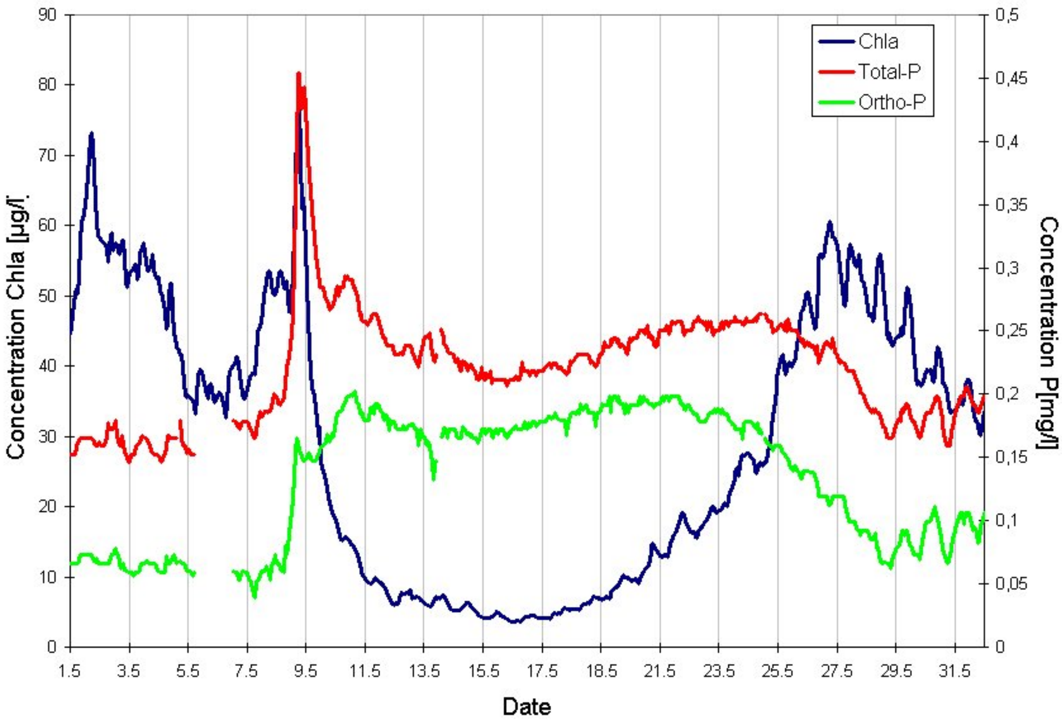

fig. 19: Concentration trend of ortho-phosphorus and total-phosphorus and the resulting increase of chlorophyll concentration in *Fremersdorf* May 2004

As shown in fig. 20 the rise of the total chlorophyll a concentration was mainly caused by the growth of diatoms.

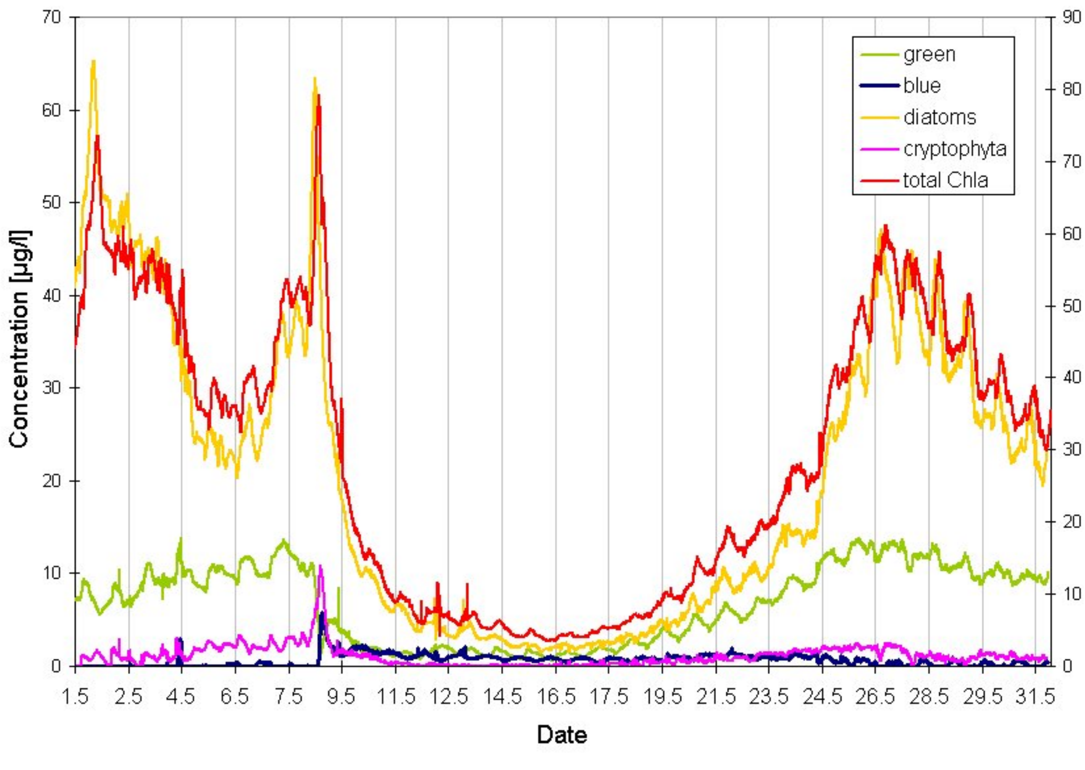

fig. 20: The concentration trend of different classes of algae and their contribution to the chlorophyll content (five minutes values, station *Niedaltdorf*, May 2004)

Conclusions

Since the containers have been put into operation, a variety of online-data were obtained allowing to draw conclusions on the dynamics of substance transports from diffuse sources in the investigated catchment areas. The measured parameters and the flow data showed correlations which indicate different mechanisms of input. These observations can be transferred to diffuse pollutants especially to the priority substances (defined in the *Water Framework Directive* [WFD]), which are transported by the same ways.

The simultaneous measurements at different locations along the rivers allowed an approximate localisation of diffuse inputs. These observations can be an important base for further operational programmes for the reduction of diffuse pollutions.

In order to be able to manage and evaluate the numerous measuring data, a detailed data base and special software was developed. For the interpretation of the registered measuring data and the localisation of the diffuse sources, a variety of further information like water levels, runoff values, precipitation amounts, agriculture, geological and pedological criteria as well as information on pollution by direct discharge was added. By connecting all measuring stations to the transfer system and the referring data banks, the responsible authorities and persons in charge can also have a look at the measured data of any station at any time, to determine variations in time and to compare different sites – even across national borders.

The project shows, that a cross-border investigation of surface water pollution was a meaningful task to understand the characteristics and particularities of the catchment areas of rivers. The international co-operation was a precondition of the success and its feasibility could be demonstrated.

Outlook

During the lifetime of the project, the investigation results met a lively interest by the public and also by the authorities involved. With respect to the implementation of the *Water Framework Directive* the project provides a lot of useful information.

The bigger part of the measuring stations will remain in operation. On the German and Luxembourgian side they will be maintained by the authorities. As the mobile containers are transferable they will be installed at different locations to investigate other catchment areas.

The inventories of the *River Basin Districts* demanded by the *Water Framework Directive* have been completed in Germany. In the frame of such investigations the surface waters are all classified and partially identified as being “at risk” (failing to meet the environmental quality objectives) or being “heavily modified”. Especially the “at risk”-water bodies will be the subject of special monitoring programmes. These monitoring programmes will focus on both pollution from diffuse sources and from point sources. Here, the combination of several parameters and the continuity of the measurements – as demonstrated in this project - will be of essential value for the identification and localisation of diffuse impacts. These programmes have to be carried out for a lot of surface waters. In Saarland for example 49% of the surface water bodies are identified as being “at risk” (19% as “heavily modified”) and thus have to be inspected further on.

Though the investigations within this project focussed on the determination of nutrients, the procedures are transferable to the monitoring of other substances as well. So the palette of the measured parameters can be expanded by measurements of the priority list substances.

Acknowledgement

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Ministerium für Umwelt des Saarlandes (Saarbrücken)

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Administration de l‘Environnement de Luxembourg (Luxembourg)

Landesamt für Umweltschutz des Saarlandes

Gemeinde Rehlingen-Siersburg

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[UBA]: http://www.umweltbundesamt.de
[WFD]: http://europa.eu.int/comm/environment/water/water-framework/index_en.html