Project no. 505428 (GOCE)

AquaTerra

Integrated Modelling of the river-sediment-soil-groundwater system; advanced tools for the management of catchment areas and river basins in the context of global change

Integrated Project

Thematic Priority: Sustainable development, global change and ecosystems

Deliverable No.: **R3.23**
Title: **Report of meeting on measurement of suspended solids in the Meuse**

Due date of deliverable: September 2007
Actual submission date: September 2007

Start date of project: 01 June 2004 **Duration: 60 months**

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Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	**x**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SUMMARY

On June 19/20, 2007 a visit was paid to a suspended particulate matter (SPM) sampling and monitoring site in the Ourthe river (Liège region), between the confluence with the Vesdre river and the mouth of the Ourthe in the Meuse river. The next day, a workshop was organised in which backgrounds, methods and procedures for SPM sampling and monitoring were discussed. Results of measuring SPM quantity and quality in the Meuse river basin were presented. The discussions were focused on the implementation of this matrix in WFD instigated monitoring programs. The workshop was very successful, with animated discussions.

MILESTONES REACHED (from DOW II p. 81 to 86)

No milestones were defined for this deliverable.

This deliverable should be regarded as a combined deliverable for the work packages FLUX 3 and BASIN R3. Monitoring SPM quality and quantity is relevant not only for the FLUX 3 and BASIN R3 work packages, but also for other FLUX and BASIN work packages, and for the TREND subprogramme. The results of this workshop (and maybe following workshops) should therefore be of interest for the work packages mentioned, as well as for the INTEGRATOR subprogramme.

Glossary

DGRNE	Direction Générale des Ressources Naturelles et de l'Environnement (Directorate-General for Natural Resources and the Environment within the MRW
HD	Hydrographic district
IRH	Hydraulic Research Laboratory of the MET
ISSeP	Institut scientifique de Service public
MET	Walloon Ministry of Equipment and Transport
MRW	Ministry of the Walloon Region
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorobiphenyls
SPM	Suspended particulate matter
TNO	Dutch Organisation for Applied Scientific Research
ULg	University of Liège
WB	Water body
WFD	Water Framework Directive

1. Introduction with Respect to Objectives

Suspended particulate matter (SPM) is an important carrier of contaminants, both heavy metals and organic micropollutants. Through transport of SPM contaminants can be spread over large areas in a river basin. Sedimentation of contaminated SPM on floodplain top soil during flooding events may cause serious environmental and ecological risk problems. This illustrates the importance of the measurement of SPM quantity and quality in river systems. Unlike water and soil quality measurements many procedures used for SPM monitoring and sampling are not well standardised. Therefore, TNO and ISSeP took the initiative to organise a workshop in order to discuss the different methods used for SPM monitoring / sampling and the results obtained in the Meuse river basin.

2. Results and Achievements

On June 19th, 2007 a visit was paid to a suspended particulate matter (SPM) sampling and monitoring site in the Ourthe river in Liège, between the confluence of Vesdre and Ourthe and the confluence of Ourthe and Meuse. On June 20th 16 participants to the workshop discussed backgrounds, methods and procedures for SPM sampling and monitoring and presented results of measuring SPM quantity and quality in the Meuse river basin. The workshop agenda is given in Annex 1; the list of participants is given in Annex 2. The workshop was hosted by ISSeP. Besides participants from ISSeP and TNO, also representatives from the University of Liège and from the Walloon government institutions MET (Ministère de l'Équipement et des Transports) and DGRNE (Direction Générale des Ressources Naturelles et de l'Environnement) joined the discussions.
In principle, the workshop language was English, but some discussions were held in French, because not everybody mastered the English language equally well. Despite the language problems the workshop can be regarded as very successful.

2.1 Visit to centrifuge site

A visit was paid to the sampling site in the Ourthe river (Liège region), between the confluence with the Vesdre river and the mouth of the Ourthe in the Meuse river. SPM is sampled with an overflow centrifuge mounted in a trailer (see following picture).

The flow rate is 1 m^3/h and the efficiency for capture of particles > 0.45 µm is about 90 %, as tested with filters. An amount of about 400 g SPM is sampled in one run.

The site in the Ourthe is part of a sampling programme covering 23 sites in the Meuse, its tributaries, canals and in the Scheldt basin. These sites are sampled four times per year.

2.2 Workshop at the ISSeP office - presentations

The next day the workshop was held at the ISSeP office in Liège. A number or presentations were given of the work carried out regarding SPM in the Meuse, followed by discussions on the backgrounds of monitoring SPM and the methods used. The agenda is shown in Annex nr. 1. The participants are listed in Annex nr. 2.

Short summaries of the work presented are given below. The PowerPoint files of the presentations are available on the AquaTerra website.

Note that for an estimation of pollutant fluxes from sediment particles to the dissolved phase (which can also give an indication of the "bioavailability"), passive samplers could be used that are placed directly in the water column and do not require sampling the SPM. However, it should be realised that with this method it is not possible to calculate pollutant fluxes transported by river SPM. Therefore, passive samplers cannot be regarded as an alternative method for SPM centrifugation. Once the samples are taken (using centrifugation or sediment traps), they can be analysed for total pollutant content, or for water-soluble ("bioavailable") pollutant content. This can be done with bioassays, or with physical-chemical methods. For organic pollutants sorption isotherms can be measured using e.g. tenax, or passive samplers in a lab-setting. For metals, other materials are available (e.g. chelex).

2.2.1 Research carried out in the Flux 3 work package of AquaTerra (Gerard Klaver, TNO)

The influence of dams on the suspended particulate matter (SPM) quality in the Danube
Large hydropower dams have major impacts on flow regime, sediment transport and the characteristics of water and sediment in downstream rivers. A section of the river Danube was studied between km 1895 (Wildungsmauer, Austria) and km 795 (Calafat, Romania). In the Gabcikovo reservoir (40 km length), water velocities are considerably reduced, causing sedimentation of suspended matter. This is reflected by a higher clay content, smaller grainsize and a slight increase in heavy metal content in the sediment and a higher organic carbon content of the suspended matter. In the Iron Gate reservoir, the sediment and

suspended matter composition was markedly different. All riverine suspended matter carried by the Danube is deposited in the Iron Gate Lake. Subsequently, suspended matter formed in the Iron Gate reservoir is carried through. Compared with “normal” Danube river sediment and suspended matter, Iron Gate reservoir sediment and suspended matter has a higher clay content, different clay mineralogy (dominated by smectite in stead of illite) and different K/Al and metal/Al ratios. The heavy metal composition of suspended and deposited sediment before entering the reservoir is similar, whereas after the Iron Gate dam, suspended matter heavy metal concentrations are distinctly higher than in the sediment.

Sources and transport of metals in the Dommel
Since halfway the 19th century, the industrial revolution left its traces in the area south of the city of Eindhoven, known as “the Kempen”. The river Dommel which has its source in Belgium flows trough the Kempen to end up in the river Meuse. The sandy soils in the Kempen area are strongly polluted with zinc and cadmium due to activities of zinc smelters at Overpelt, Lommel (Belgium) and Budel (Nederland). Since the seventies, the atmospheric emissions of these smelters have been greatly reduced. The zinc smelter at Overpelt still discharges wastewater containing high concentrations of Cd, Zn, Tl, Cs, Li, Pb, K, Sr and Cl in a tributary to the river Dommel.
The historical anthropogenic pollution of Cd and especially Zn in the soils in the Kempen and the discharge of the smelter waste water is reflected in the high Zn and Cd concentrations of the unfiltered water of the Dommel and its tributaries. SPM and metals show a seasonal variation, high values in the winter and low values in the summer. The seasonal variation is caused by variations in the contribution of unpolluted deep groundwater (high relative contribution during dry periods) and polluted upper and shallow groundwater (high contribution during wet periods).
Analyses of the solid and dissolved phases in the Dommel and its tributaries indicate that the metals are carried mainly by the dissolved phase. The metals in the water and SPM of the Dommel are influenced by the discharge of the wastewater and are distinctly higher than in its tributaries.

2.2.2 Quality and quantity of suspended particulate matter (SPM) in the Dutch part of the Meuse (Ingrid Bakker, TNO)

Monitoring results of suspended particulate matter (SPM) quantity and quality of the Dutch part of the Meuse were obtained from RIZA (State Institute for Inland Water Management and Waste Water Treatment) along with some additional analyses of SPM samples by TNO. A large seasonal variation of the SPM composition was observed near the Dutch-Belgian border with high input of primary production during summer and variable input of organic and inorganic pollutants. The seasonal variation decreases going downstream until a reasonable constant level of pollutant concentration and only small influence of primary production in the beginning of spring. Results of the 1993 flooding showed that SPM composition is controlled by input of coarse material during high water levels leading to a dilution of the pollutant concentration.

2.2.3 Sedimentation in Pommeroeul-Condé Canal. Development of a sediment inflow measurement station (Didier Bousmar, Hydraulic Research Laboratory, Ministry of Equipment and Transport, Belgium)

The Pommeroeul-Condé Canal is situated in the south of Belgium, near the French border and is meant to be a class IV canal (ships up to 1350 tons) as part of a waterway connection between the rivers Scheldt and Meuse (Sambre). In the years 1970 - 1980 a new canal was dug and the river Haine outlet was connected to the canal. Sedimentation in the canal is a severe problem for sustainable sediment management. It mounted to 1.5×10^6 m^3 in the period 1993 - 2005. The deposited material stems from land erosion, urban sanitation and industry. In order to cope with the situation and define adequate measures, monitoring of the sediment quantity is a prerequisite. Therefore, a sediment monitoring station has been installed and the first results of the measurements were presented. At the moment many questions still need to be answered and further expansion of the station (turbidimeter, second sampling point, network on the watershed) is foreseen.

2.2.4 Sediment transport in Walloon rivers (suspended load and bedload) (Prof. François Petit, ULg)

In order to differentiate the suspended sediment transport in Walloon rivers, the relationship between the concentration of suspended sediments and discharge was determined. Based on this relationship, the mean annual suspended sediment yield (expressed in the coefficient of denudation [$t.km^{-2}.y^{-1}$]) was calculated. The highest coefficients of denudation were found in the regions north of the Ardennes (Hesbaye 86 - 89 $t.km^{-2}.y^{-1}$, Pays de Herve 33 $t.km^{-2}.y^{-1}$ and Condroz 55 $t.km^{-2}.y^{-1}$), distinctly lower values in the North Ardennes (14 - 19 $t.km^{-2}.y^{-1}$) and the lowest values were determined in the South Ardennes (5 $t.km^{-2}.y^{-1}$).
In the bedload transport the research was focussed on the following issues:

- Occurrence of bedload mobilisation
- Thickness of sediments eroded

- Amount of bedload transport

From the different studies and methods used, the following conclusion about the Ardennes rivers can be drawn:

- Bedload movement occurs 10 to 20 days per year
- Bedload yield = 0.5 - 2.5 $t.km^{-2}.y^{-1}$
- Size of material transported varies between 2 and 10 cm
- Bedload propagation: 3-5 km per century
- The active layer involved varies in depth between 5 and 15 cm.

2.2.5 Monitoring the SPM in the hydrographic districts of Wallonia (Yves Marneffe, ISSeP)

The Walloon Region includes four parts of international hydrographic districts (HD): Meuse, Scheldt, Rhine and Seine HD). Following the requirements of the Water Framework Directive (WFD), they were divided in 351 water bodies (WB).

The Walloon Region carried out an assessment of the risk of failing to achieve the objectives set under Article 4 in the WFD (especially the good status). Two thirds of the WB were assessed as being « at risk », whereas one third will probably achieve their objectives. This analysis has induced a lot of changes in the monitoring network, since the article 8 of the WFD requires the adaptation / improvement of the monitoring network. In this directive, three types of monitoring are defined: surveillance, operational and investigative monitoring. The new monitoring network in Wallonia includes 54 sites of surveillance monitoring and 227 sites of operational monitoring + other sites chosen for additional and investigative monitoring.

Neither the WFD nor the future daughter directive on ecological quality standards require the monitoring of suspended matter and associated pollutants. Nevertheless, the Walloon Region thinks that it is important to follow those parameters in some rivers: 23 points have been chosen: 11 in the Meuse hydrographic district (HD), 11 in the Scheldt HD and one in the Rhine district. Among these points, a complete monitoring program is carried out for 11 points and a reduced monitoring program is carried out for 12 less important points. The selection criteria were the following ones: international commission points, comparison between inlet and outlet of the Walloon Region, outlets of important basins, transboundary points and highly polluted tributaries.

The 2006 results show that the higher concentrations of heavy metals in suspended matter are observed in the river Vesdre (historical + natural contamination), in the river Meuse downstream from Liège and in the river Sambre (industry). In the Scheldt hydrographic district, the metal concentrations are usually higher in the Dendre. PCBs and PAHs concentrations are higher in the river Sambre (Meuse HD) and in the rivers Haine and Espierre (Scheldt HD). On the other hand, a lot of pollutants are under the detection limits (isoproturon, simazine, tri- & pentachlorobenzene, tetrachloroethane, alachlorine, ….).

2.2.6 Effect parameters for the quality assessment of sediments and suspended solids: the Walloon part of the Meuse river as case study (Matthieu Hémart, ISSeP)

In the Meuse three locations were sampled: before (701) and after (702) confluence with the Sambre and at the Belgian-Dutch border (703). In the Meuse tributaries two locations were sampled: one in the Sambre (706) and one in the Vesdre (723). Samples were taken of sediments, porewater in the sediments, suspended solids, leachates from the suspended solids and water. Beside the physical-chemical analysis the following bioassays were tested:

- *Vibrio fischeri* (bioluminescence inhibition) and *Brachionus calyciflorus* 2d (survival) bioassays on sediment porewater and suspended solid leachate
- *Chironomus riparius* 7d (growth) and 28d (survival and emergence) bioassays on sediments and suspended solids

Chemical analyses show that sediments are most polluted in metals on the locations 703 (Meuse) and 723 (Vesdre) and the suspended solids in both the tributaries Sambre (706) and Vesdre (723).
The two bioassays on the porewater and leachates gave different results:

- In porewater, the results of the *V. fischeri* bioassay indicate that the pore waters in all locations except 701 are very toxic ("severe effect" class). In the *B.calyciflorus* bioassay on the other hand only a slight toxicity of the porewaters is shown.
- In the suspended solids leachates the *V. fischeri* bioassay shows that only the 703 leachate sample is highly toxic. Similar as in the porewaters the *B.calyciflorus* bioassay classifies all leachates as having a slight toxicity (EC50 < 50%).

The main conclusions are:

Although there is no support for the very toxic classification of the *V. fischeri* bioassay from the chemical analyses, this test provides good responses for toxicity evaluation in case of this study.
The 7-days survival and growth test with *Ch. riparius* was preferred to the 28-days emergence test because the effects of the 7-days test are more clearly visible.
The 7-days *Ch. riparius* test with suspended solids as unique food source is a promising test design. Confirmation and improvement of this specific use of the *Ch. riparius* bioassay is in progress.
In order to enhance the results of the bioassays in terms of interpretation and functioning (causal chain), the bioconcentration of metals and organic substances could be measured in the animal tissues.

3. Conclusions and Implementation of Results

3.1 Discussions during the workshop

Discussions took place about the reasons and importance of monitoring SPM (why monitor SPM?) and on the way this should be done (where / when / how monitor SPM?). Short summaries of the results of these discussions are given below.

3.1.1 Why monitor SPM?

The first discussion round included all participants of the workshop. The general question which should be answered was: why should we monitor suspended particulate matter (SPM)?
The arguments given were diverse with emphasize on the SPM quantity and quality and ecological aspects but also on the limitations. The following arguments were mentioned:

General:
- SPM is an integrative matrix which relates aspects of the water and sediment phase.

SPM quantity :
- SPM quantity is a tracer of soil erosion processes that take place in the river basin which are related to land use and artificial changes of the river basin.
- SPM quantity gives an indication of the actual deposition and erosion rates of bed load and floodplain sediments in the river basin and is a proxy for future changes of the sediment balance.
- Knowledge of the variation in SPM quantity increases the understanding of river dynamics and related processes that take place.

SPM quality:
- Most pollutants (metals and organics such as PCB's and PAH's) are adsorbed mainly to the suspended matter / sediment phase.
- Analyses of pollutants in the water phase are mostly close to the limit of detection while pollutants are easily measured in the suspended matter or sediment phase.
- SPM quality gives a good estimate for pollutant fluxes in the river basin.
- SPM quality gives an indication of future deposition (concentrations) of pollutants on floodplains which leads to an extension of the pollutant problem on longer time scales.

Ecological:
- Suspended pollutants can have a large influence on biota.
- Variation of SPM quantity and quality influences the possible habitat function of the river basin.

Limitations:

- SPM quality is linked to historical pollution and can not give a good indication of recent changes in pollutant concentration.
- Collected SPM samples can not be compared easily, as it is difficult to make a normalization for SPM composition.

This list of arguments about why SPM should be monitored is not exhaustible, but it presents a rather diverse view of the most important aspects. All participants agreed that only monitoring the water phase would not suffice to gain a full understanding of river dynamic fluxes and variation in pollutant composition and fluxes.

3.1.2 When, where monitor SPM? Qualitative and Quantitative Aspects

The discussions on the backgrounds of SPM monitoring and the methods to be used resulted in the following tables.

Table showing objectives of SPM analyses for qualitative reasons

Objective	**Where** *Location in the river, scale*	**When** *Frequency, events*	**How** *Method, parameters, data evaluation*
Flux monitoring	- Near location of discharge measurement - Ideal in middle of river - Practically on the side - Homogeneous section - 50 cm below surface level - Transgressing - Outlet of large tributaries - River basin scale	- Four times a year - Covering flooding events only SPM concentration	
Trend monitoring	- River basin or sub-basin scale	- Cover all four seasons	- Centrifuge sampling - Pollutants (both inorganic and organic) - Grain size - Fertilizer / agriculture related parameters - Total organic carbon - Indicate presence of pollutant - Absence of pollutant leads to change in monitoring program
Investigation Contrôle d'enquète	- Local scale - Based on hypothesis	- Flooding events / dry periods - Depends on case	- Parameters depend on case - Special interest of bioassays at this comprehensive level

Table showing objectives of SPM analyses for quantitative reasons

Objective	**Where** *Location in the river, scale*	**When** *Frequency, events*	**How** *Method, parameters, data evaluation*

Objective	**Where** *Location in the river, scale*	**When** *Frequency, events*	**How** *Method, parameters, data evaluation*
Flux monitoring	- Basin / catchment scale: stations have to be near measurement of discharge - Need to get good mixing at the measurement site - If no sufficient mixing: gradient, points at different depths	- Depends on homogeneity; first identify representative measurement point for different discharges - Difference in frequency between samplers and automatic station (e.g. laser diffraction measurement)	- Bottle sampler, measurement with sedigraph / laser particle sizer - In-situ turbidity / laser diffraction - Choice of instruments dictated by SPM concentration
Trend monitoring	No difference between trend and flux monitoring for quantitative aspects; quantitative trends are linked to river discharge, to land use changes and to changes (natural or anthropogenic) in the river channel cross section / course		
Investigation Contrôle d'enquète	- Extra measurements to validate / investigate specific observations at representative points and at different river places along the river course	- Repeated measurements during a given discharge to determine whether the site is stable	- Compare different methods

3.2 Conclusions

The importance of SPM monitoring is generally underestimated. As mentioned before, a large fraction of the contaminant loads transported by river water is attached in some way to suspended particles. Therefore, measurement of SPM should get much more attention and should be inbedded in regular monitoring programs. These measurements should be carried out both during average and extreme flow conditions (floods and droughts). Standardised methods should be developed for monitoring and sampling of SPM.

Different methods should be considered for different purposes and provide answers to different questions. For quantitative SPM monitoring for example, turbidity measurements based on laser diffraction can be considered, but if an estimate of the pollutant load is required, a method should be used in which the SPM can be analysed for the various constituents. Examples of these methods are the centrifuge method (relatively short sampling time, all size fractions sampled), or the sediment trap method (long sampling times, predominantly large-particle size fractions sampled).

A number of interesting contacts have been established during the workshop and this is expected to lead to further co-operation between the institutes represented. The discussions in the workshop can be a first step in writing a strategic paper on how to monitor SPM in the context of the WFD. It will be examined whether a next workshop can be organized with participation of other European basins (e.g. Danube, Elbe).

Annex 1 Workshop agenda

9.00	Welcome and round table (Claire van der Wielen, ISSeP)
9.15	General introduction of the AquaTerra project (Jan Joziasse, TNO)
9.30	Research carried out in the Flux 3 work package of AquaTerra (Gerard Klaver, TNO)
10.00	Quality and quantity of SPM in the Dutch part of the Meuse river (Ingrid Bakker, TNO)
10.20	Discussion
11.00	Sedimentation in Pommeroeul-Condé Canal. Development of a sediment inflow measurement station (Didier Bousmar, IRH)
11.20	Sediment transport in Walloon rivers (suspended load and bedload) : attempt for a regional differentiation (Prof. François Petit, ULg)
11.50	Monitoring SPM in the hydrographic districts of Wallonia (Yves Marneffe, ISSeP)
12.10	Effect parameters for the quality assessment of sediments and suspended solids: the Walloon part of the Meuse river as case study (Matthieu Hémart, ISSeP)
12.30	Discussion
12.45	Lunch
14.00	Discussion: why, when, where, how monitor SPM?
15.45	Conclusion

Annex 2 List of participants

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