Erftverband monitoring campaigns in the M³-project

Introduction

To enable precise characterisation of the immission situations for watercourses, it is first necessary to characterise the emissions in the catchment area. The data required to yield useful information on emissions can be collected via monitoring (e.g. at wastewater treatment plant outlet) and can also be generated as the result of running a suitable model (e.g. by sewer network simulation modelling). The combined approach of monitoring and modelling permits development of an emission inventory. This inventory can be used in conjunction with weather data and data specific to the region as a data input set to run a water quality model for rivers which, when used in conjunction with valid methods of river monitoring, provides valuable information about the immission situation (immission inventory).

1. Emission monitoring

To obtain a useful knowledge base regarding the immission situation in rivers it is first necessary to determine the relevant sources, pathways and inputs of pollutants in the form of an emission inventory. Relevant emissions in the Swist catchment include, surface runoff, subsurface flow, natural groundwater flow and urban effluents, the latter mainly flow from WWTPs and sewerage system outlets.

1.1 Wastewater treatment plants (WWTPs)

In a high-population-density catchment such as that of the Swist river, ascertaining load stemming from wastewater treatment plant outflow is essential in order to establish a valid emission inventory. Effluent load is assessed in terms of substance concentration, discharge volume and discharge wastewater temperature.

1.2 Combined sewer overflows (CSOs)

The emission inventory for combined sewer overflows is based upon reliable data for volume and substance concentration of discharge.

Precipitation-induced emissions in urban areas are in the first instance reflected by CSOs and by outflows from separate sewerage systems (SSO). Since more combined sewerage systems than separate sewerage systems exist in the Erft catchment (60% CSOs vs. 40% SSOs), the focus here is on CSOs.

A few of the storm water retention tanks deployed in the combined sewerage systems in the Swist basin have been equipped with flow gauges. At a number of these locations the flow gauges have been calibrated using portable measurement devices. As the calibrations serve to verify the CSO discharge volumes, it has been possible to obtain long term, reliable discharge volume data at these locations. It follows that substance monitoring could also be successfully undertaken here.

Monitoring substance concentrations of CSOs requires considerable input of equipment, personnel, material and analytical effort. The goal is to determine approximate concentration ranges for a wide variety of substances stemming from CSOs. Two distinct CSO systems are taken into account in the Swist monitoring campaign.

To illustrate the set-up of event based sampling, figure 1 presents a schematic diagram with flow gauge at the outlet of a CSO. In case of overflow a connected programmable logic controller activates sampling at the outlet. Pumps, which are situated in pumping stations in the riverbed up- and downstream of the discharge, are also activated by signal and deliver water to the sample collectors situated in well protected places on the adjacent riverbank. Additionally, the programmable logic controller (PLC) sends a message to the staff to enable timely examination of the samples.

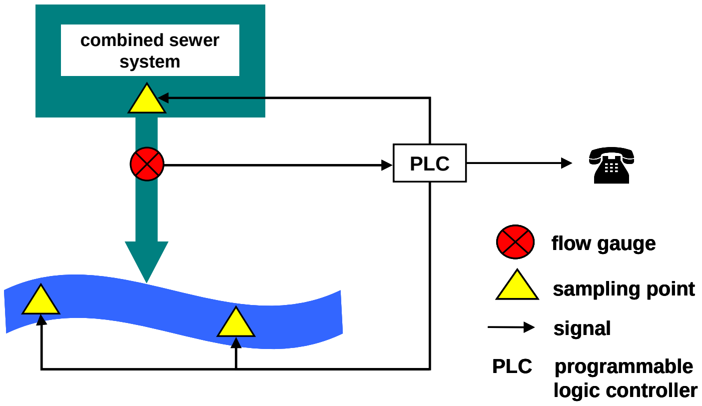

Figure 1: Set-up for event based sampling of CSOs (schematic illustration)

1.3 Soil filter retention sites

In the more modern combined sewerage systems, soil filter retention sites planted with reeds have been established to perform advanced purification of excess wastewater flowing out of storm water retention tanks before release into watercourses. The Altendorf soil filter retention site in the Swist catchment area is considered as representative for the monitoring campaign (figure 2). To assure the sampling of blast events in Altendorf at any time, an automatic sampling system has been established and implemented. The autosampler is installed at the inflow and the outlet of the soil filter retention site. Water samples are taken by an immersion pump. The activation of the pump is controlled over a programmable logic controller which also sends a message to the staff once the sampling device is activated.

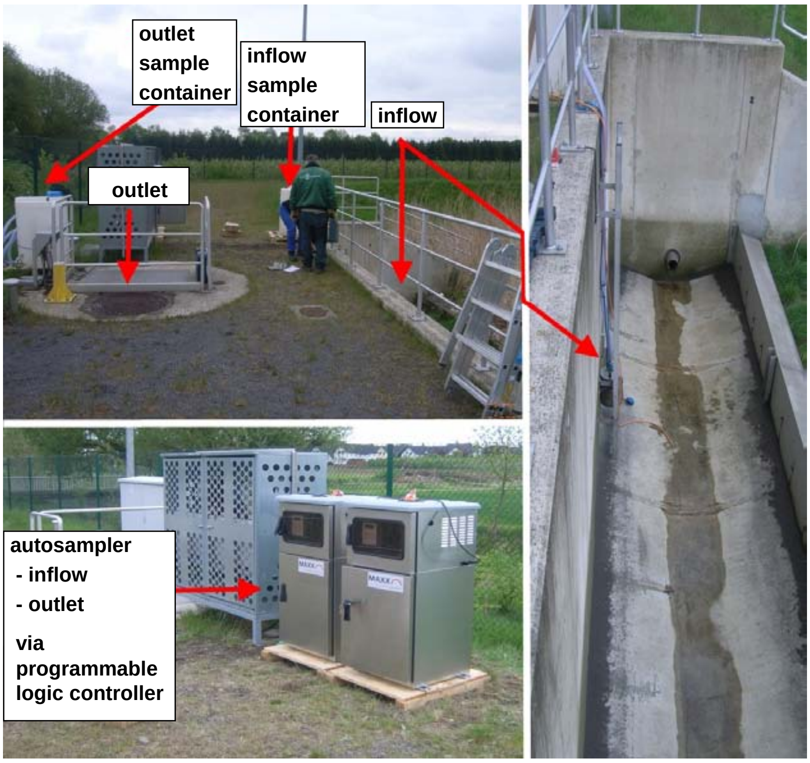

Figure 2: Soil filter retention – monitoring system Altendorf site

1.4 Separate sewerage outlet

To describe the quality of discharges from outlets of separate sewer systems which drain and collect water from rainfall in urban areas monitoring data are barely available. For this reason a monitoring system has been established at the Meckenheim stormwater retention tank in the Swist river catchment (figure 3).

An ultrasonic sensor is measuring the water level. When the threshold value is exceeded, the programmable logic controller triggers the sampling and sends a message to the staff (same method as adapted for the CSOs). In this way the water samples can be analysed in a timely manner. Water level data will be recorded via the record unit.

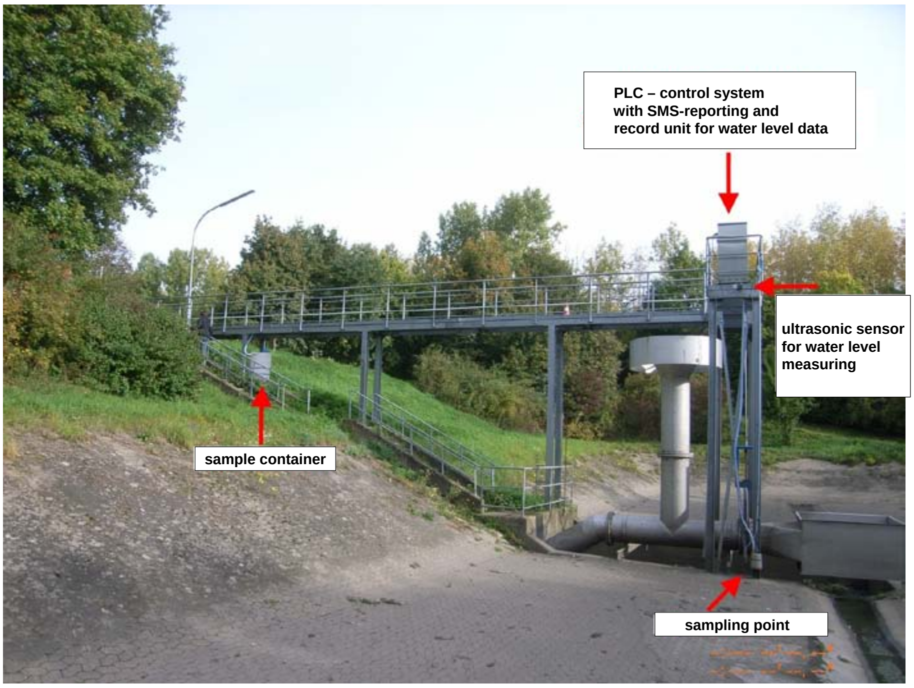

Figure 3: Stormwater retention tank – separate sewerage system Meckenheim site

1.5 Runoff from landscape

Besides encompassing discharge data from the point sources of WWTPs and CSOs, a complete emission inventory accounts for volume and substance concentration of discharges from non-point sources: overland flow; subsurface flow (interflow); and groundwater flow.

Discharge volumes from these categories of non-point sources can be quantified by basin wide application of a precipitation runoff model (NASIM©). Additionally, a sampling method provides the ability to collect monitoring data on surface and subsurface flow which can be used to determine substance concentrations.

Integrated in the monitoring system, this sampling method permits separate capture of runoff from surface waters (overland flow) and runoff from soil moisture (subsurface flow) from land under various utilizations (figure 4). Four distinct land uses were considered:

- Forest;
- Pasture;
- Cropland;
- Orchard.

The runoff samples are representative of real-life conditions. Likewise, the measuring system interferes with the natural soil structure and soil surface as little as possible. After installation of the monitoring system the natural direction of surface runoff and subsurface water flow is restored as soon as possible. Furthermore, it is even possible to interpret samples of current water flows coupled with their corresponding rainfall events. For this purpose the system is enable the recovery of samples in highly discrete solutions depending on time.

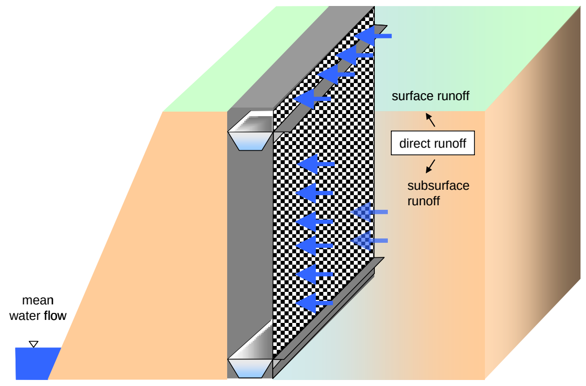

Figure 4: Monitoring landscape runoff (schematic illustration)

The landscape runoff monitoring system (figure 4) consists of a rectangular box which is embedded in the soil right along the watercourse. The long side facing away from the watercourse is perforated. The water enters the device and is collected in detachable collection pans. One collection pan within the box collects surface runoff and a second, subjacent pan catches subsurface runoff from the soil matrix. To track and measure the filling process sensors are installed in the collection pans. The filling level is transmitted daily via SMS to field staff.

1.6 Groundwater flow

For describing substance concentration of the groundwater flow which reaches rivers via exfiltration, a special programme is conducted in the Swist catchment. One the one hand this programme considers sampling points in rivers upstream of point sources and on the other hand the time of sampling during long term dry weather phases.

1.7 Atmospheric deposition

Atmospheric deposition on paved areas provides a significant contribution to the material composition of the collected wastewater in the sewers. Relevant data is rarely available. The Erftverband operates seven sampling sites under various utilisations, one out of these seven in the Swist catchment. In view of the fact that emissions from atmospheric deposition in the Swist catchment couldn't be defined by one sampling site, the sampling results of all sampling sites in the whole Erft catchment are considered.

At the following sampling sites in the Erft catchment, atmospheric deposition data (dry and wet deposition) is collected regularly:

- Grevenbroich (power plant)
- Metternich (motorway)
- Vettweiß (rural)
- Mechernich (heavy metal loads)
- Bergheim (coal mining)
- Flerzheim (rural)
- Euskirchen (urban)

The sites are selected according to the land utilisation.

Figure 3: Atmospheric deposition – Bergheim sampling site

1.8 Soil erosion

Since the land on the river Swist is not very prone to soil erosion, another sub-catchment of the Erft, the Rotbach catchment, is chosen to be representative for the soil erosion sampling campaign. The arable land at the headwaters of the Rotbach catchment is considered highly erodible. Especially during heavy rain events large amounts of soil wash into the watercourse. In the year 2011 a sampling system has been established in the upper reaches of the Rotbach which automatically takes samples with high temporal resolution from the erosion induced transport of suspended matter. Solid contents and the associated pollutants are examined in this monitoring program.

Figure 4: Eroding farmland viewed from Rotbach stream bank

1.9 Monitoring table – emission

To characterize the substance concentrations of the emission pathways in the Swist river basin, the parameters shown in table 1 are analyzed. Most of these parameters are also studied to characterize the immission situation.

Table 1: Parameters examined in point / non-point sources and surface waters (water column) of the Erft river basin

sampling method: grab sample	annual frequency: 3 (I., II., III. quarter)							
	parameter	**unit**		**paramter**	**unit**		**parameter**	**unit**
common parameter	air temperature	°C	**pesticides**	Bentazon	µg/l	**pharmaceuticals**	Carbamazepin	µg/l
	water temperature	°C		Bromacil	µg/l		Clofibrinsäure	µg/l
	oxygen	mg/l		Bromoxynil	µg/l		Diclofenac	µg/l
	oxygen after 2 d	mg/l		Carbetamid	µg/l		Fenoprofen	µg/l
	pH-value	-		Chloridazon	µg/l		Ibuprofen	µg/l
	turbidity	TEF		Chloroxuron	µg/l		Naproxen	µg/l
	filtrate dry residue	mg/l		4-Chlorphenoxyessigsäure	µg/l		Pentoxifyllin	µg/l
	filtrate annealing residue	mg/l		Chortoluron	µg/l			
	suspended solid	mg/l		Clopyralid	µg/l			
	acid capacity 4, 3	mmol/l		Cyanazin	µg/l			
	total hardness	°dH		2,4-D	µg/l			
	carbonate hardness	°dH		2,4-DB	µg/l			
	Mg	mg/l		Desethylatrazin	µg/l			
	Ca	mg/l		Desethylterbuthylazin	µg/l			
	Na	mg/l		Desisopropylatrazin	µg/l			
	K	mg/l		Dicamba	µg/l			
organoleptic parameter	colour	-		Dichlorprop	µg/l			
	exhalation	-		Diuron	µg/l			
	floating solids	-		Ethofumesat	µg/l			
	transparency	cm		Fenoprop	µg/l			
oxygen depletion indicator	BOD_5	mg/l		Fluroxypyr	µg/l			
	COD	mg/l		Fluortamon	µg/l			
	TOC	mg/l		Hexazinon	µg/l			
	$KMnO_4$-demand	mg/l		Ioxynil	µg/l			
nitrogen	NH_4-N	mg/l		Isoproturon	µg/l			
	NO_2-N	mg/l		Linuron	µg/l			
	NO_3-N	mg/l		MCPA	µg/l			
	$N_{organic}$	mg/l		MCPB	µg/l			
	N_{total}	mg/l		Mecoprop (MCPP)	µg/l			
phosphorous	phosphorous total	mg/l		Metalaxyl	µg/l			
	phosphorous dissolved	mg/l		Metamitron	µg/l			
salt content	conductivity	mS/cm		Metazachlor	µg/l			
	chloride	mg/l		Metabenzthiazuron	µg/l			
	sulfate	mg/l		Metobromuron	µg/l			
heavy metal	Ni	mg/l		Metolachlor	µg/l			
	Zn	mg/l		Metoxuron	µg/l			
	Cu	mg/l		Metribuzin	µg/l			
	Cr	mg/l		Monolinuron	µg/l			
	Cd	mg/l		Monuron	µg/l			
	Hg	mg/l		Prometryn	µg/l			
	Pb	mg/l		Propazin	µg/l			
	Co	mg/l		Sebuthylazin	µg/l			
	Fe	mg/l		Simazin	µg/l			
other metals	Mn	mg/l		2,4,5-T	µg/l			
organic halogens	AOX	µg/l		Tebuconazol	µg/l			
pathogenic germs	colony forming unit after 20 h	/100 ml		Terbumeton	µg/l			
	colony forming unit after 44 h	/100 ml		Terbuthylazin	µg/l			
	coliforme germs	/100 ml		Terbutryn	µg/l			
	faecal coliform germs	/100 ml						
	Escherichia coli	/100 ml						

2. Immission monitoring

With the emission inventory established through the activities described above, immission monitoring strategies can be implemented to produce valid information on surface water quality in the Swist river basin. Within the project the Erftverband examines the water column, suspended solids in surface waters and the river sediment. In a special measuring initiative, the focus is on anthropogenic micro-pollutants.

2.1 Water column

For the purpose of monitoring, both conventional methods and new ones are employed. Under conventional methods, samples of flowing water are collected twice a year at 12 sampling points for physical, chemical and biological examinations at the beginning of the growing season in spring and at the end of the growing season in autumn.

2.2 Online monitoring

Eighteen years ago the Erftverband initiated an online monitoring network for continuous recording of contents of surface water in the Erft catchment. One of this online monitoring stations is located in the Swist Catchment. With this system data on the most important water quality variables can be collected. For a number of important parameters, data collection stations are established with computers connected online to central processing facilities e.g. via the standard telecommunication network *(figure 5)*. Data is then recorded continuously and transmitted automatically or on demand.

At the central facility the measurement data are processed to yield information needed to assess and if necessary to improve water quality.

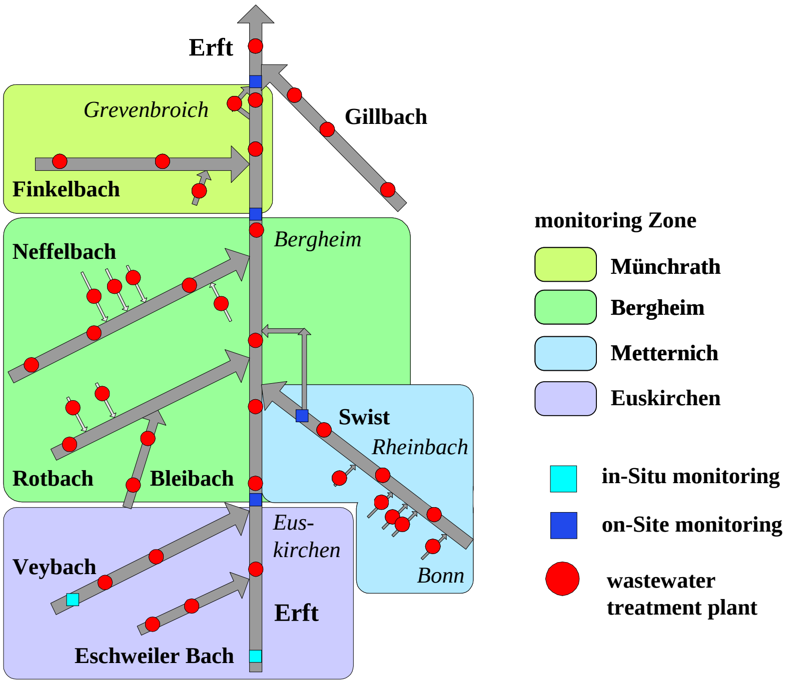

Figure 5: Online monitoring in the Erft river basin

2.3 River sediment

Once in two years Swist sediments are examined with particular focus on heavy metals. For riverine habitat conditions grain size distribution can be a key factor. Therefore, the upper sediment layer is investigated using 11 grain size fractions.

Table 2: Examination of Erft river sediments

fraction [µm]	<63	≥63 – <100	≥100 - <200	≥200 - <250	≥250 - <315	≥315 - <400	≥400 - <500	≥500 - <630	≥630 - <710	≥710 - <900	≥900 - <1000
Pb											
Cd	Object of investigation:										
Hg	upper sediment layer at 38 sampling sites										
Zn											
Ni	Frequency:										
Cu	Once every two years										
Cr											
Co	Grain size:										
Fe	11 fractions (<1mm) via wet sieving										
Mn											

P		Method:
glowing residue		drying until reaching constant weight (105°C) aqua regia dissolution Assessment: LAWA-ZV, AbfKlärV, BBodschG, Geoakkumulationsindex

2.4 Micropollutants

A special study is being conducted to expand knowledge of both the fate and behavior of anthropogenic micropollutants in watercourses of the Erft region. Micropollutants such as pesticides and pharmaceuticals are receiving increasing attention in water quality management. However, data available from literature about emission and behaviour of micropollutants in river systems is still insufficient.

In order to distinguish the sources of pollution, samples are to be taken from selected wastewater treatment plants, surface waters, combined sewer overflow, separate sewerage outlet and landscape runoff from cropland as well as an orchard. In this manner, it is possible to identify various input sources of emissions and further to differentiate between non-point sources and point sources of pollution.

Monitoring to measure micropollutant load is performed under three diverse types of weather conditions: dry weather, steady rain and heavy rain. These weather types serve to define the relevant scenarios for modelling purposes.

Along with the pesticides already tested in a pre-existing program, pharmaceuticals and personal care products were covered in the micropollutant monitoring campaign (Table 3).

Table 3: pharmaceuticals and personal care products tested in the micropollutant monitoring campaign

Antibiotics	Amoxicillin	X-ray contrast media	Diatrizoat
	Cefaclor		Iohexol
	Chlortetracyclin		Iomeprol
	Ciprofloxacin		Iopamidol
	Doxycyclin		Iopromid
	Enrofloxacin	Beta blockers	Atenolol
	Erythromycin		Bisoprolol
	Minocyclin		Metoprolol
	Oxytetracyclin		Propranolol
	Penicillin G		Sotalol
	Penicillin V	Other drugs	Benzafibrat
	Roxithromycin		Carbamazepin
	Sulfadimidin		Clofibrinsäure
	Sulfamethoxazol		Diclofenac
	Trimethoprim		Fenoprofen
	Tylosin		Gemfibrozil
Musks	AHTN		Ibuprofen
	HHCB		Iminostilben
	Keton		Naproxen
	Xylol		Pentoxifyllin
Estrogens	17-alpha-Ethinylestradiol	Flame-retardants	
	17-beta-Estradiol	Bisphenol A	
	Estron		

2.5 Monitoring table – synoptic view monitoring table

Table 4 provides an overview of the investigated emission pathways and the means of assessment employed to obtain knowledge of the immission situation.

Table 4: Monitoring table – overview. The number of sites refer to the sites in the whole Erft catchment, including the Swist catchment. The number in brackets refer to the sites in the Swist catchment.

Emission pathway	Principle	Compartiment	Period of coverage	Number of sites	Analytes	Benefit
Atmospheric deposition on impervious urban areas	Passive sampling: Bergerhoff-method	Dry and wet deposition	12 per year during project time	7 (1)	Cr, Cu, Cd, Pb, Ni, As, Co, Al, Fe, Zn, Ca, Mg, Mn, Hg	Quantifying loads in sewerage systems stemming from atmospheric deposition
Wastewater treatment plant	Grab sampling Continuous recording	Outlet		45 (4)		
Combined sewer overflow	Event-specific (time discretization: 12 min.)	Effluent of drainage systems	During project time	3 (2)	BOD, COD, TOC, oxygen, temperature, conductivity, pH, nutrients, heavy metals, pesticides, pharmaceuticals	Quantifying loads in rivers stemming from combined sewer systems
Separate sewer overflow (Swist river - Miel)	Event-specific (time discretization: 12 min.)	Effluent of drainage systems	Year 2010-2012	1 (1)	BOD, COD, TOC, oxygen, temperature, conductivity, pH, nutrients, heavy metals, pesticides, pharmaceuticals	Quantifying loads in rivers stemming from separate sewer systems
Surface and subsurface runoff from homogenous land surfaces	In-situ passive collector	Overland flow / Interflow	During project time	6 (6)	BOD, COD, TOC, oxygen, temperature, conductivity, pH, nutrients, heavy metals, pesticides, pharmaceuticals	Quantifying loads in rivers stemming from non-urban runoff
Soil filter retention site (Altendorf - Swist river)	Event-specific (time discretization: 12 min.)	In-/ Outflow of soil filters	Year 2010-2012	1 (1)	BOD, COD, TOC, oxygen, temperature, conductivity, pH, nutrients, heavy metals, pesticides, pharmaceuticals	Specifying efficiency of advanced wastewater teatment techniques
sum of precipitation-induced pathways	Event-specific (time discretization: 5 min.)	Rainfall	Permanent	70 (6)	Precipitation height	Quantifying loads in rivers stemming from landscape and urban drainage systems

Immission situation	Principle	Compartiment	Period of coverage	Number of sites	Analytes	Benefit
Routine spot check program	Grab sampling	Water column / River bed	During project time 2-3 / a	64 (6)	BOD, COD, TOC, oxygen, temperature, conductivity, pH, nutrients, heavy metals, pesticides, pathogens, biota	Assessment to water quality information at the beginning / at the end of vegetation period
Online monitoring	On site continuous recording	Water column	During project time	6 (1)	pH, temperature, oxygen, conductivity, turbidity, NO_3, NH_4, ortho-P, Fe, Ni	Assessment to water quality information with various conditions (base flow, flood waves etc.), Calibration of water quality models
Sediment monitoring	Sediment quality with respect to particle size distribution	Sediment	During project 0,5 /a	38 (1)	PAK, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg, Ca, P, ignition loss	Interaction between water column and river bed, Specifying retention reservoir
Soil erosion (Outlet of subcatchment Upper Rotbach river at Schwerfen)	Event-specific (time discretization: 12 min.)	Water column stemming from saturation excess overland flow / Hortonian overland flow	Year 2010-2012	1 (0)	BOD, COD, TOC, oxygen, temperature, conductivity, pH, nutrients, heavy metals, pesticides, pharmaceuticals	Quantifying loads in rivers stemming from soil erosion
Substance accumulation downhill crop land (Rotbach river basin)	Grab sampling	Recent soil surface	Year 2010	1 x 9 (0) 1 x 10 (0)	Heavy metals phosphorus species	Quantifying particle loads stemming from soil erosion
Surface water runoff	On site continuous recording	Water column	Permanent	40 (3)	Water level	Substance load
Micropollutant monitoring	Grab sampling	Outlet / Water column	Autumn 2011 - Summer 2012	15 (15)	pesticides, pharmaceuticals, personal care products	Substance load with various weather conditions