WESS Water & Earth System Science Competence Cluster

Calibration of Turbidity as a Proxy for the Transport of Hydrophobic Contaminants in Rivers

Hermann Rügner, Marc Schwientek

Water & Earth System Science (WESS), University of Tübingen, Germany

Peter Grathwohl

University of Tübingen, Germany

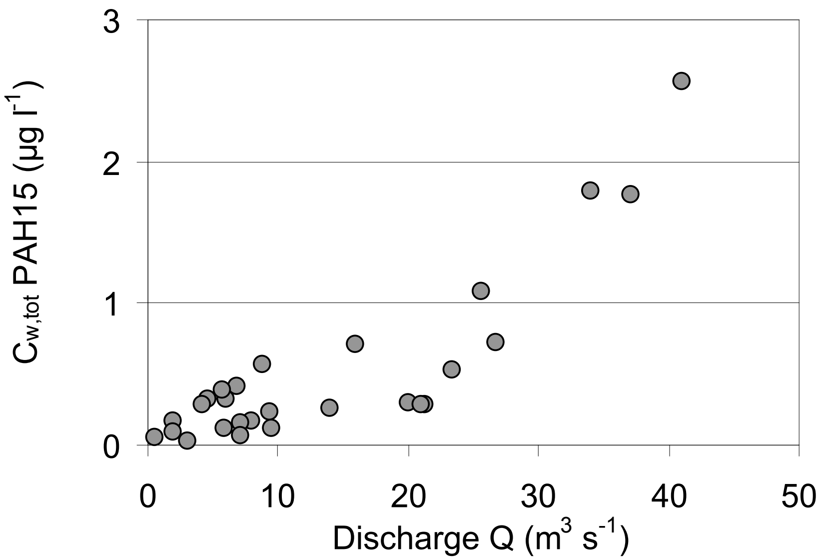
EBERHARD KARLS UNIVERSITÄT TÜBINGEN

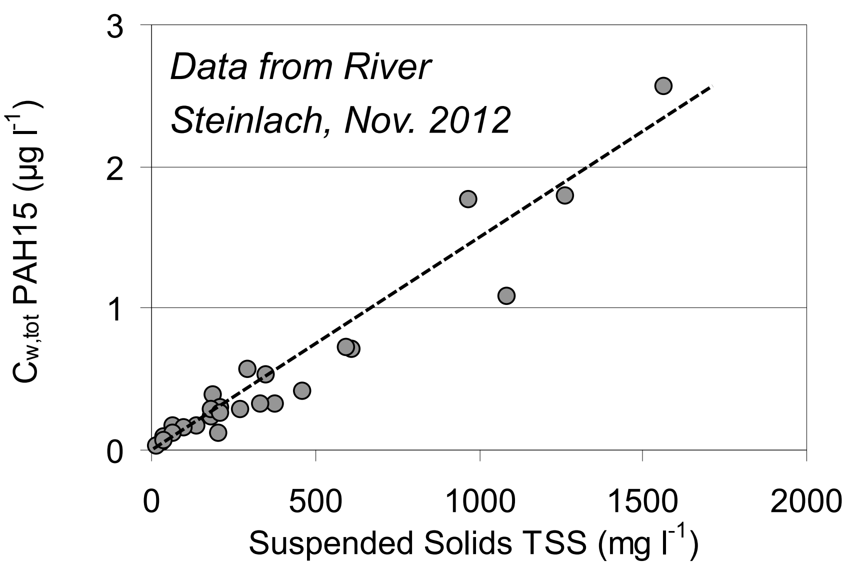
Universität Stuttgart

UNIVERSITÄT HOHENHEIM

HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

Transport of hydrophobic pollutants (e.g. PAHs) → Coupled to particles

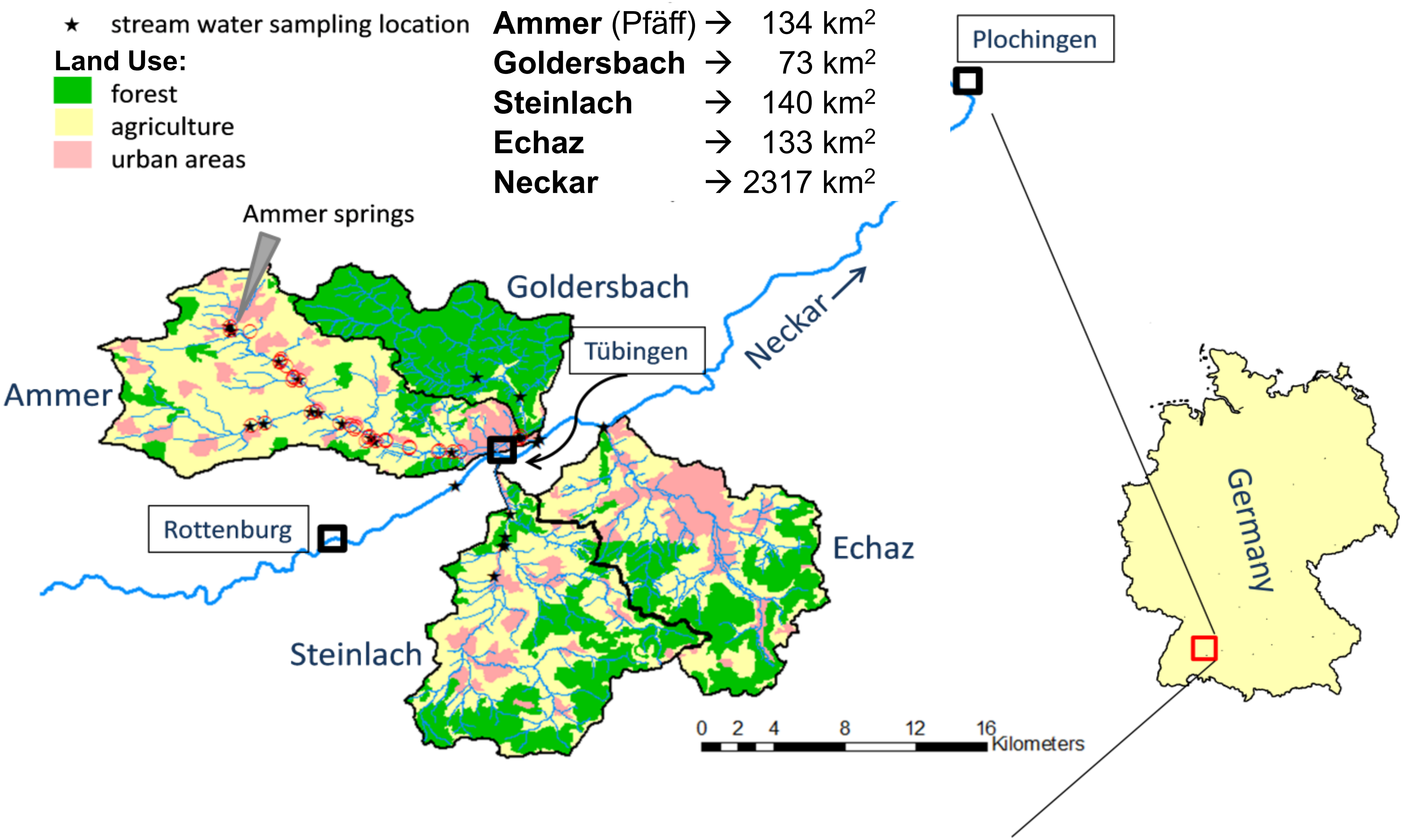




$$C_{w,tot} = C_{w(free)} + C_{sus}\ TSS$$

→ Use of turbidity (cloudiness) as proxy

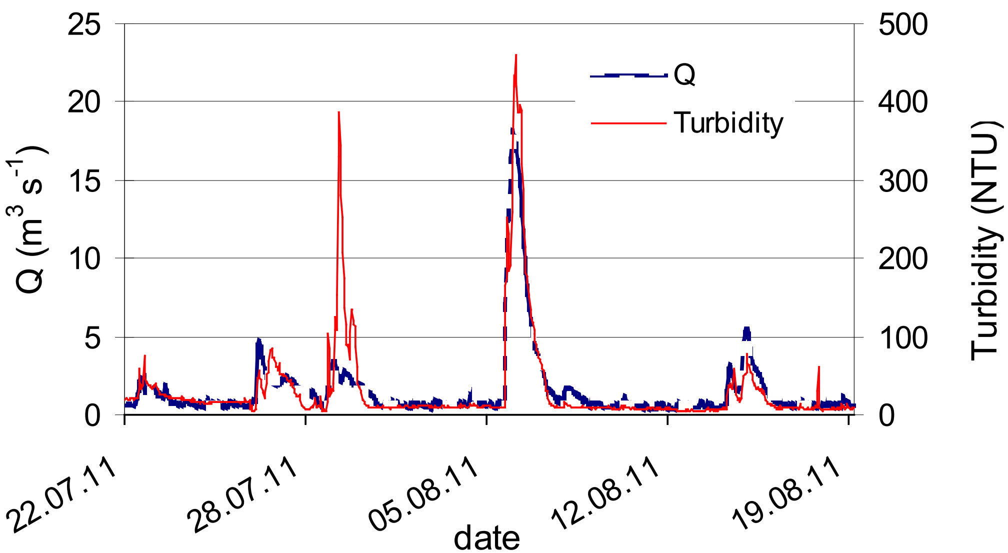
WESS catchments (SW Germany)



Sampling campaigns

→ 1.5 years monthly sampling campaign (#300 samples) 2010-2012 mainly at catchment outlets (Ammer: + further locations) and variable discharge conditions (base flow … floods; *1 - 250 NTU*)

→ Event-based sampling (floods) with automatic samplers at selected gauging stations (#100 samples; *30 - 2200 NTU*)



Analysis:

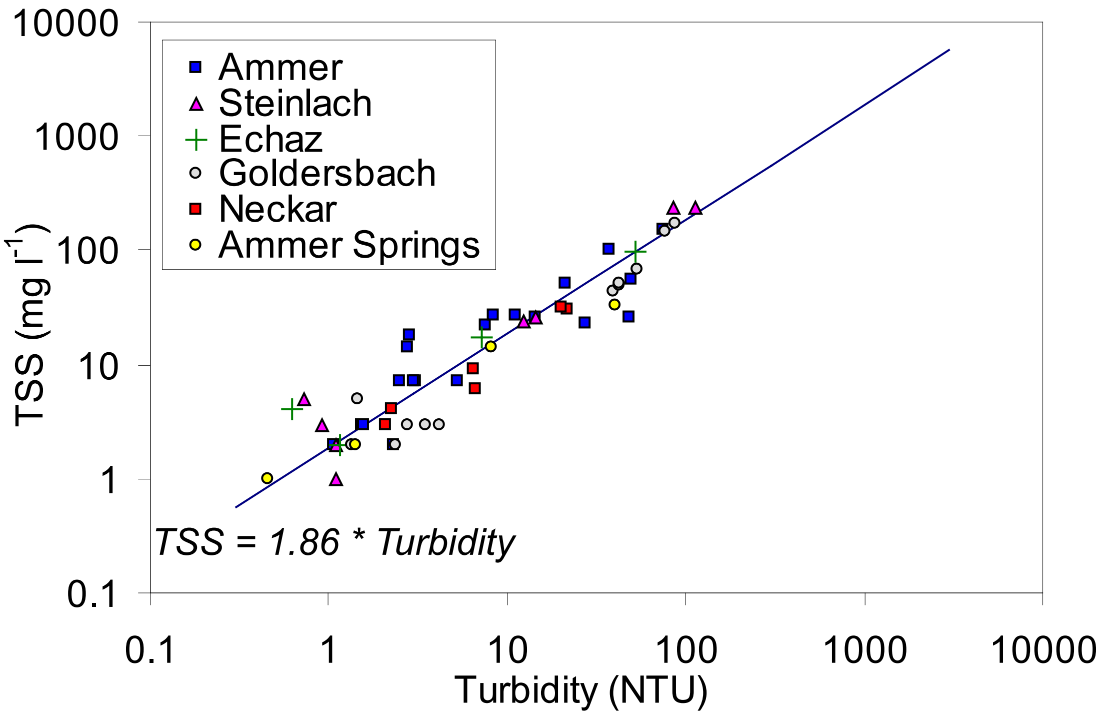
→ Turbidity,

→ Total suspended solids (TSS)

→ PAH (DOC, Ions, Particles,…)

Turbidity as a proxy for total suspended solids (TSS)

→ monthly sampling



→ Linear TSS-turbidity correlation

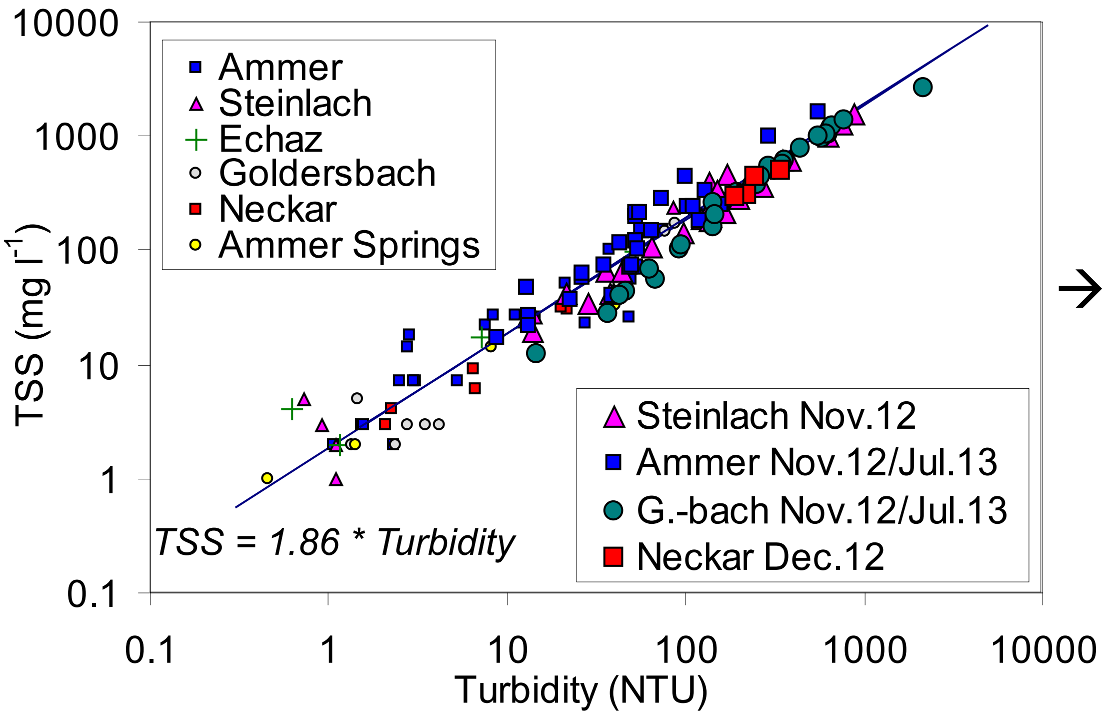
-) slope (m) = 1-2.7 (mg l^{-1} NTU^{-1})

-) good agreement with literature data

Turbidity as a proxy for total suspended solids (TSS)

→ monthly sampling

→ plus event-based sampling



→ Linear TSS-turbidity correlation

-) slope (m) = 1-2.7 (mg l^{-1} NTU^{-1})

-) good agreement with literature data

→ Established correlations

-) hold for high discharge events (> 2.000 NTU)

-) are similar for all catchments investigated

→ Turbidity may serve as a proxy for TSS in rivers

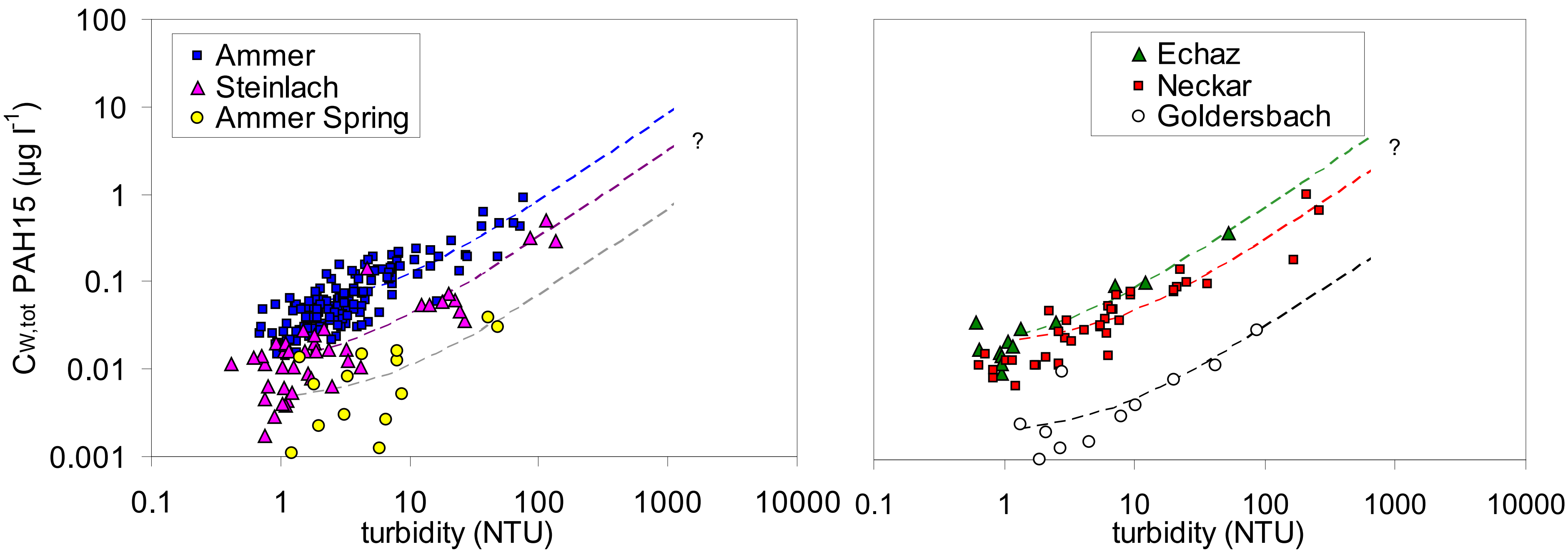
Rügner et al. (2014): Sci. Total Environ. (accepted).

WESS Water & Earth System Science Competence Cluster

Turbidity as a proxy for total PAH concentration

Monthly sampling campaigns

→ $C_{w,tot} = C_w + C_{sus} * m * turbidity$



→ C_{sus} different for different catchments

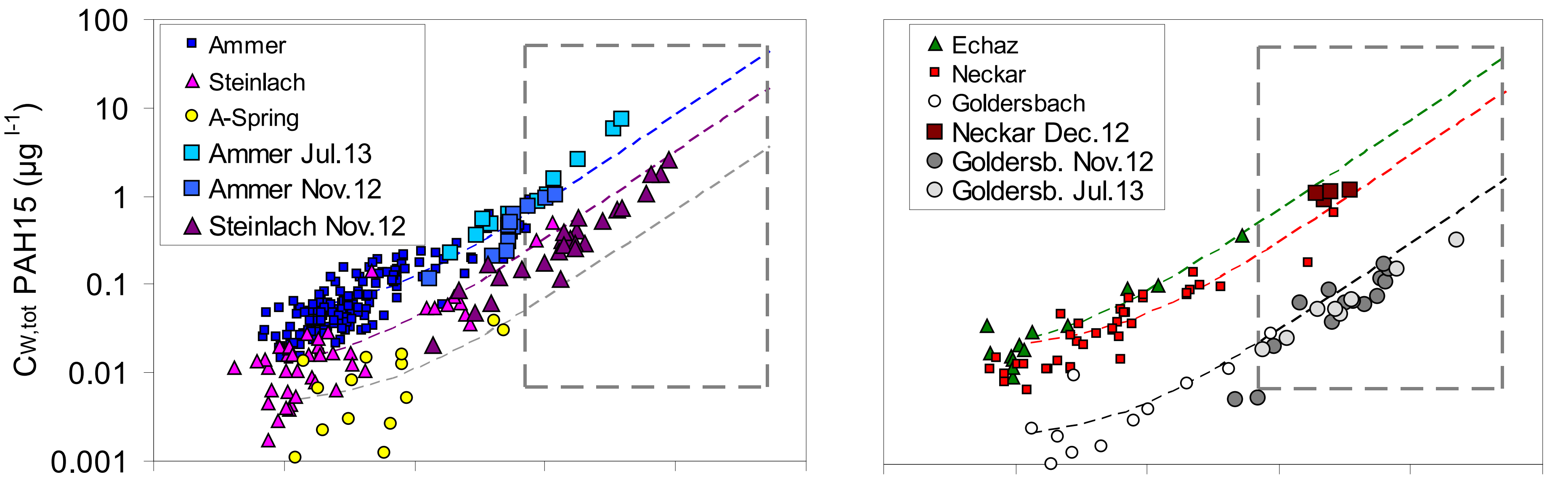
	Ammer	Echaz	Neckar	Steinlach	A-Spring	Goldersbach
C_{sus} (mg kg^{-1})	**5.4**	**2.9**	**2.6**	**1.4**	**0.75**	**0.13**
m (mg l^{-1} NTU^{-1})	2.7	2.4	1.5	1.7	1.0	1.4

Turbidity as a proxy for total PAH concentration

Monthly sampling campaigns

Events (floods; *30-2.200 NTU*)

→ $C_{w,tot} = C_w + C_{sus} * m * turbidity$



→ Why is C_{sus} different / catchment specific?

→ What are PAH sources and pathways?

	Ammer	Echaz	Neckar	Steinlach	A-Spring	Goldersbach
C_{sus} (mg kg^{-1})	**5.4**	**2.9**	**2.6**	**1.4**	**0.75**	**0.13**
m (mg l^{-1} NTU^{-1})	2.7	2.4	1.5	1.7	1.0	1.4

Rügner et al. (2014): Sci. Total Environ. (accepted).

PAHs: Sources and Pathways

Atmospheric deposition

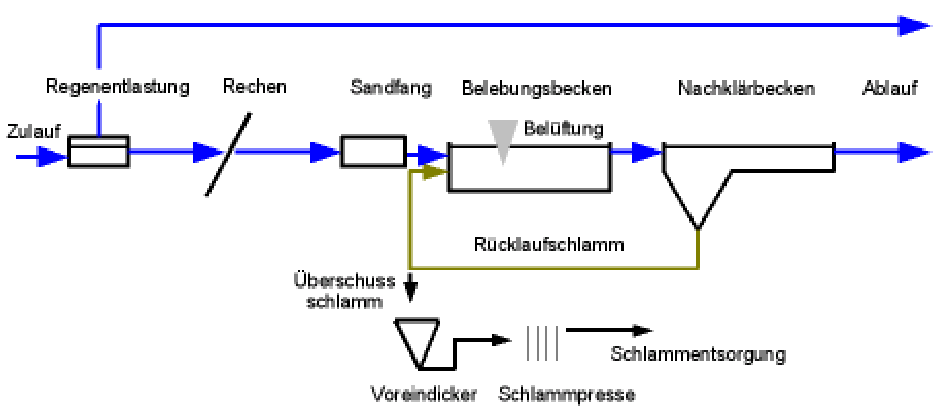
Urban/industrial areas

High PAH emission

Run-off from urban surfaces

Sewer system

Sewer overflow



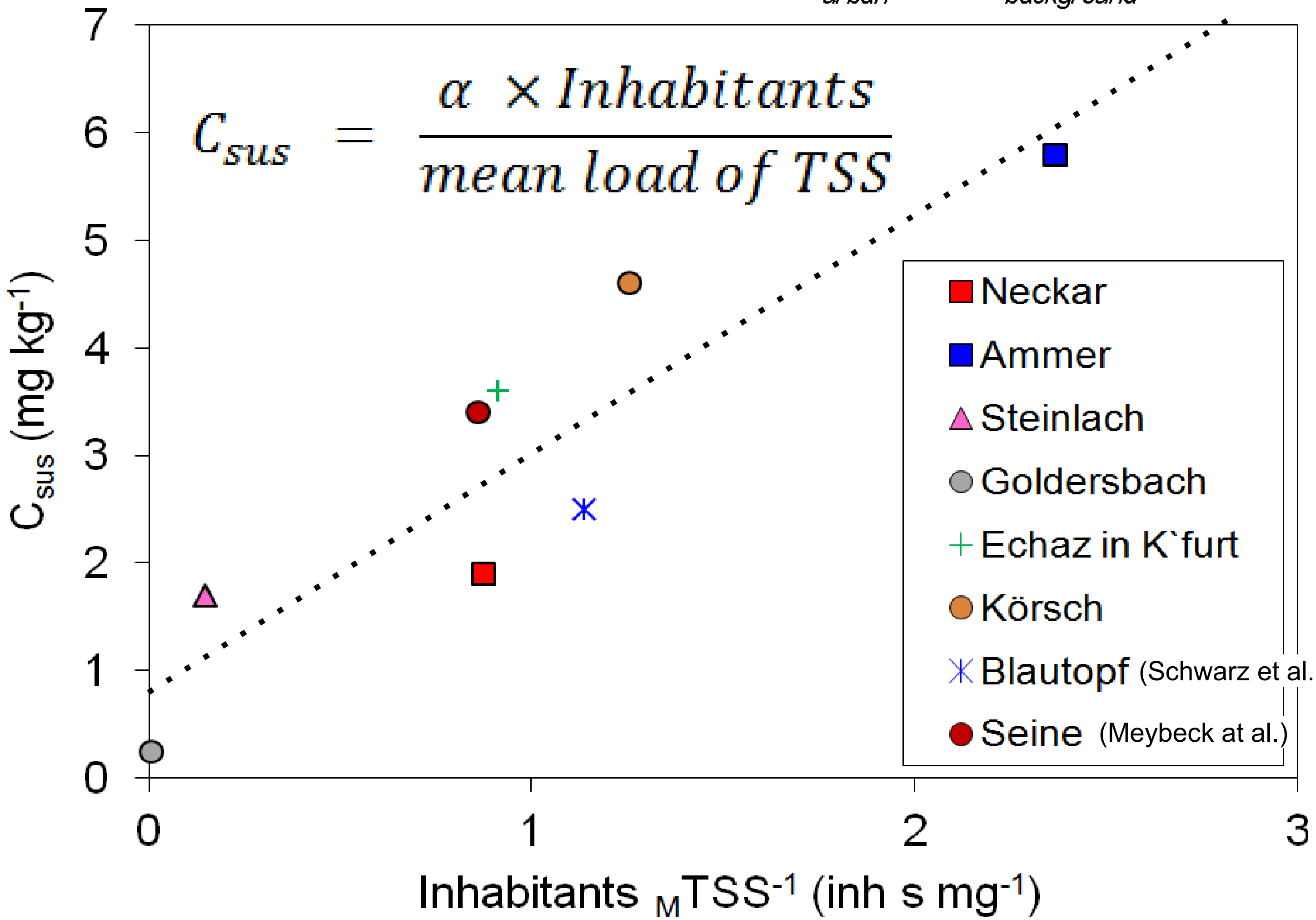
WWTP

Rivers

What governs concentration of PAHs on suspended solids?

Urban pressure/particle flux:

$$C_s = \frac{C_{s,urban}\,TSS_{urban} + C_{s,background}\,TSS_{background}}{TSS_{urban} + TSS_{background}}$$



Testing the hypothesis: Ammer River

Measured concentrations (Ammer)

C_{sus} (Ammer, suspended solids): 5.4 mg kg^{-1} (this study)

$C_{S\ MEAN}$ (Ammer sediments): 8.6 mg kg^{-1} (Liu, Rügner, Schwientek et al. 2013)

C_{sus} calculated from atmospheric deposition (Ammer, urban space)

$$C_{sus} = \frac{urban\ atmospheric\ deposition \times urban\ area}{mean\ load\ of\ TSS}$$

urban atmospheric deposition: 1 µg m^{-2} day^{-1} (Tübingen area, Gocht & Grathwohl 2004)

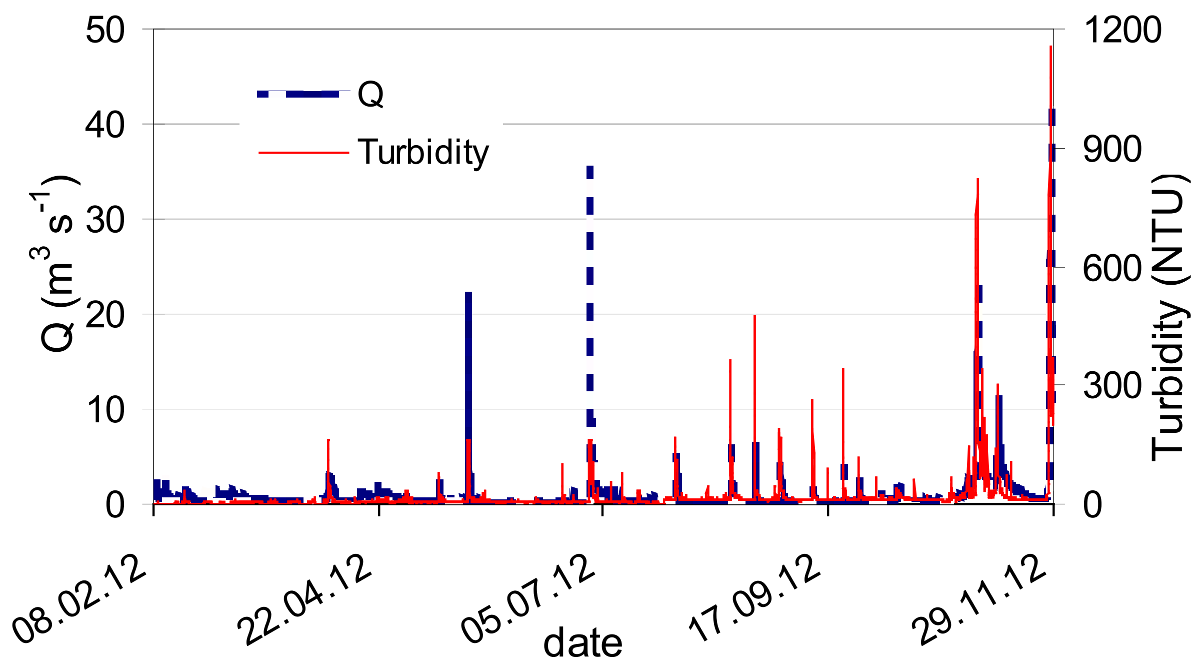
urban area in Ammer catchment: 23 * 10^{6} m^{2} (Gauge Pfäffingen)

mean load of TSS (2012): 3150 kg day^{-1}

$$C_{sus} = \frac{1 \cdot 10^{-3}\ [\mathrm{mg\ m^{-2}\ day^{-1}}] \cdot 23 \cdot 10^{6}\ [\mathrm{m^{2}}]}{3150\ [\mathrm{kg\ day^{-1}}]} \qquad C_{sus} = 7.2\ \mathrm{mg\ kg^{-1}}$$

On-line Turbidity Measurements

On-line turbidity sensors ⟹ Q + turbidity curves (Steinlach, Feb.-Nov. 2012)



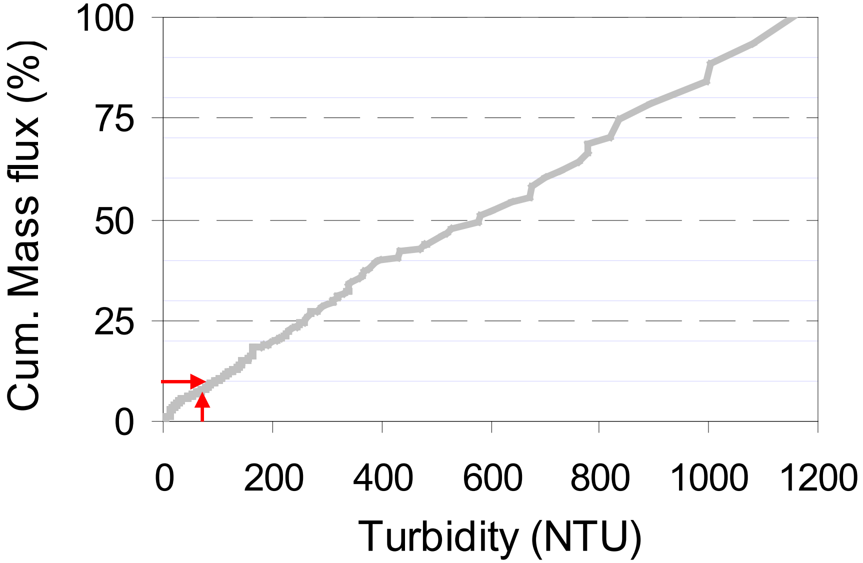
→ Turbidity: few major events, usually discharge related

→ These events should not be missed!

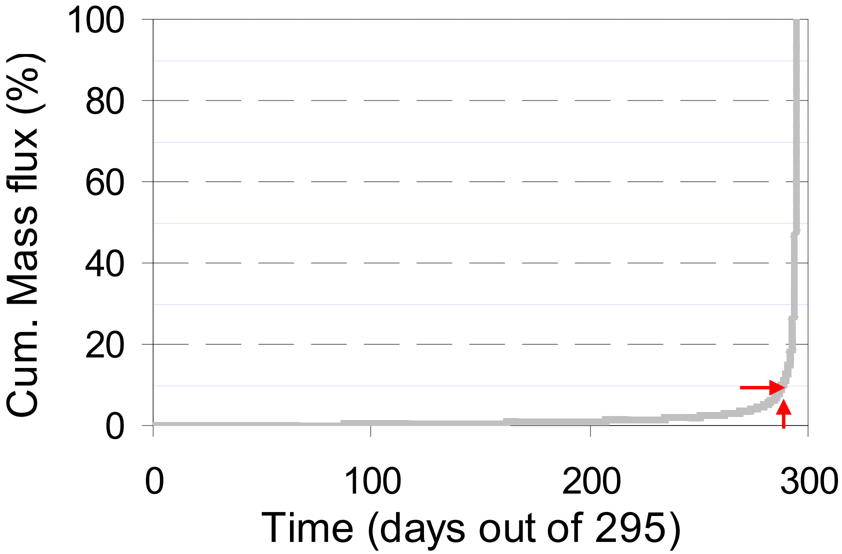
Short-Term Events and Pollutant Mass Flux

⇓ ⇓

Cumulative mass flux vs. turbidity



Cumulative mass flux vs. time



→ High turbidity/discharge events account for major proportion of pollutant fluxes (90% PAH flux > 90 NTU)

→ These are short-term events: 90% PAH flux within 7 days - out of 295 (< 2.5 % of observed time period)

Conclusions

- Turbidity is an easy to monitor proxy for concentration of total suspended solids (TSS) and hydrophobic pollutants (e.g. PAH).
- Robust linear correlations of total PAHs versus turbidity (or TSS) are obtained.
- Slopes represent contamination of suspended particles..
- …which are catchment specific and increase with urban pressure per sediment flux.
- On-line turbidity measurements are needed to obtain reliable estimates of pollutant fluxes because of short term turbidity events.

Rügner et al. (2013): Environ. Earth Sci. 69(2), 373-380.
Schwientek et al. (2013): Environmental Pollution, 172, 155-162.
Rügner et al. (2014): Science of the Total Environment, 490, 191–198.

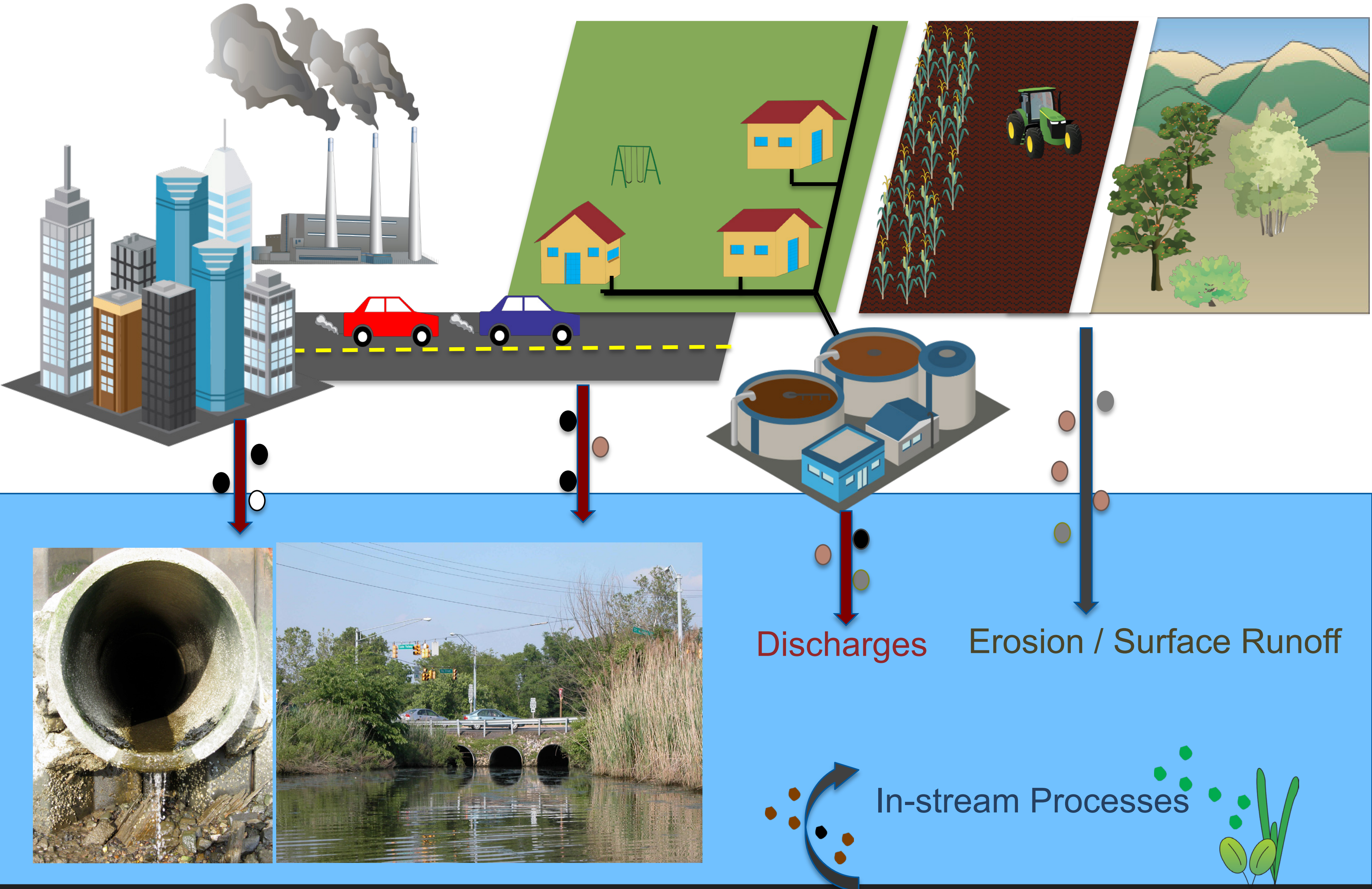
Acknowledgement:

WESS Cluster (funded by the Helmholtz-Centre for Environmental Research, UFZ, and the Ministry for Science, Research and Arts Baden-Württemberg

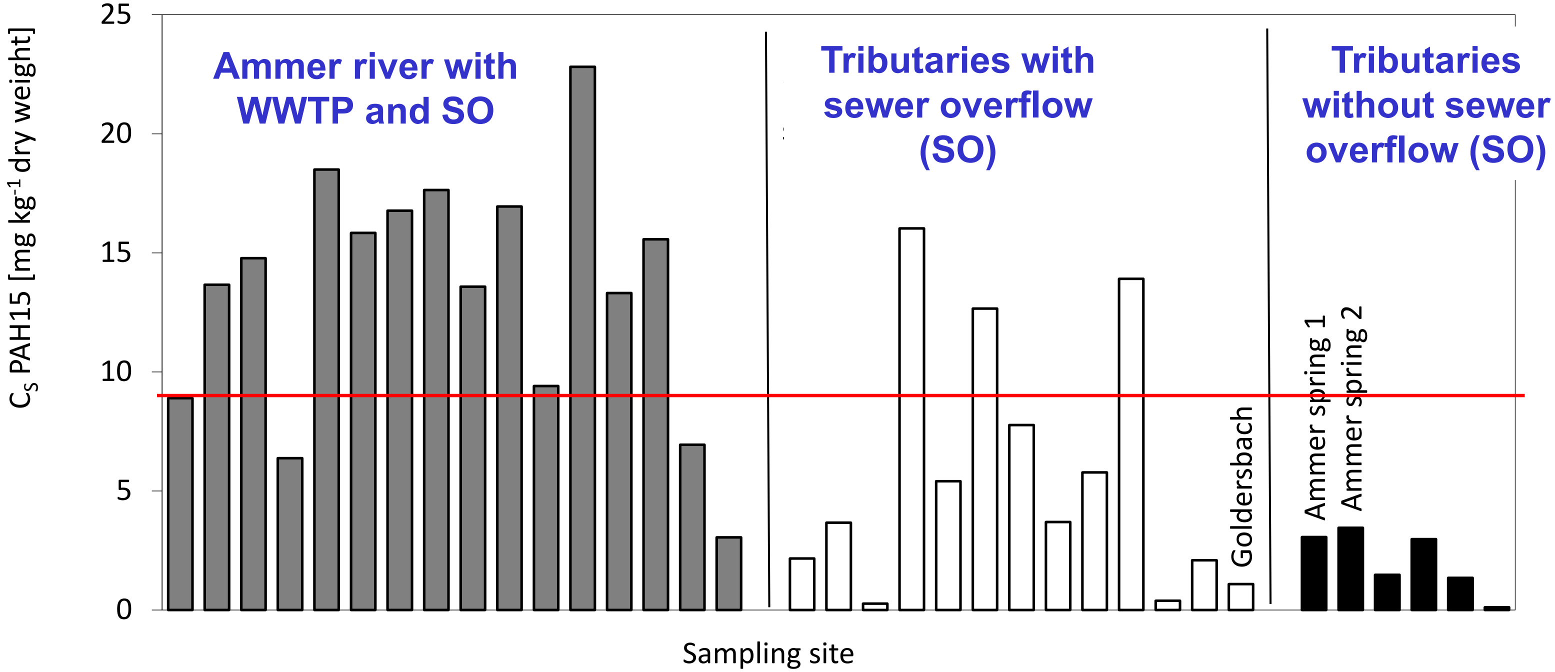
GLOBAQUA Project (funded by the European Communities 7th Framework Program: Grant Agreement no 603629-ENV-2013-6.2.1)

GLOBAQUA

Landscapes export particles



Sources: PAH concentrations in Ammer sediments

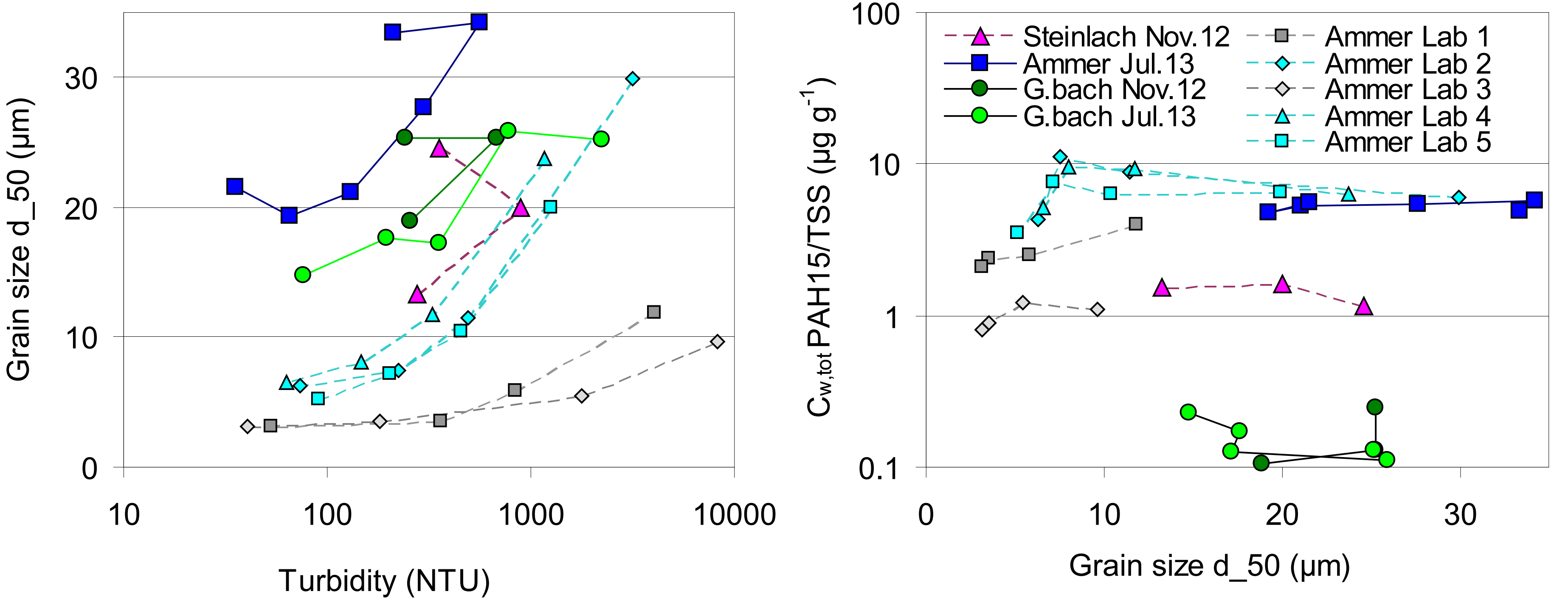


PAH (mg/Kg)	Ammer (channel)	Tributaries with SO	Tributaries without SO	Ammer (all)
Mean	13,4	5,8	2,1	8,6
Std.dev.	5,0	5,1	1,2	6,5
Mean f_oc	2,5%	2,0%	1,9%	2,2%

→ Strong heterogeneity of PAH concentrations

→ Urban source: sewer overflows

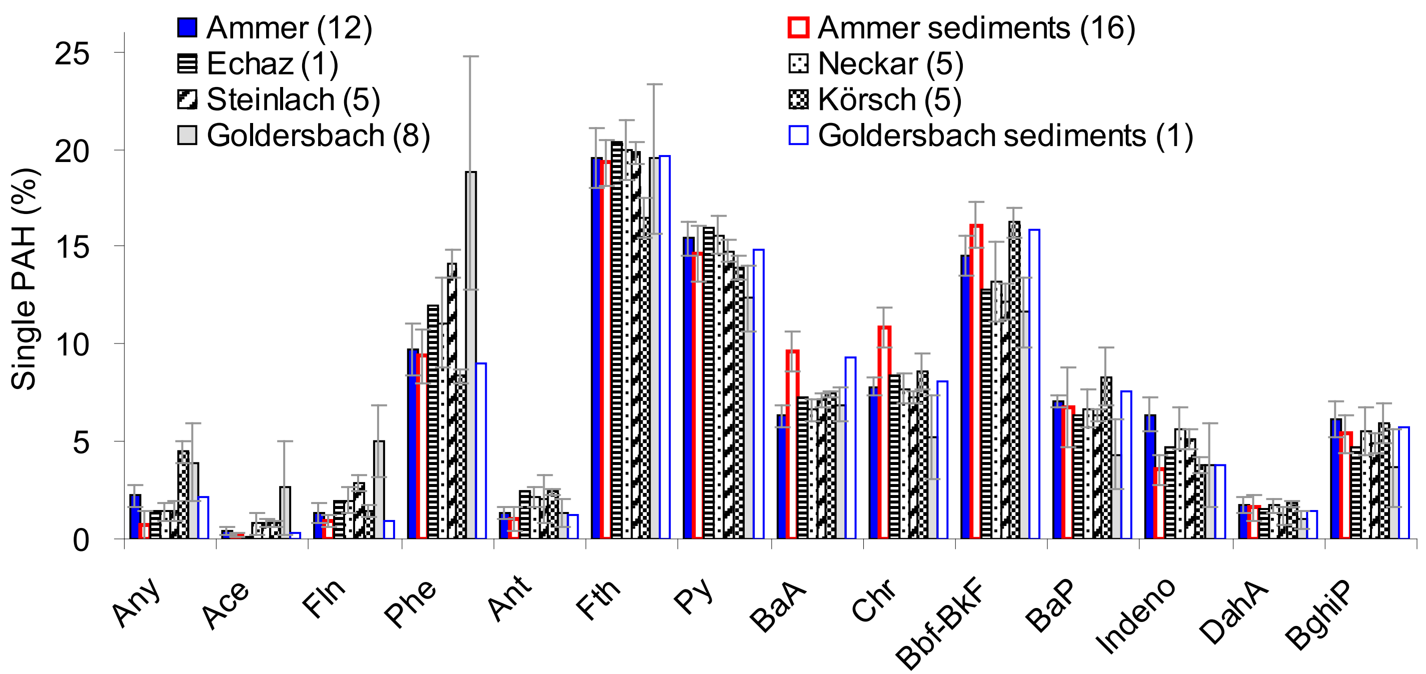
PAH Concentrations vs. Turbidy and Particle Size



➔ PAH concentrations does not significantly change with particle size

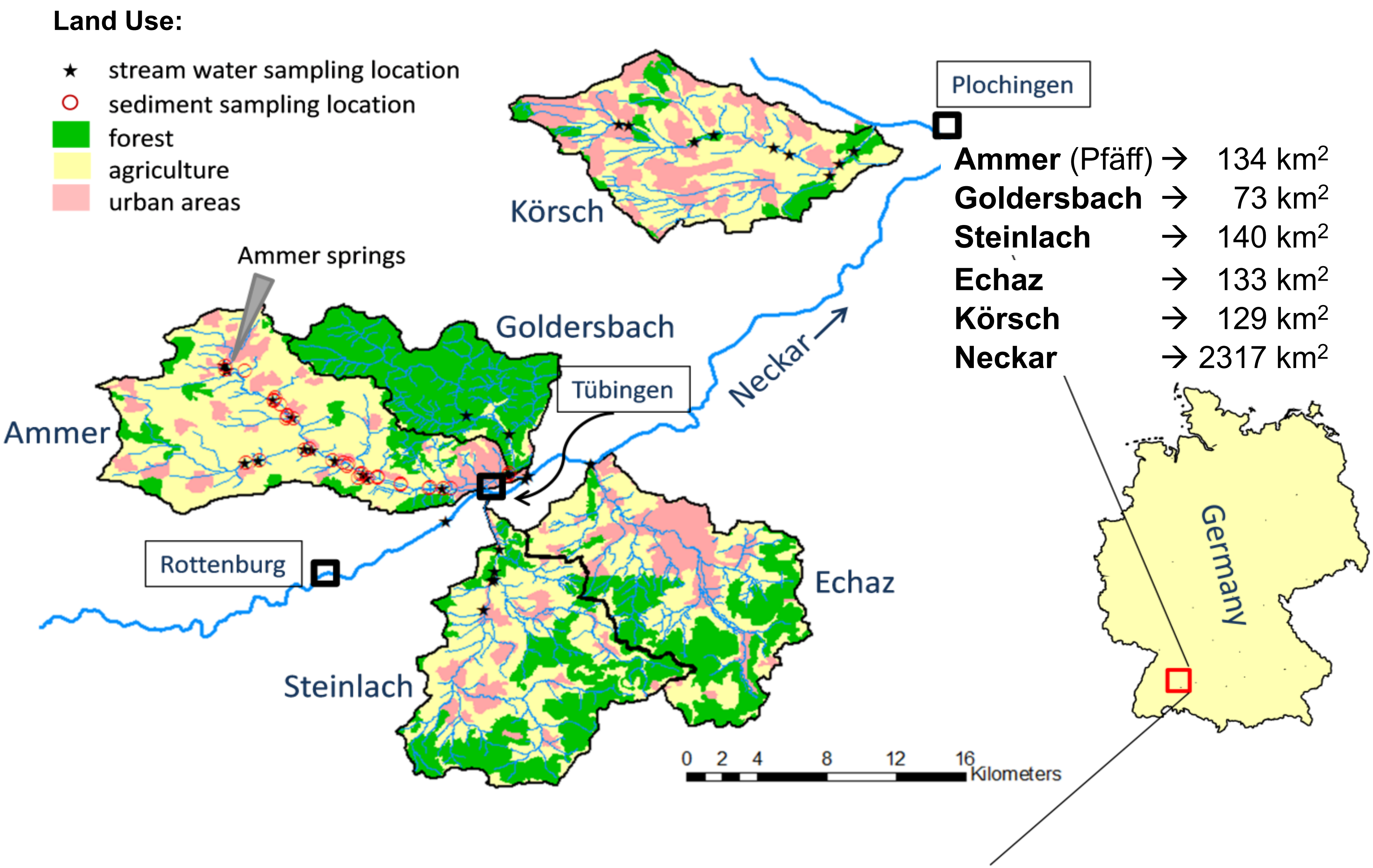
Rügner et al. (2014): Sci. Total Environ. (accepted).

PAH Distribution Patterns



"PAH distribution patterns in sediment samples and liquid-liquid extracted samples (for TSS > 47 mg l-1 in Körsch or turbidity > 25 NTU in other catchments). Number of samples considered given in brackets."

WESS catchments (SW Germany)



Ammer (Pfäff) → 134 km^2
Goldersbach → 73 km^2
Steinlach → 140 km^2
Echaz → 133 km^2
Körsch → 129 km^2
Neckar → 2317 km^2