

How much SPM enters long-term in-channel storage?

**Monitoring sediments
contaminated by an PCB incident**

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Motivation – or why to use PCBs as unique tracer experiment

Routing of SPM

..... **transport times and periods with resting times** in deposits e.g. areas with low-flow conditions close to the channel bed.

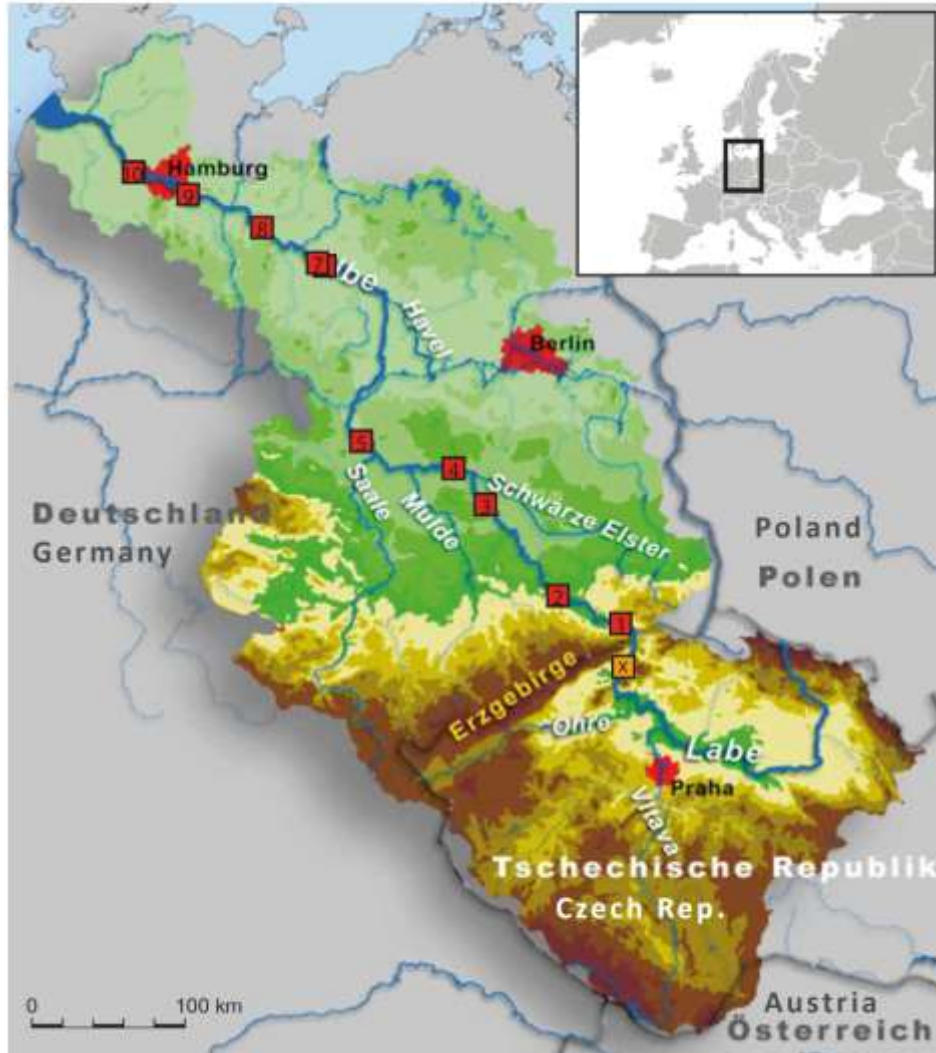
Unique tracer for transport

..... **transport pathways of SPM along the entire river stretch** (over 700 km length), including low mountain ranges, lowlands, and the estuary.

Low-discharge conditions.

In 2015 the Elbe River was characterized by **low-discharge conditions**. Thus, the **export of SPM on flood plains** was strongly limited. Possibility for **near/in-channel storage of SPM?**

Monitoring within the Elbe Catchment



Map of the Elbe river in Central Europe with its catchment and topography including the incident site (x) as well as the major stations (FGG Elbe, BfG).

Monitoring of the PCB incident

	Station 0	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9
km UnL	27	43	129	212	256	357	509	514	625	649
site	Decin	Schmilka	Zehren	Dommitzsch	Wittenberg	Magdeburg	Cumlosen	Schnackenburg	Geesth. Wehr	Bunthaus
Elbe-km	-12	4	90	173	217	318	470	475	586	610
Jan_15	178	87	112	64	51	38	45	34	45	26
Feb_15	68	289	107	81	62	31	59	41		22
Mar_15	204	662	430	173	85		52	46		23
Apr_15	1710	1600	709	372	337		64	57		25
May_15	3730	6010	1621	741	479	84	95	103		33
Jun_15	3600	1840	1133	697	460	50	63	54		22
Jul_15	1450	1080	771	518	386	57	42	103	73	
Aug_15	1440	1090	497	464	322	67	59	58	54	18
Sep_15	1260	666	467	331	354	72	102	90	39	20
Oct_15	1410	541	525	381	453	76	115	65	36	
Nov_15	1480	512	331	233	478	76	142	73	38	38
Dec_15	1990	1140	535	344	439	73	134	118	53	49
Jan_16	1800	530							62	
Feb_16	910	300							63	
Mar_16	850	290							62	
Apr_16	870	310							62	
May_16	620	280							54	
Jun_16	1000	200							35	

- no congener > 20 µg/kg
- sum 6 PCB ≤ 120 µg/kg, but min one congenere > 20 µg/kg
- sum 6 PCB ≤ 1200 µg/kg
- sum 6 PCB > 1200 µg/kg
- sum 6 PCB > 6000 µg/kg

Most of the data are provided by FGG Elbe and ELSA, Geesthacht is measured by the BfG



Research questions - Methods

Method 1 – How fast ...

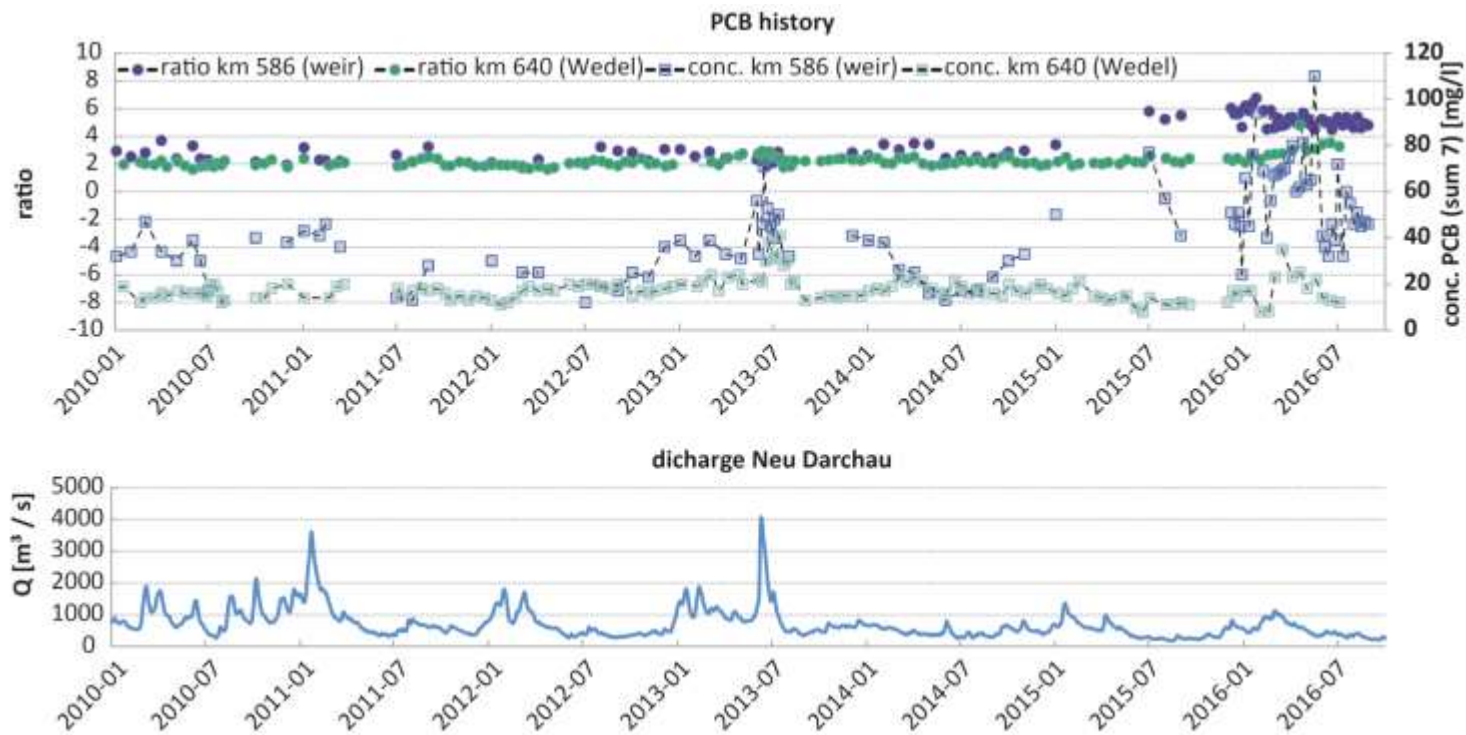
- Proxy for suspended load transport: PCB ratio (chemical fingerprint)
- Estimation of average transport velocities

Method 2 – How much ...

- Measurement of the monthly PCB loads
- Where and how much of the PCB-marked SPM has settled?

PCB6 ratio and concentration

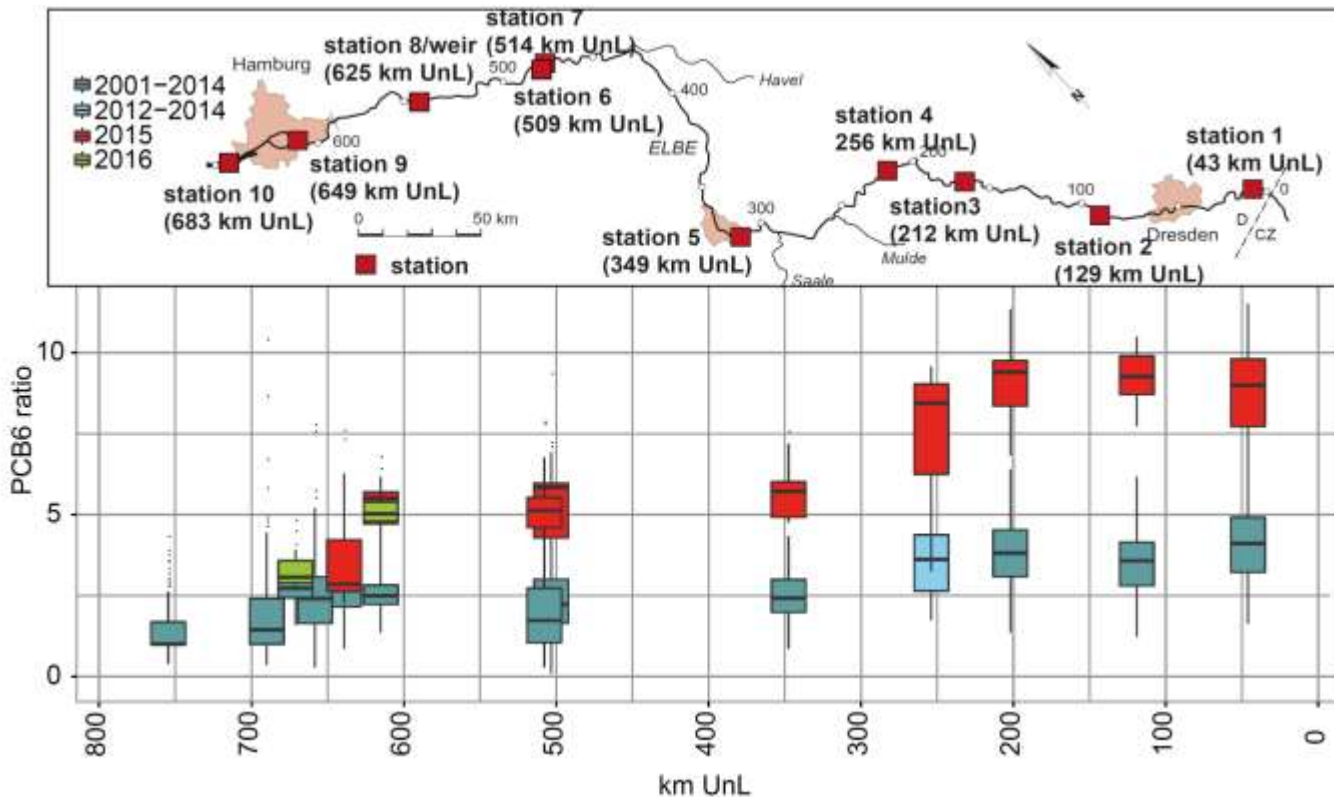
The PCB6 ratio as a chemical fingerprint



Time series for both, PCB6 ratio and concentration for the tidal weir Geesthacht (614 km UnL) and Wedel (683 km UnL; within the estuary) as well as river discharge.

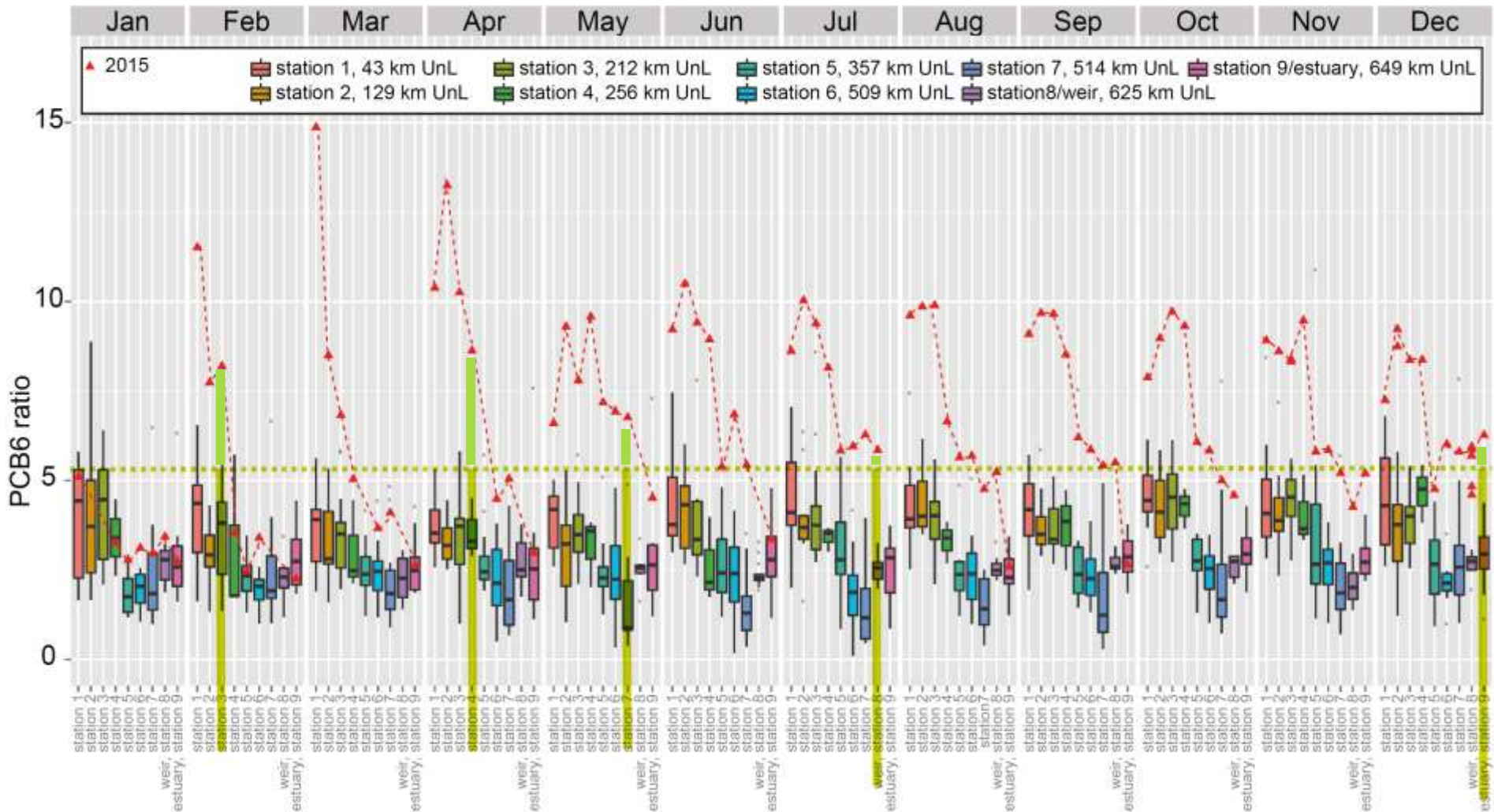
Flood events increase the PCB concentration but does not affect the PCB6 ratio.

Annual distribution of PCB6 ratios along the Elbe river



Longitudinal development of the PCB6 ratios (2015/16 vs long-term background)

Monthly migration of PCB-tagged suspension along the river



Research questions - Methods

Method 1 – How fast ...

- Proxy for suspended load transport: PCB ratio (chemical fingerprint)
- Estimation of average transport velocities

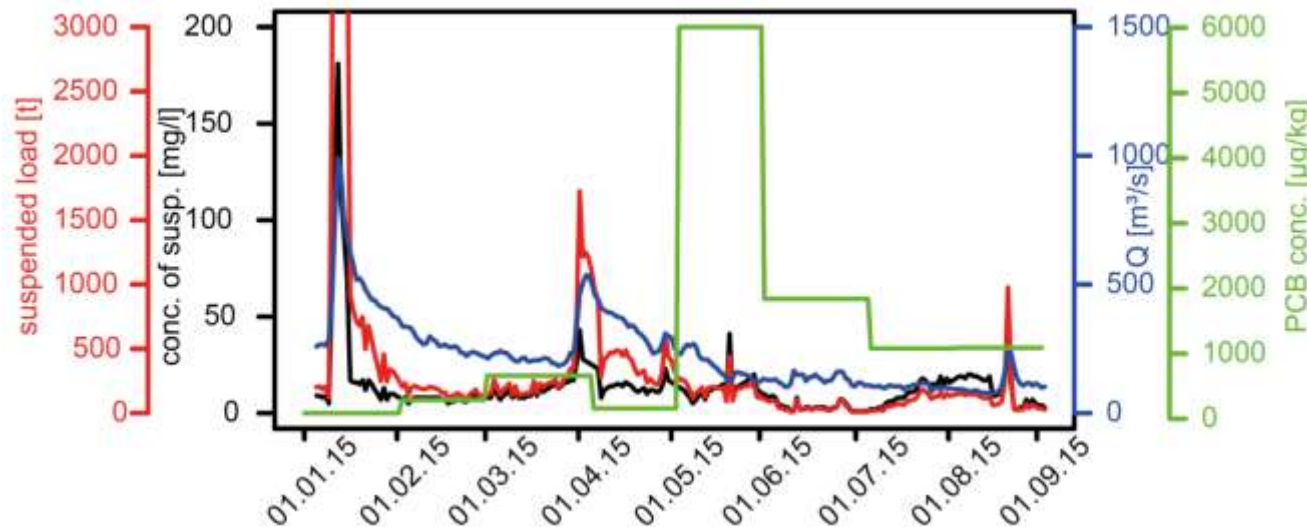
Method 2 – How much ...

- Measurement of the monthly PCB loads
- Where and how much of the PCB-marked SPM has settled?

Calculation of the PCB load

1. Load Calculation according to IKSE, 2014

$$F_{PCB} = \sum_{i=1}^n C_{i(PCB)} \cdot \underbrace{SBZR_i}_{\text{monthly suspended load}}$$

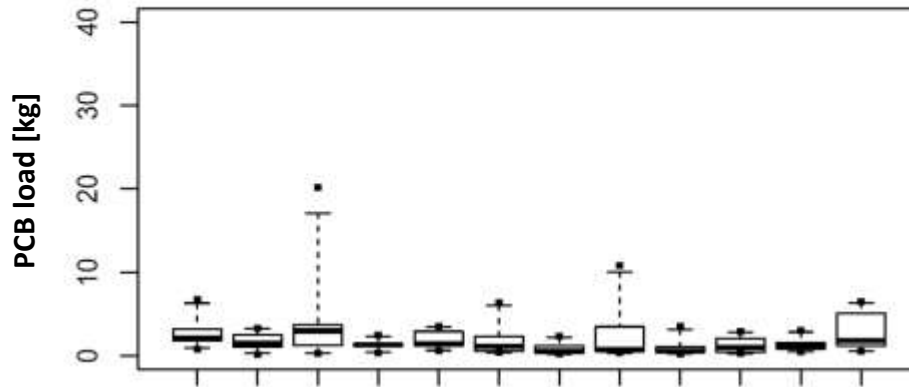


2. Estimation of uncertainties via Monte Carlo Experiments

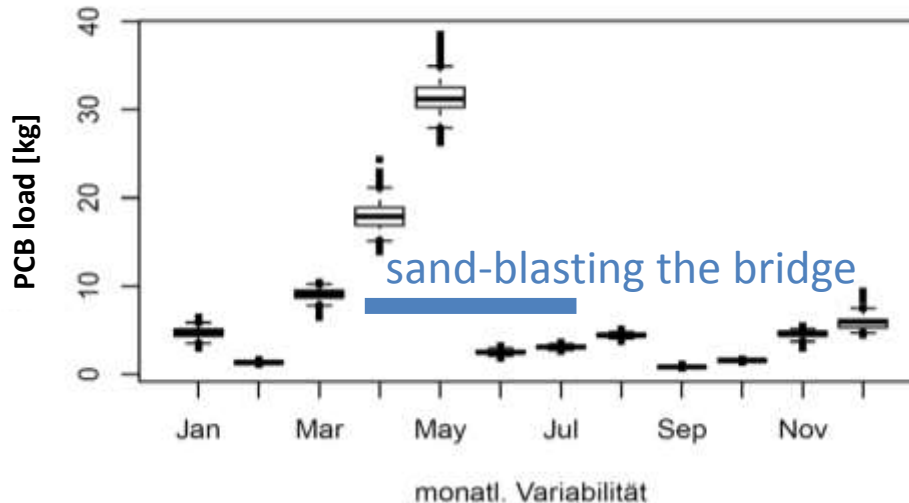
Monthly distribution of PCB load

Station 1 „Schmilka“ ...

monthly variability of PCB load 2006 -2014 | Schmilka



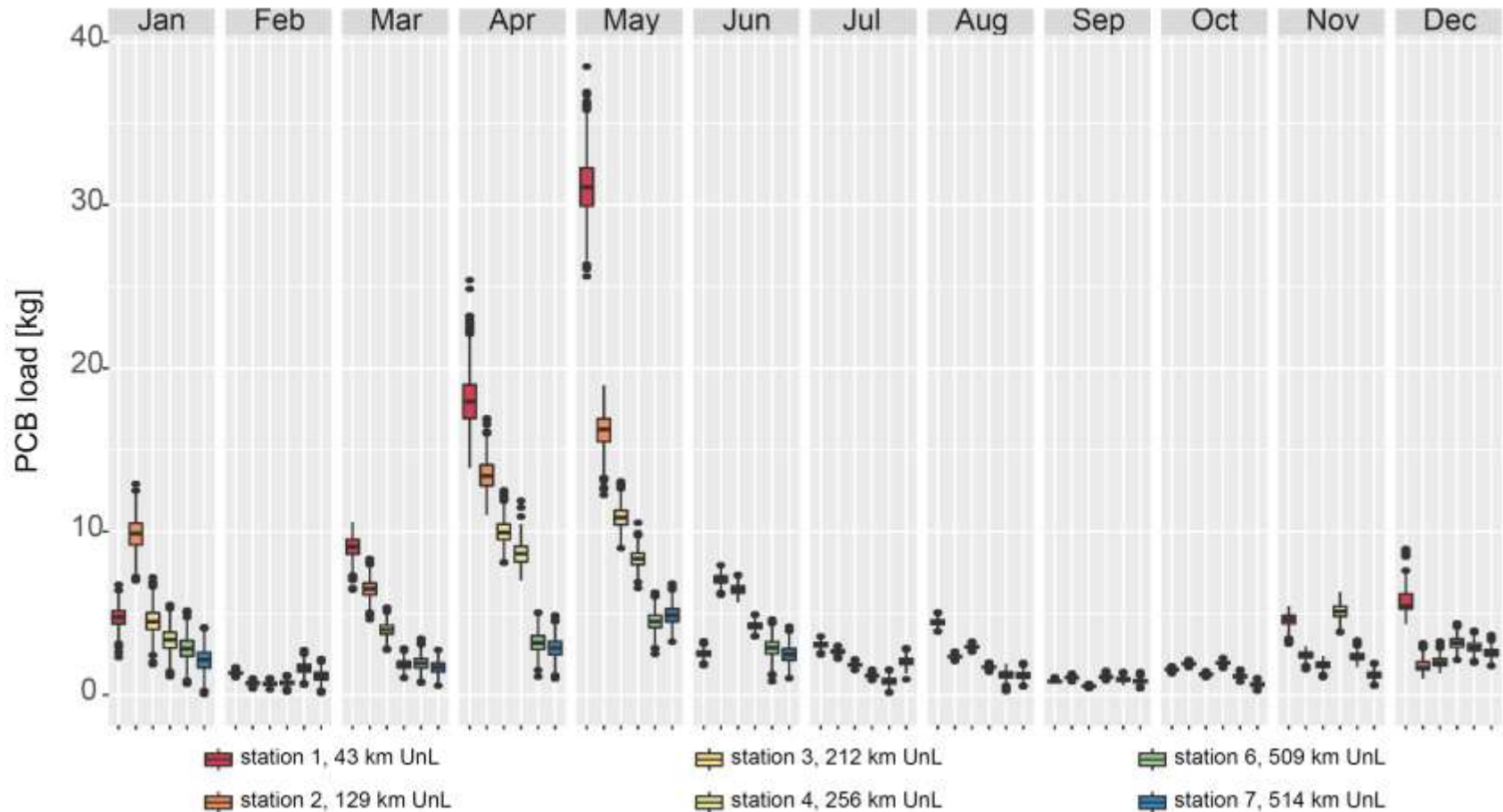
monthly variability of PCB load 2015 | Schmilka



	Median	25%-75%-Quantil
ann. mean 2006-2014	16,5 kg	11,0 – 30,8 kg
April-June 2016-2014	3,9 kg	3,0 – 6,8 kg
ann. mean 2015	87,2 kg	75,0 – 100,2 kg
April-June 2015	51,6 kg	45,1 – 59,1 kg

Monthly distribution of PCB load

Not only for station 1 but for all stations ...



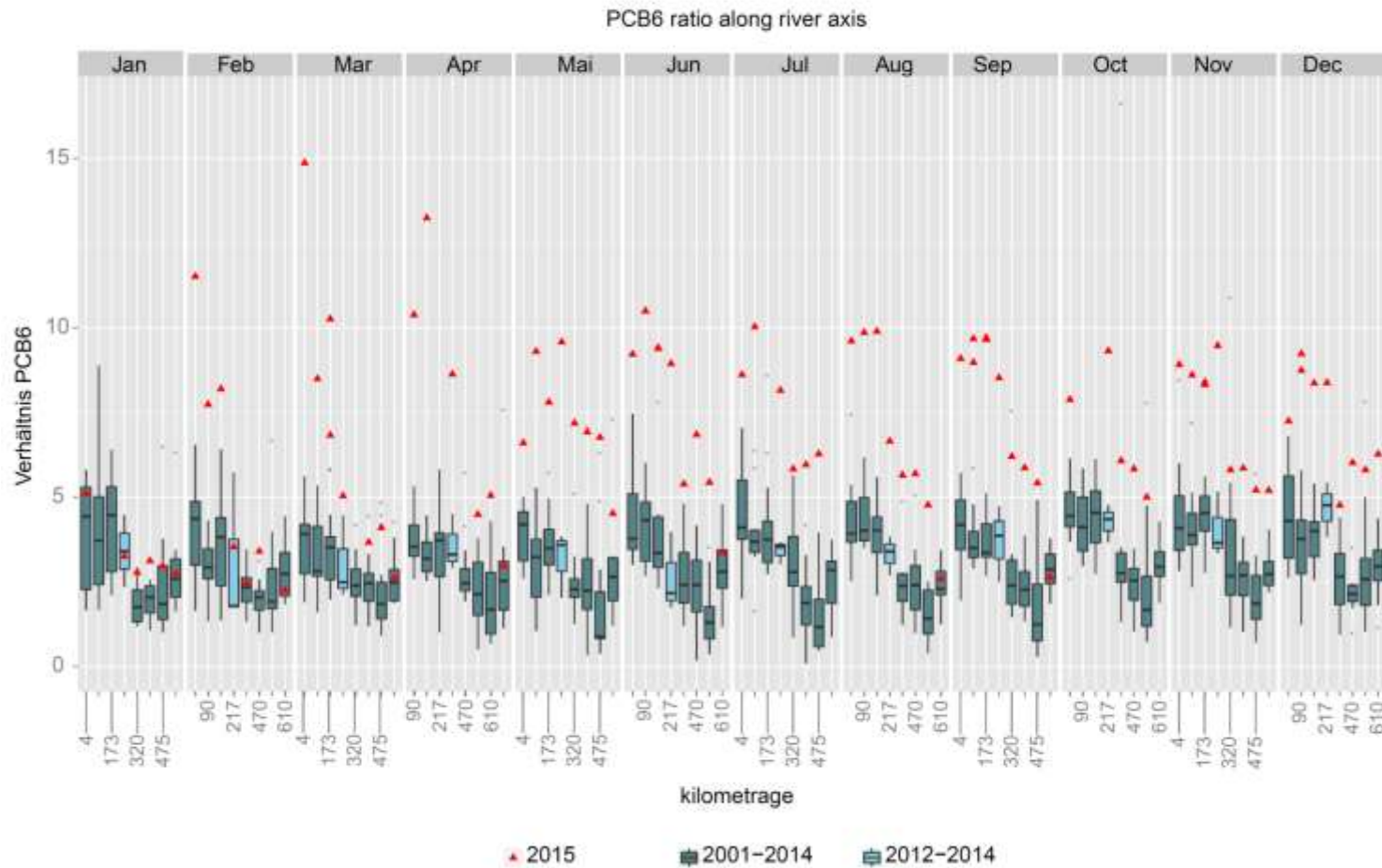
Where and how much of the PCB-marked SPM has settled?

	station 1 43 km UnL	station 2 129 km UnL	station 3 212 km UnL	station 4 256 km UnL	station 6 509 km UnL	station 7 514 km UnL	sum
F [kg]	87.2	66.1	46.9	41.4	26.5	23.7	
ΔF [kg]		21.1	19.2	5.5	14.9	2.8	63.5
$\Delta F_{\text{station 1}}$ [%]		24%	22%	6%	17%	3%	73%

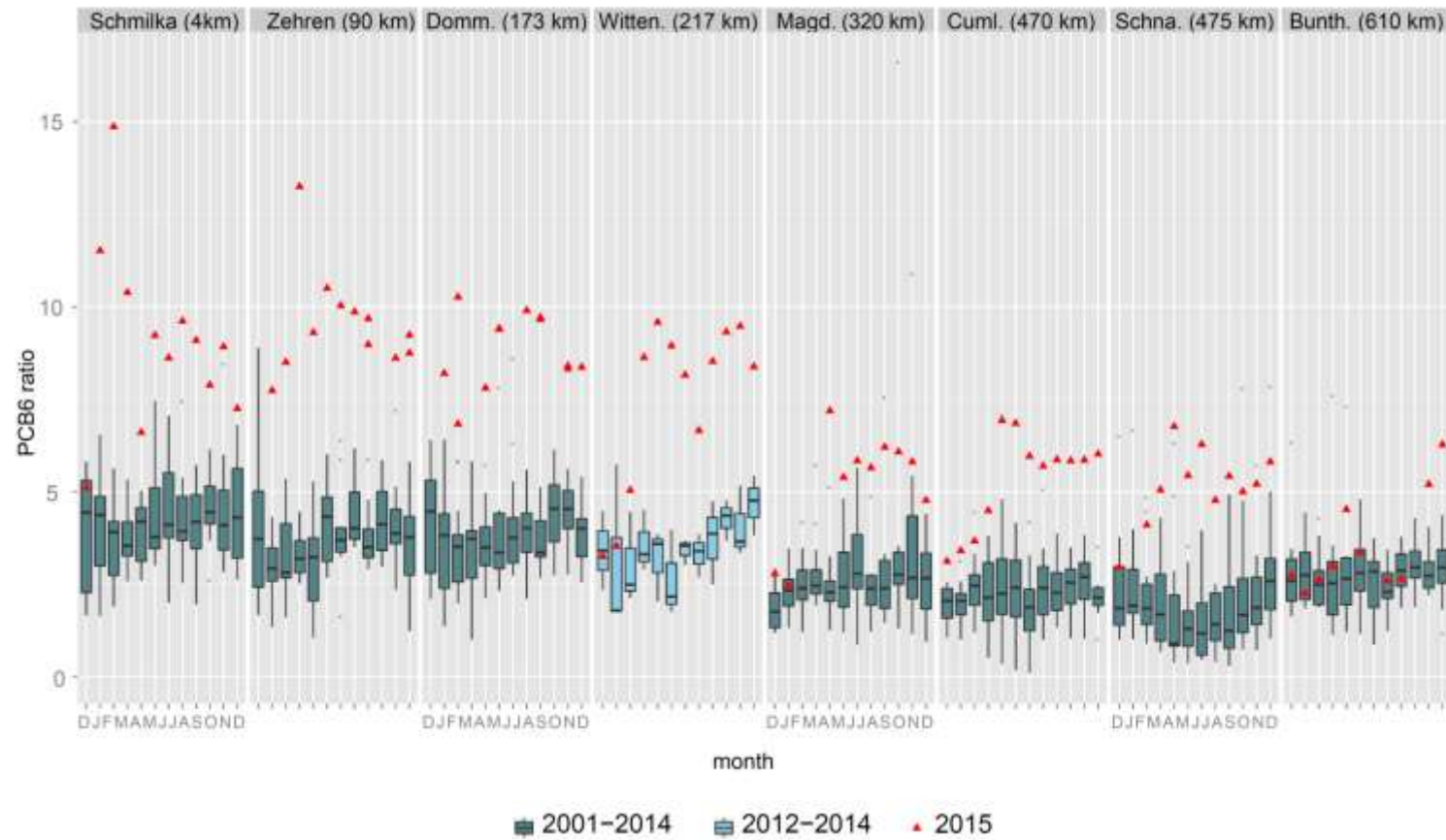
- Significant reduction of total PCB tagged SPM load within the first 514 km downstream of the incident site
- Roughly 73% of the annual SPM load (relative to station 1 “Schmilka”, 43 km down stream of the incident site) is stored in the sediments of the Elbe River
- SPM in transport enters storage after a relatively short distance/time.

Conclusions

- A direct transport of **wash load** via the mean flow velocity of the water **was not observed** (data gap at Geesthacht weir).
 - in **July 2015 PCB tagged SPM** reaches the tidal weir at Geesthacht, 626 km downstream and enters the estuary.
 - Within the **tidal Elbe river the transport velocity strongly decreases** and the PCB6 ratio was not detected 25 km downstream the tidal weir before December 2015.
- The **major part** of the PCB-marked suspension is transported via **suspended load**.
 - Roughly **73% of the annual SPM load is stored in the sediments** of the Elbe River, suggesting that suspended sediment in transport **enters storage after a relatively short distance**.
 - Once SPM settle, **significant storage can occur over decadal time scales**. This might strongly complicate sediment management issues in the future.



PCB6 ratio along river axis



How long will the sediment stay settled?

