Mapping and managing sediment-bound pollutants in estuaries – *Closing knowledge gaps at the Elbe*

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Outline

1. Introduction – pollution loads into the estuary
2. Modelling transport of sediment-bound pollutants
3. Partitioning of heavy metals in the phases water and SPM in the estuary

II Part:

The analytical procedure of important pollutants of the Elbe River, Pascal Richtarski

Banned but still found in the environment

+ Human-made contaminants were once released into water, air, or on land and **end up in rivers and estuaries often.**

+ Toxic chemicals that degrade very slow **linger in soil, sediments and water**.

+ Even when banned decades before, they can still be found bound to soils and sediments and in **blood and tissues of organisms**.

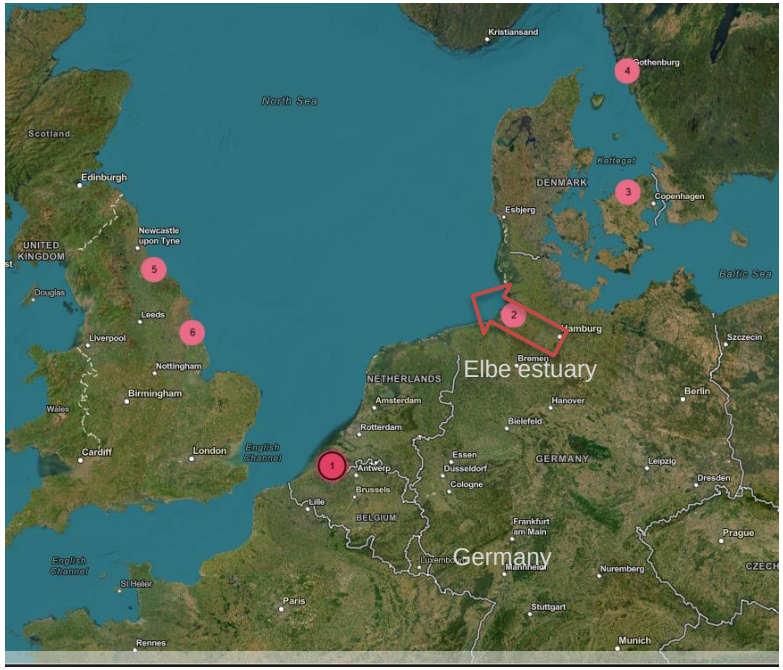
Legacy pollution

Schwartz (2019), modified

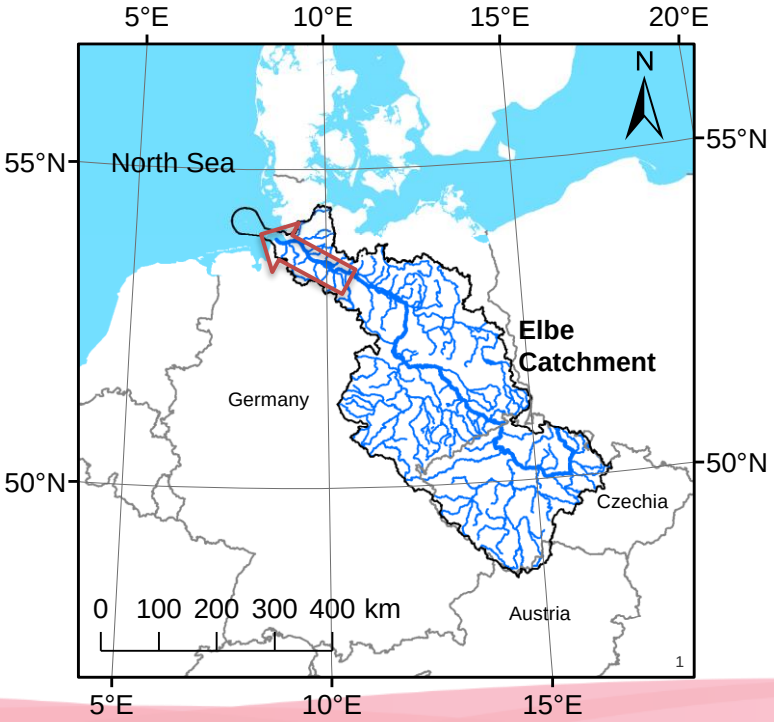
Loads into the Elbe estuary

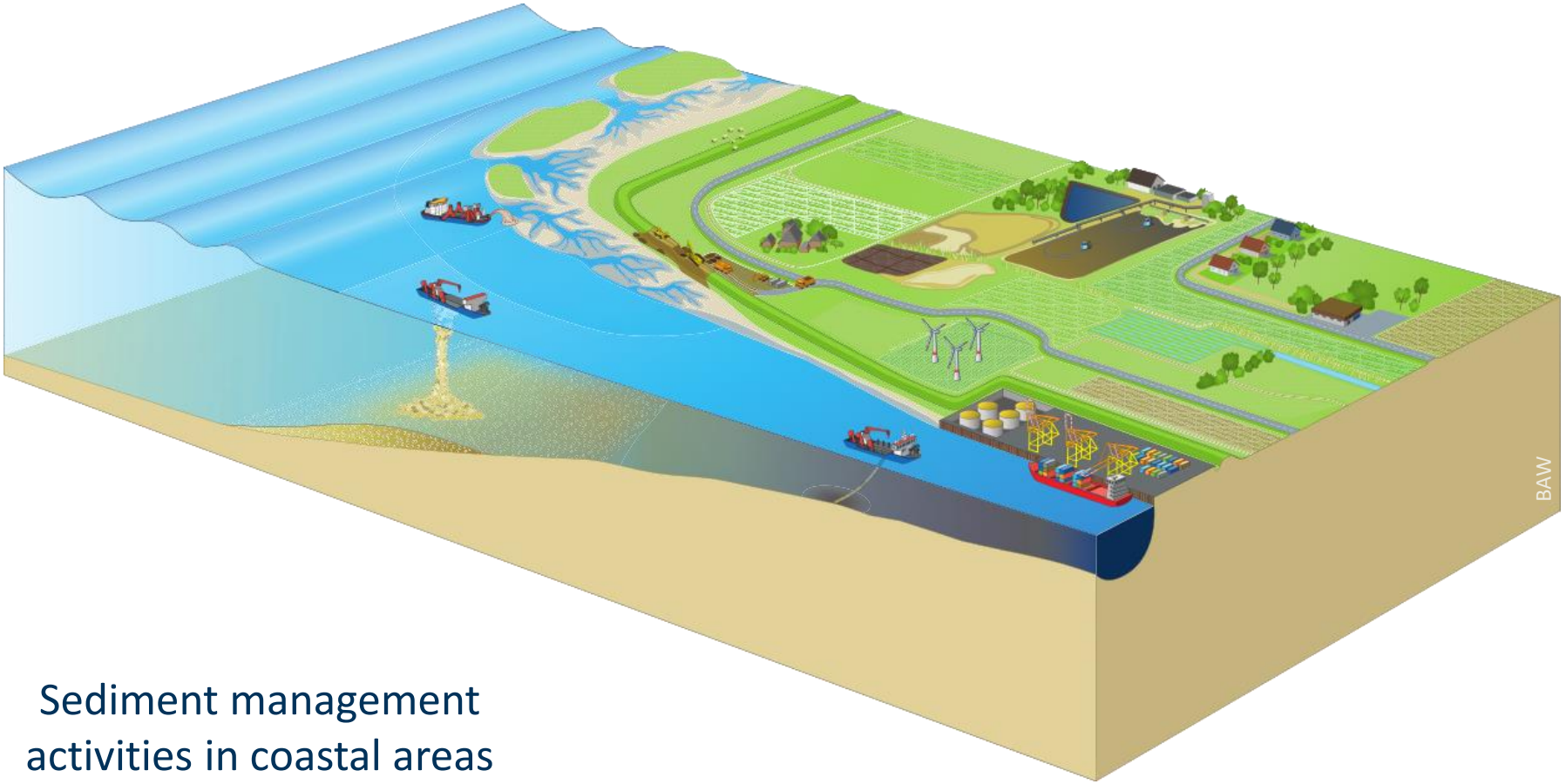
Riverine sediments and SPM from the Elbe basin depict levels of pollution

- Heavy metals (e.g. Hg, Cd, Zn, Cu)
- POP's (e.g. HCB, DDx, PCB's)



IMMERSE-Estuaries (red dots) – Location of Elbe estuary

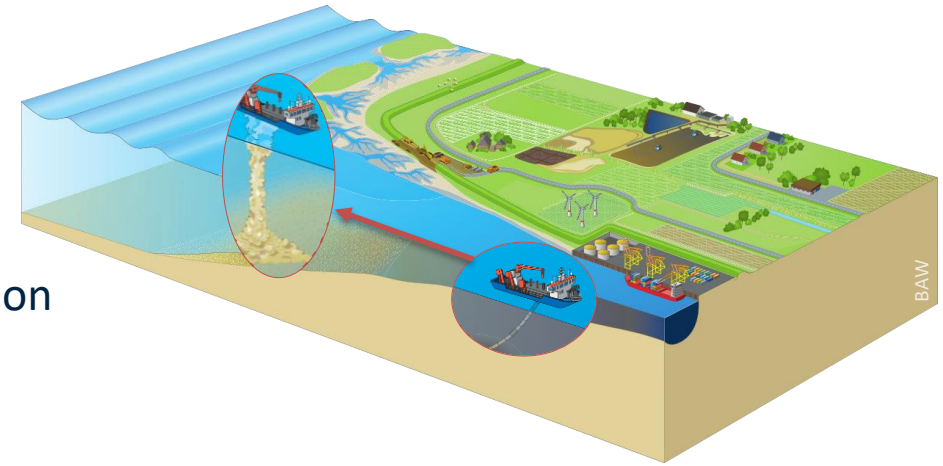




Sediment management activities in coastal areas

Needs of quantitative estimates

+ The pollution of the riverine sediments restricts the estuary management in the tidal Elbe and **strategies for the reuse and relocation of sediments.**
+ For the approval **of future relocation measures**, the forecast of the expected pollutant drift will become even more important, especially for the implementation of the MSFD targets.
+ Estimates of **the effect of remediation** measures in the Elbe (inland waters) or of **climate change** on future management measures

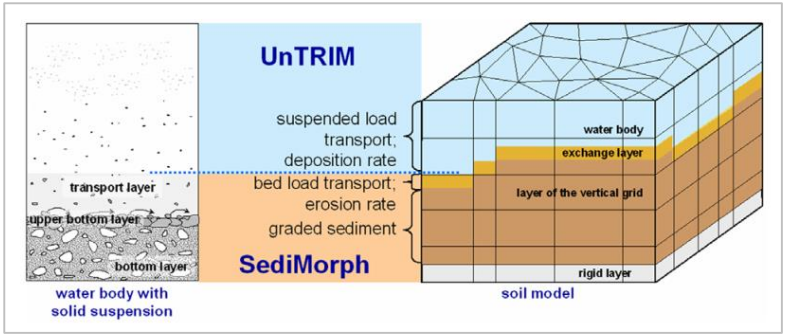


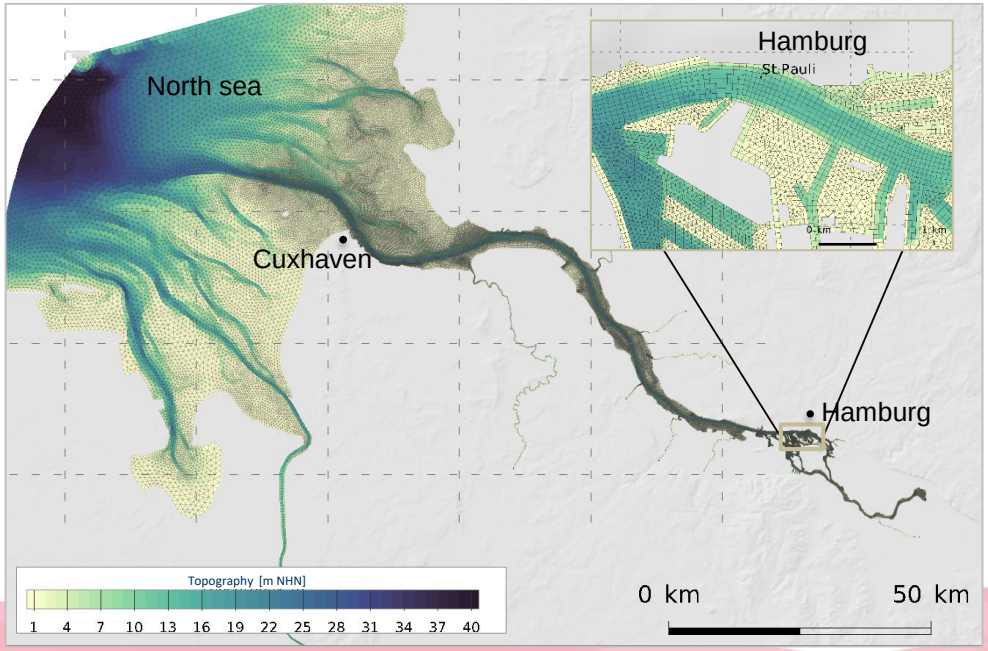
Sediment management activities in coastal areas

3D- HN-model-based investigations

hydrodynamics and sediment transport

Numerical simulations are used to compute the spread and distribution of pollutants in the water-sediment compartment and thus, to create an improved quantitative **basis for the risk assessment of sediment management** measures.

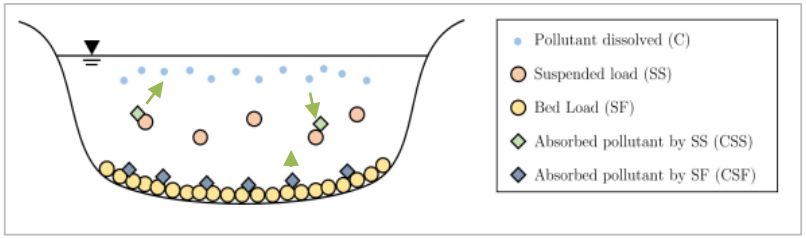




Modelling
the transport of pollutants in tidal rivers

+ Pollutants relevant for the Elbe are **transported by water and SPM** dynamically, which means that their pathway follows the water movement and sediment drift.

+ Pollutant concentration in the two-phase system water-particle **varies** along the river **in dependency on physicochemical conditions** like pH, Temperature, salinity and organic content (sorption tendency varies)[1].



Conceptual representation of the distribution of micropollutants

Partitioning coefficient K_D [2]

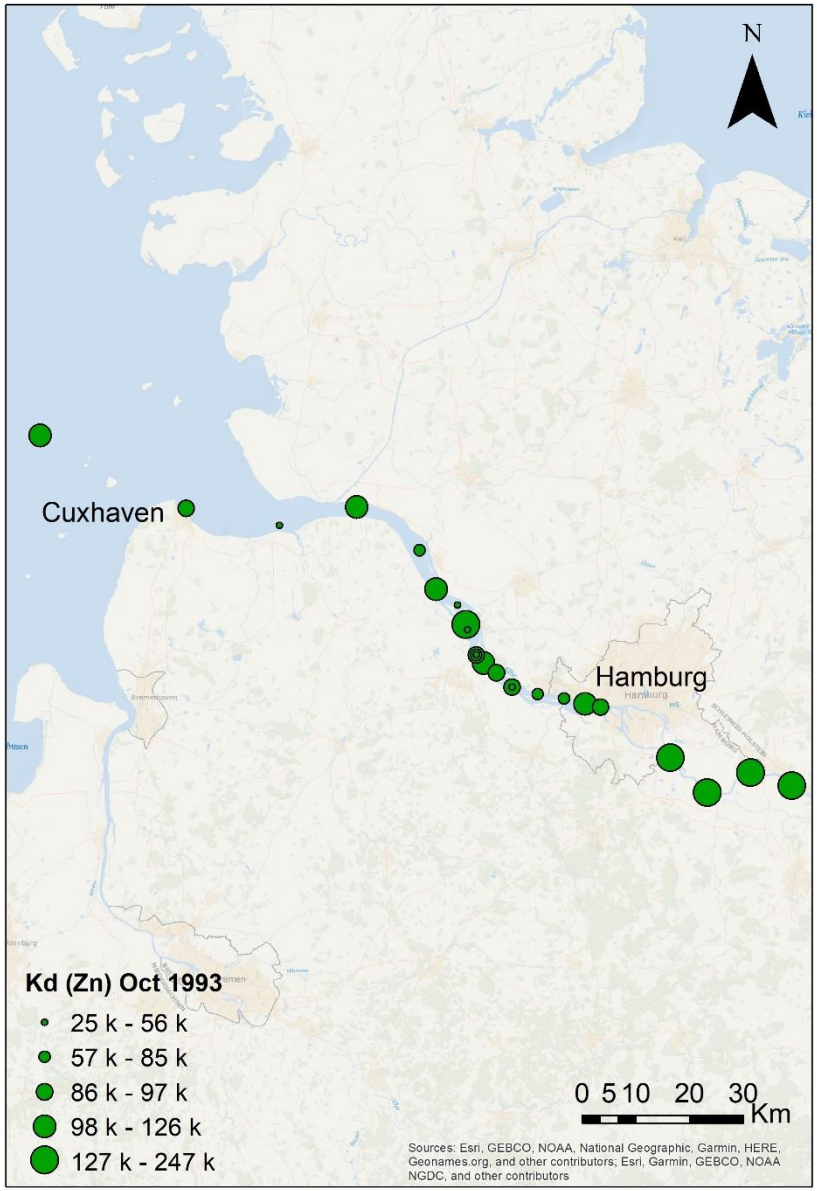
$$K_D = \frac{P}{C}$$

[1] Fitzsimons (2011). [2] Turner (1993).

Application of the concept partitioning coefficient K_D

K_D – Variability in the Elbe

-> Zinc concentration:
bound Zn / dissolved Zn



Field campaign in Prange (1997). Data provided by Hereon

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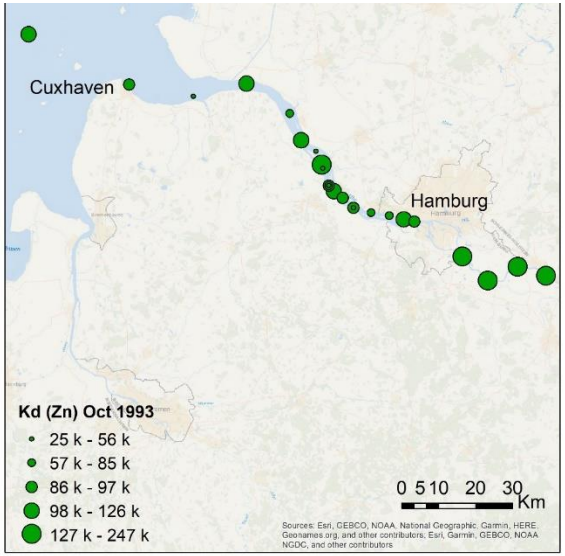
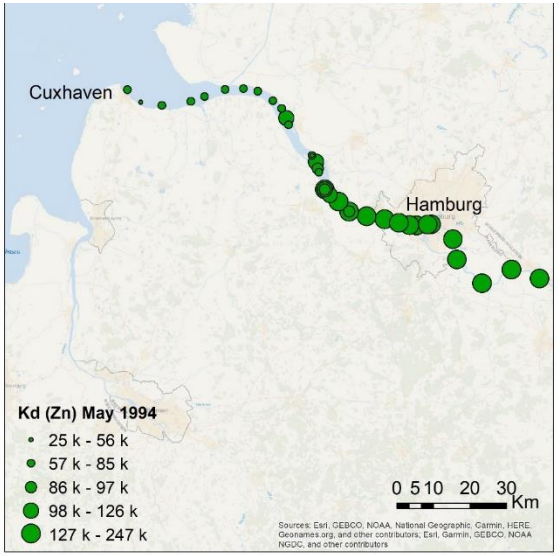
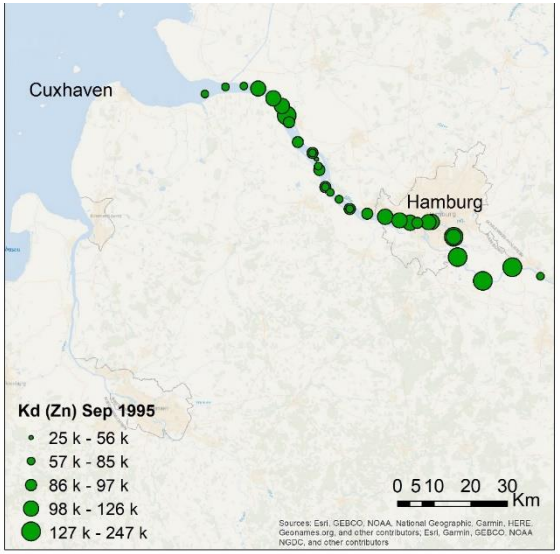
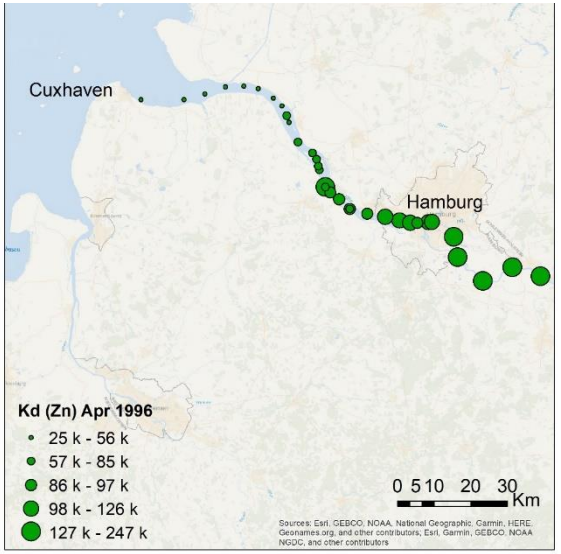








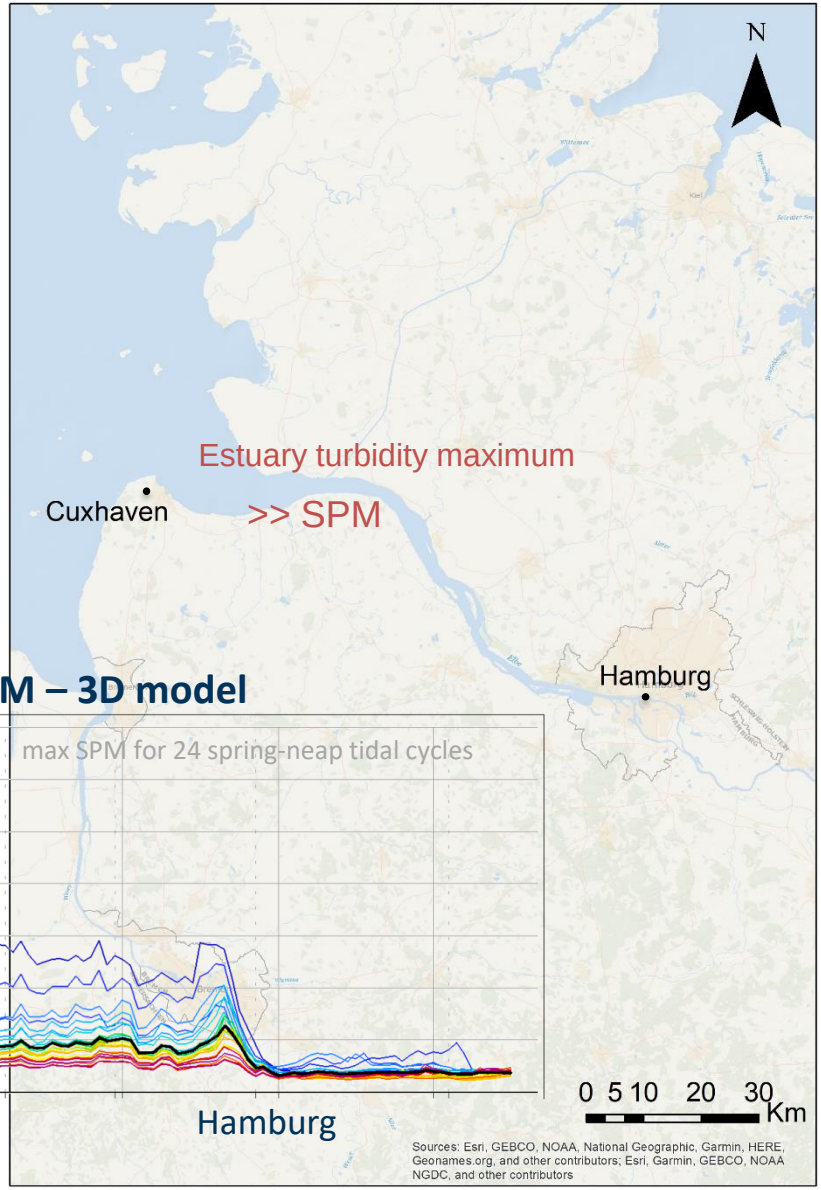
Field campaign in Prange (1997). Data provided by Hereon

Application of the concept partitioning coefficient K_D

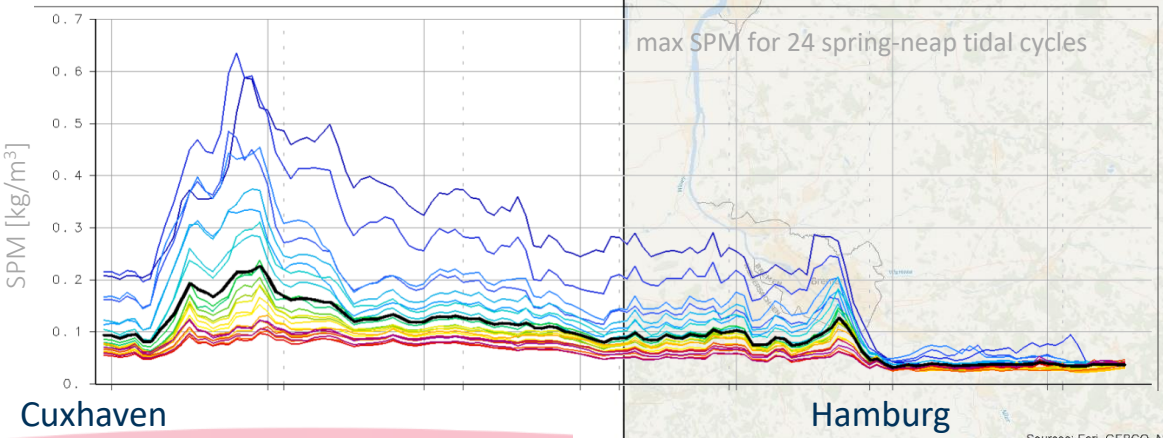
Influence of:

- **SPM dynamic**

- Salinity



Variation of SPM – 3D model



Application of the concept partitioning coefficient K_D

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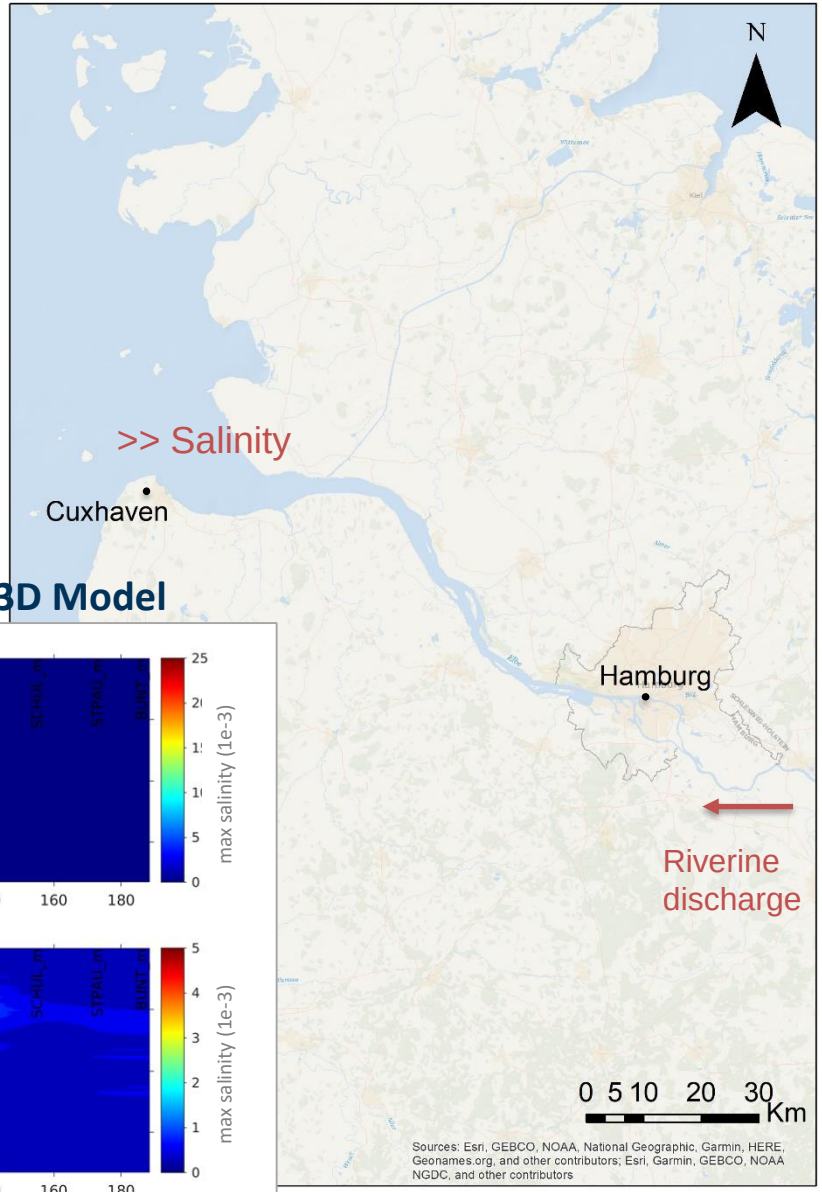
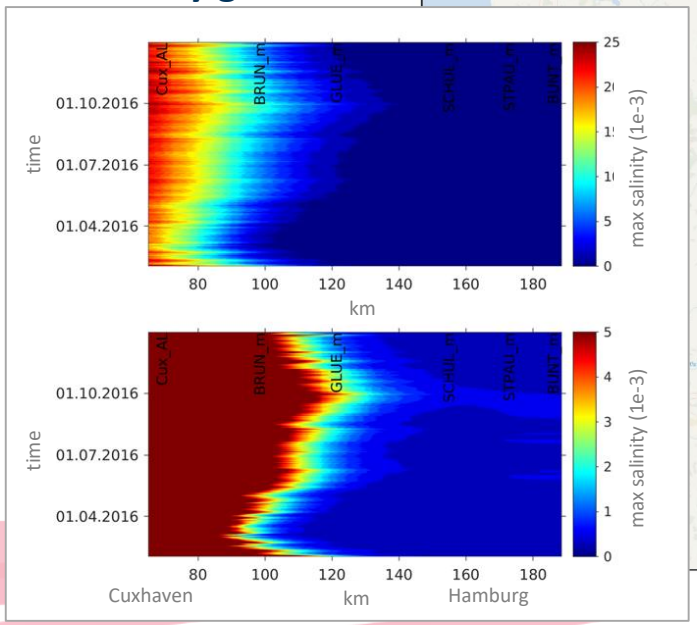
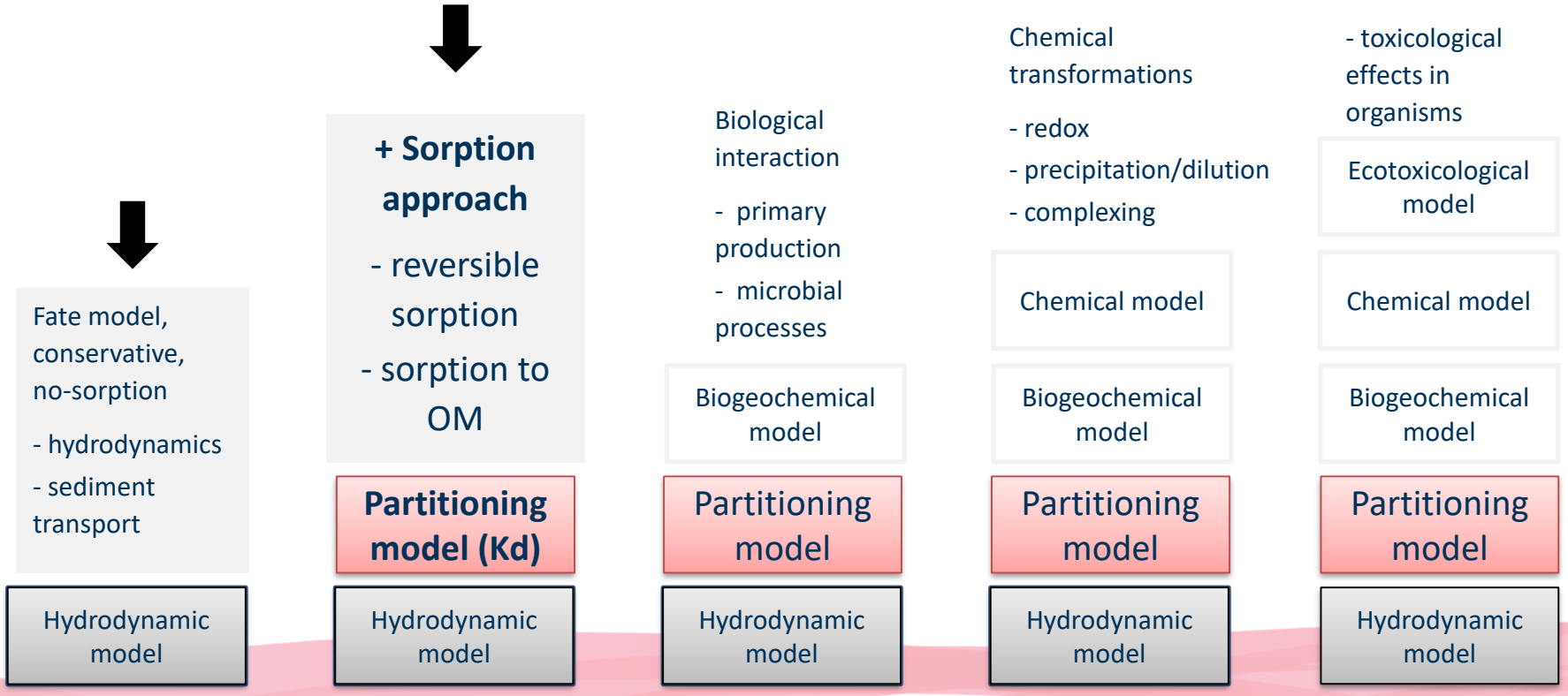


Salinity gradient – 3D Model



Modelling framework

Complexity levels modelling contaminants in water bodies



CTM-Elbe (**C**ontaminant **T**ransport **M**odelling -**E**lbe)

Laboratory & modelling experiments

Development of a numerical model for the Elbe estuary

Hereon

BAW

Measurements and laboratory experiments

Numerical modelling

Monitoring (WFD)

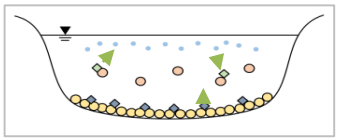
Process understanding

Validation data

Depending on scale and incl. processes:

hydrodynamic, morphodynamic and sorption processes

Assessment of pollutants transport



under **variable estuarine** conditions

References

Fitzsimons, M. F.; Lohan, M. C.; Tappin, A. D.; Millward, G. E. (2011): 4.04 - The Role of Suspended Particles in Estuarine and Coastal Biogeochemistry. In: Eric Wolanski und Donald McLusky (Hg.): Treatise on Estuarine and Coastal Science. Waltham: Academic Press, S. 71–114. Online verfügbar unter https://www.sciencedirect.com/science/article/pii/B9780123747112004046.

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Schwartz, 2019. Vortrag Dr. René Schwartz: „Auswahl kosteneffizienter Maßnahmen (-kombinationen) und Bestimmung der Kosten(un-verhältnismäßigkeit von Schadstoff-/Sedimentsanierungsmaßnahmen im Kontext der EG-WRRL-Umsetzung“. https://elsa-elbe.de/massnahmen/fachstudien-neu/kosten-nutzen-analyse.html

Turner, A.; Millward, G. E.; Bale, A. J.; Morris, A. W. (1993): Application of the KD Concept to the Study of Trace Metal Removal and Desorption During Estuarine Mixing. In: *Estuarine, Coastal and Shelf Science* 36 (1), S. 1–13. DOI: 10.1006/ecss.1993.1001

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Helmholtz-Zentrum
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North Sea Region
IMMERSE
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EUROPEAN UNION

The analytical procedure of important pollutants in the Elbe River

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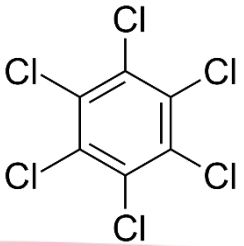
Relevant pollutants in the Elbe River

Inorganic pollutans

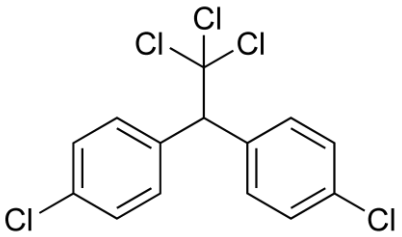
- Cadmium (Cd)
- Mercury (Hg)
- Copper (Cu)
- Zinc (Zn)

Organic pollutans

- Hexachlorobenzene (HCB)
- Dichlorodiphenyltrichloroethane (DDT and metabolites DDD, DDE)
- Polychlorinated biphenyls (PCBs) like PCB28, PCB52, PCB101, PCB138, PCB153, PCB180

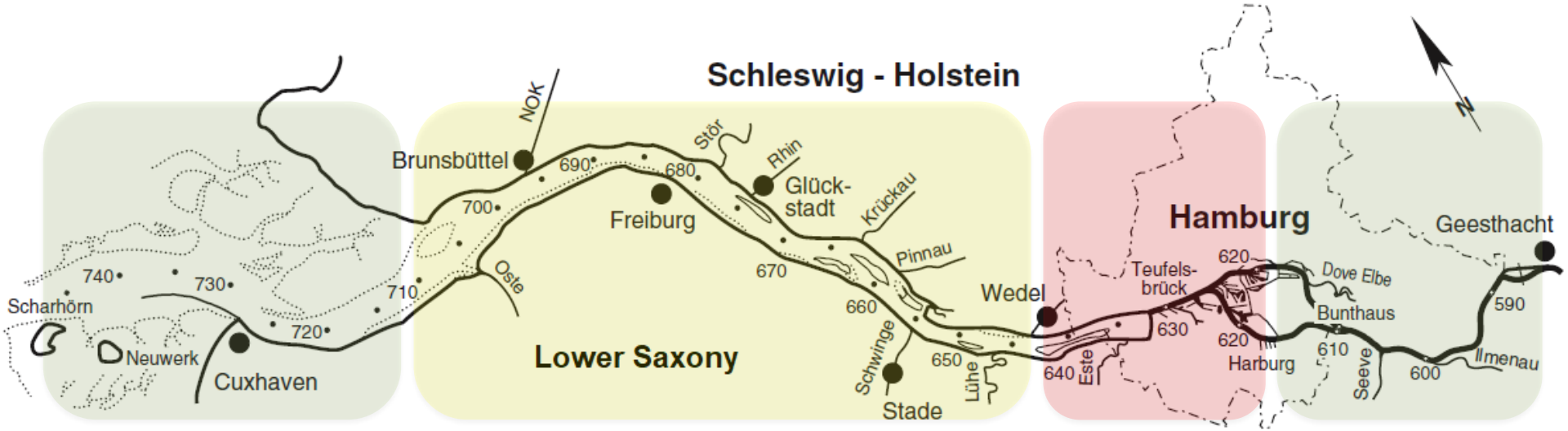


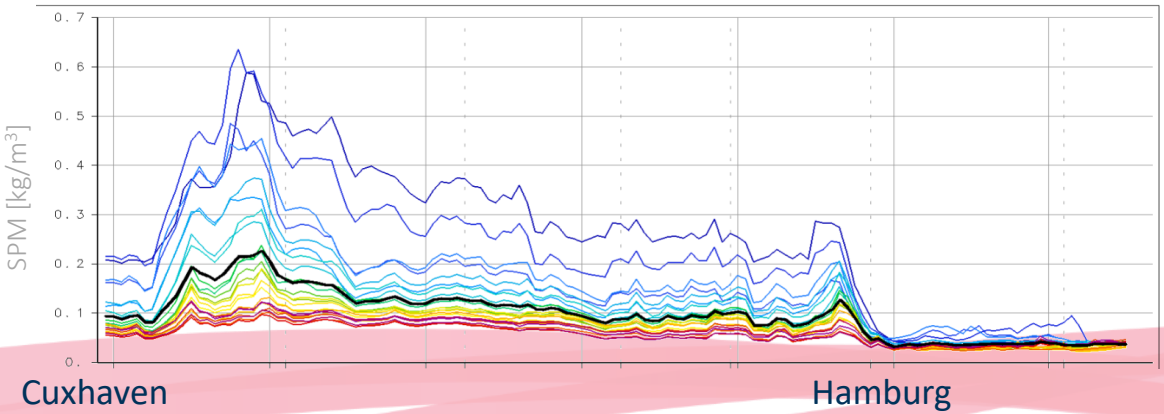
Structual formula of HCB



Structual formula of DDT

Sampling location and samples





[1] M. Bergmann, Die Trübungszone in der Tideelbe – Beschreibung der räumlichen und zeitlichen Entwicklung, Wassergütestelle Elbe, S. 3, **2004**, to be found at: https://www.fgg-elbe.de/files/Download-Archive/Fachberichte/Truebungsverhaeltnisse/04Truebungsz.pdf

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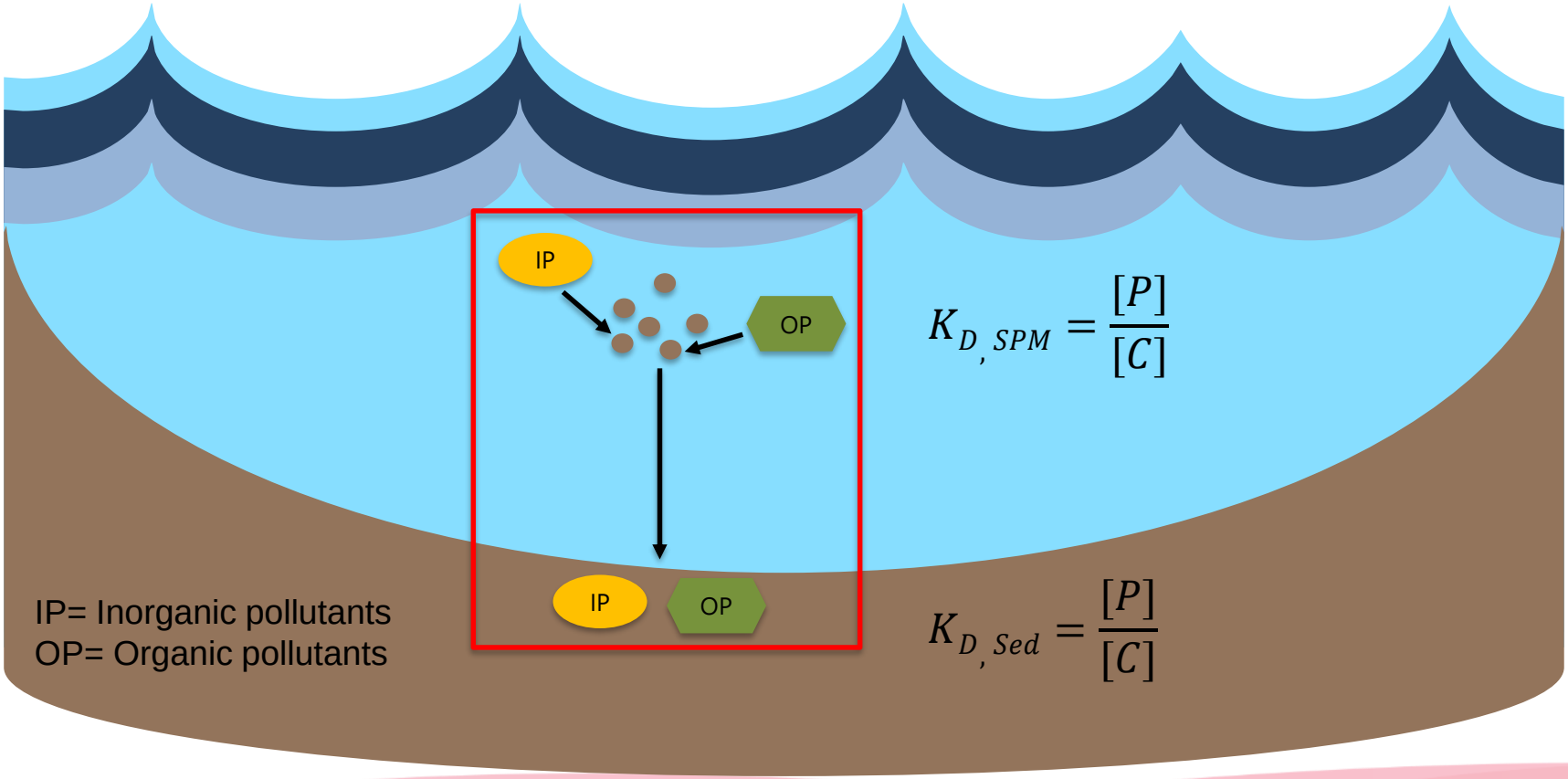

SPM sampling techniques

Two methodes tested:

"Conventional" sampling

Hydro-cyclone pumping

Sample preparation and analysis

Experimental setup of the CFC

Isolated SPM

Sample preparation and analysis

ICP-MS/MS in the clean room[2]

GC-MS/MS[3]

[2] T. Zimmermann, M. von der Au, A. Reese, O. Klein, L. Hildebrandt and D. Pröfrock, *Anal. Methods*, **2020**,12, 3778-3787.
[3] M. Anastassiades, S. J. Lehotay et al., *WTQA* **2002**, *18*, 231–241.

Planed sampling campaign

- From 02.04. to 06.04.2023
- Sampling of water, SPM and sediment
- 14 sampling stations from Cuxhaven to Geesthacht

Research vessel “Ludwig Prandtl”

Thank you for your attention!

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Literature

[1] M. Bergmann, Die Trübungszone in der Tideelbe - Beschreibung der räumlichen und zeitlichen Entwicklung, Wassergütestelle Elbe, S. 3, **2004**, to be found at: https://www.fgg-elbe.de/files/Download-Archive/Fachberichte/Truebungsverhaeltnisse/04Truebungsz.pdf

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