New Substances

THAT ARE EMERGING IN THE LIGHT OF THE ENERGY TRANSITION

AND ARE RELEVANT FOR SEDIMENTS

„New“ or „emerging“ substances

- not necessarily new chemicals
- ..but those, that we (society) have only currently paid attention to.
- not included in routine monitoring programmes (yet)
- potentially provide an environmental risk
- fate, behaviour and (eco-)toxicological effects not (well) understood
- no effect thresholds established

Energy Transition

Transformation of the global energy sector from fossile-based to zero-carbon sources, reducing CO2 emissions

e.g. cars: from gasoline-fueled to hybrid to electric vehicles….

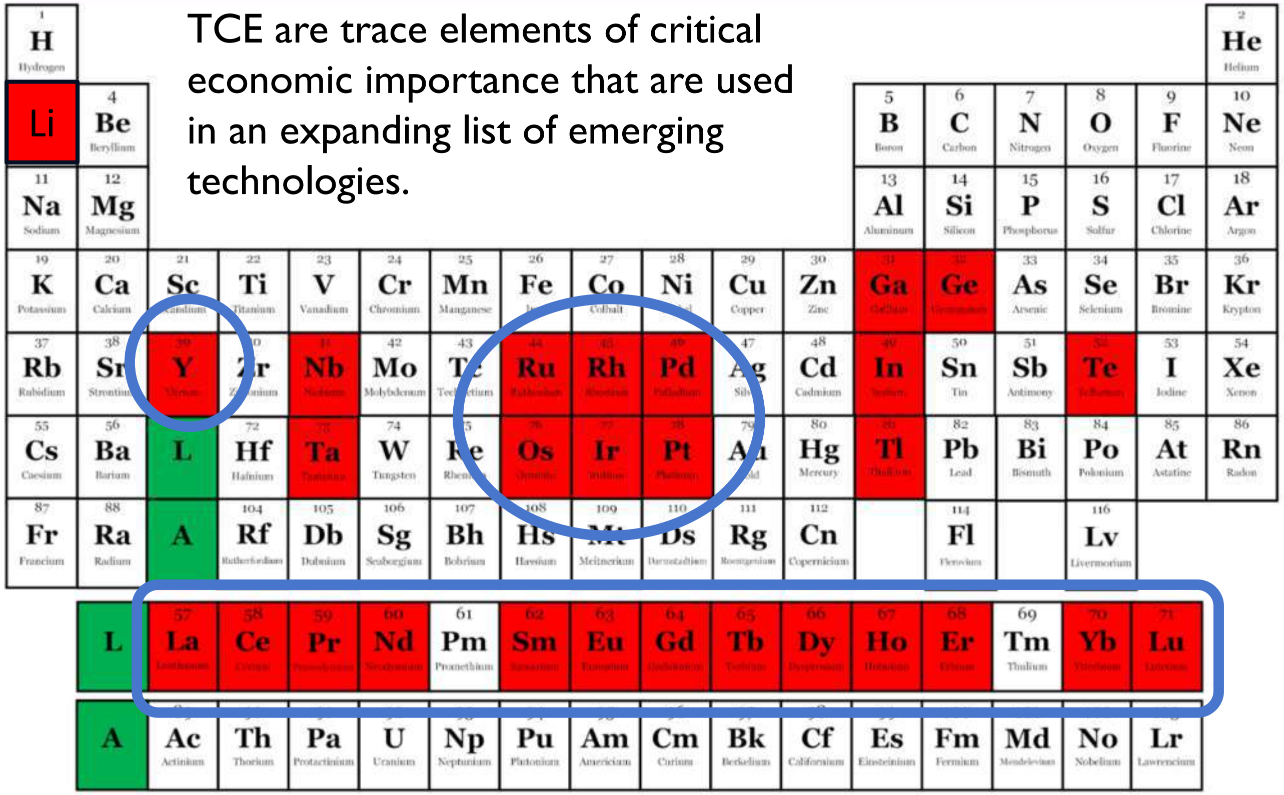
TIL the Toyota prius is described as "the biggest user of rare earths of any object in the world" as each battery pack uses 10–15 kg (22–33 lb) of lanthanum, and each electric motor contains 1 kg (2 lb) of neodymium

„Good intentions do not always go hand in hand with good consequences….“

Emerging Substances in the Light of the Energy Transition are Metals.

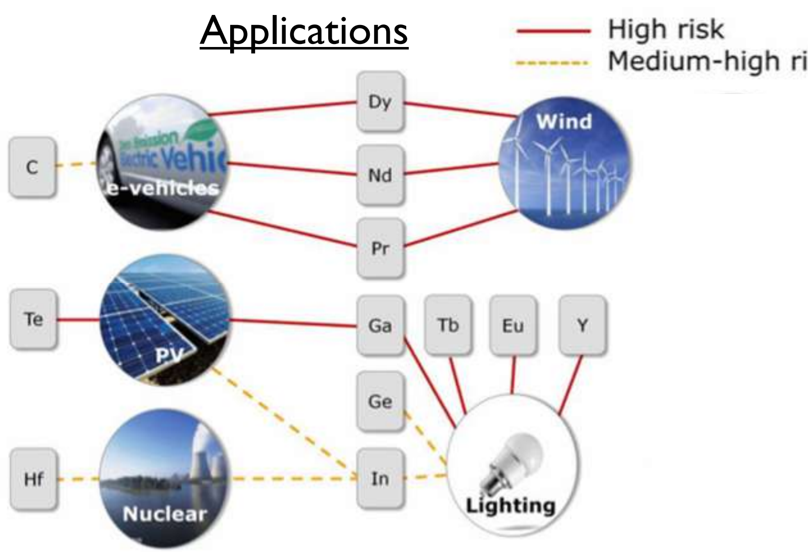
Main Technology Critical Elements (TCE)

TCE are trace elements of critical economic importance that are used in an expanding list of emerging technologies.



TCE (Cobelo-García, Filella et al. 2015)

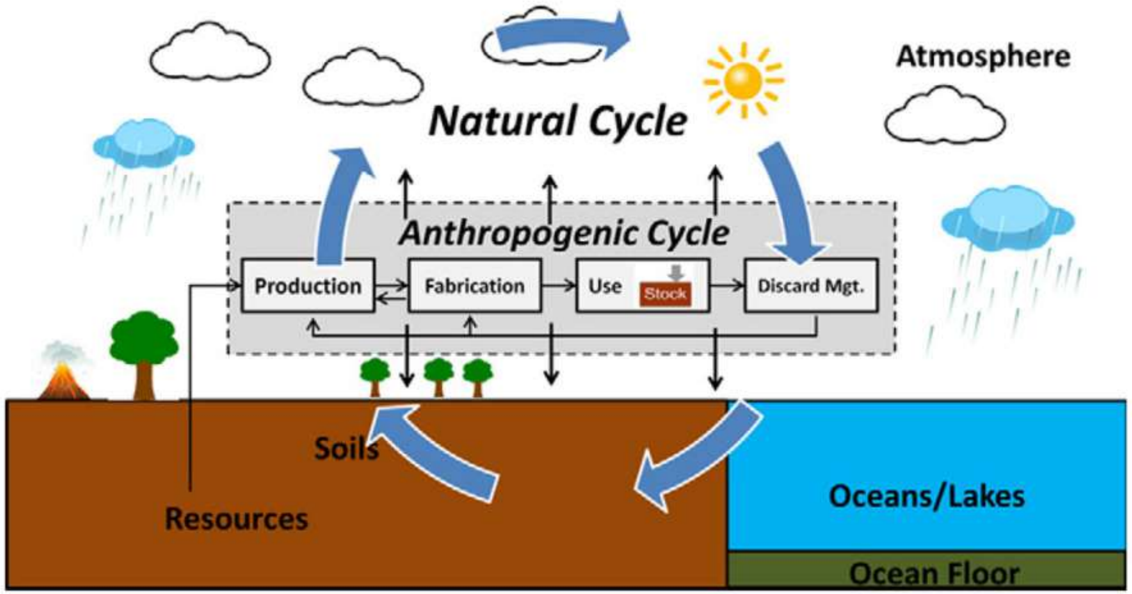
- Platinum group elements (PGE)
- Lanthanides and Yttrium (REY)
- Other elements



(Source: COST Action TD1407)

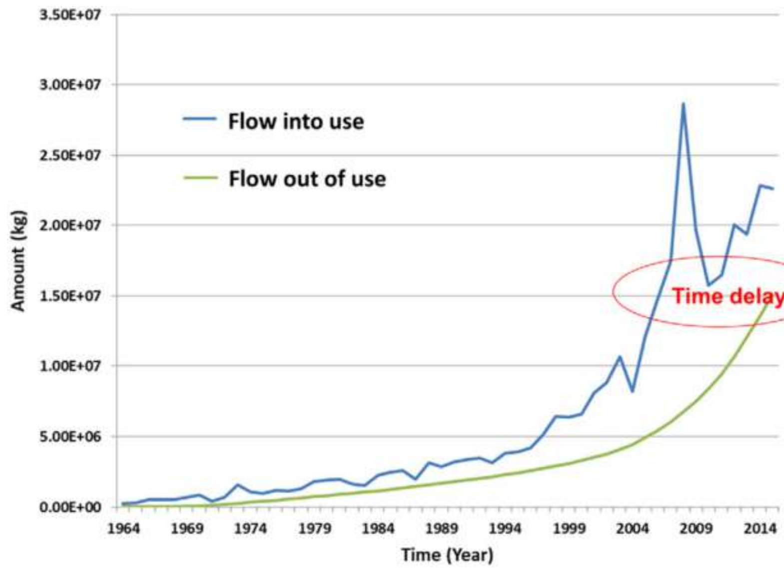
https://rmschools.isof.cnr.it/resources/energy-critical-elements/

Overlap of natural and anthropogenic cycles (Nuss and Blengini 2018)



Major environmental impact:

- Mining
- Production and use
- After-use phase (time delay of about 10 yrs.)



Environmental risks from TCE – what do we / don‘t we know?

Platinum group elements (Batley and Campbell 2022)

Environmental concentrations/distribution	Aquatic toxicity
Very low concentrations in waters (< 1 ng/L)	Effects may turn up at > 100 ng/L (Pd)

Current data suggest: no risk to water living organisms

BUT:

- PGE-concentrations seem to rise
- Data on chronic toxicity are lacking
- Even data on acute toxicity are scarce (especially marine)
- No data on sediment toxicity, even though concentrations in sediments can be high in areas with heavy vehicle traffic.

Risk for sediment organisms?

Lithium (Batley and Campbell 2022)

Environmental concentrations/distribution	Aquatic toxicity
Surface water: 1 – 10 µg/L (freshwater) 170 µg/L (marine waters)	Speciation in water is similar to K^{+}, Mg^{2+}, Ca^{2+} → Toxicity probably very low

Highly soluble, no complexation (no issue for sediments)
Current data suggest: no risk to water living organisms

Li is highly bioavailable, but does not seem to be toxic
Na-antagonism: Na prevents Li toxicity

Assumed to be of very low toxicity (at current environmental concentrations):
Gallium, Indium, Germanium, Rhenium, Tellurium, Niobium, Tantalum

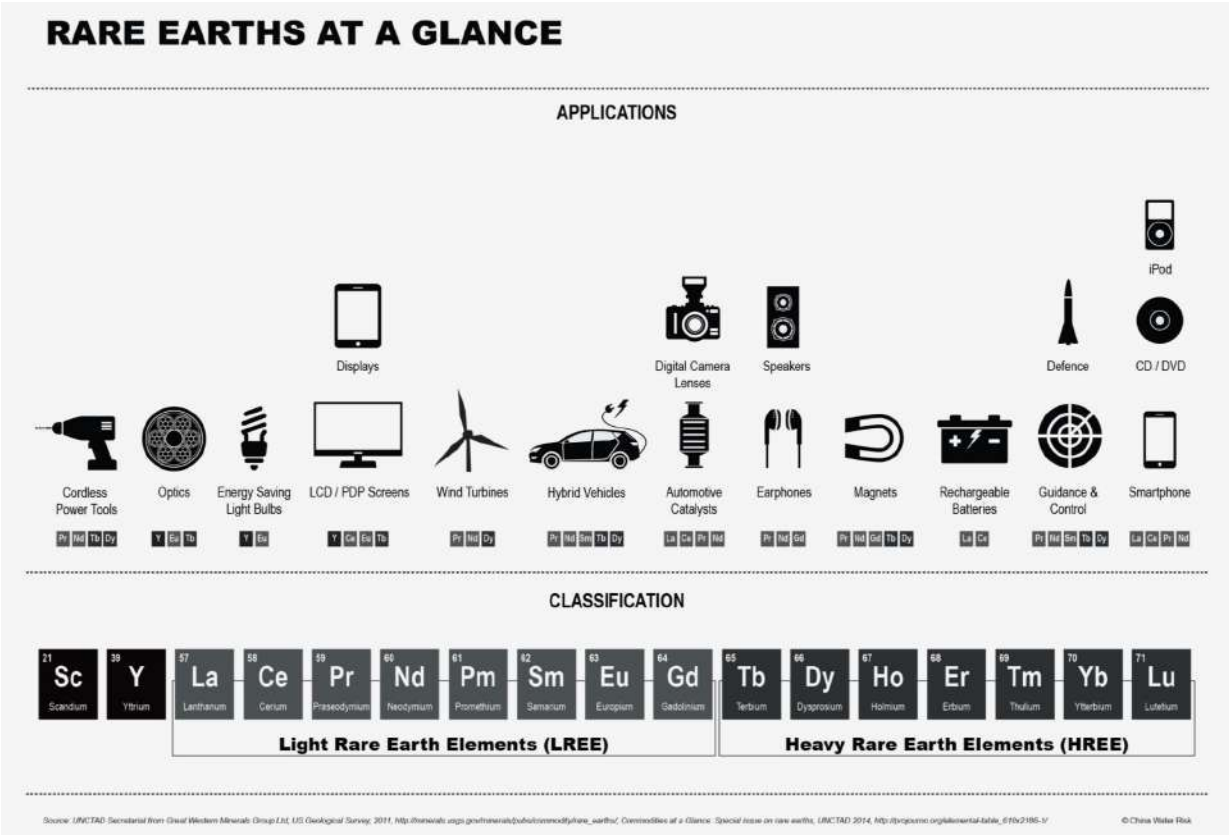
Thallium (Batley and Campbell 2022)

Environmental concentrations/distribution	Aquatic toxicity
1.3 – 20 ng/L (seawater, rivers) Mining areas: up to 1000 µg/L 2 oxidation states (I, III) Tl(I): mostly present as free ion, or $(CH_3)_2Tl^+$ Tl(III): binding to humic acid	Complex speciation → toxicity still unclear Could be similar to copper and cadmium Tests with *D. magna*: NOEC of

There may be a risk **in wastewater streams**, but yet, no WQ guideline values could be derived.

But TikTok knows better

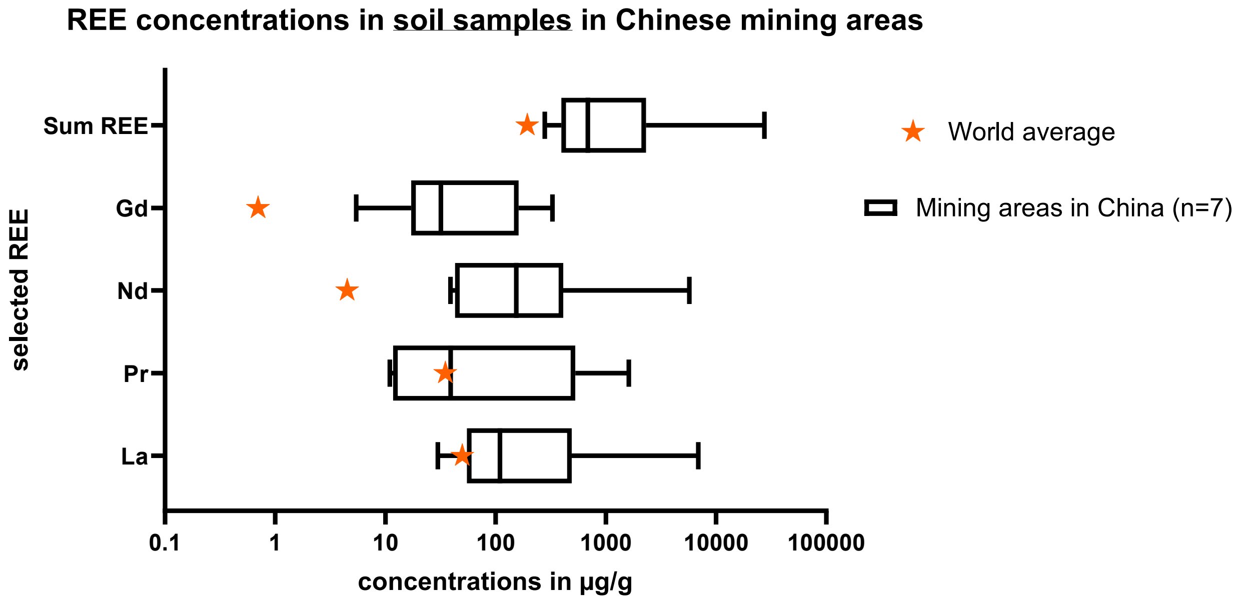
Rare Earth Metals



A group of 17 elements:
The lanthanide group
and yttrium and scandium

Properties:
Magnetic (Nd, Pr, Dy)
Optical (fluorescing – e.g. Eu)
Catalytical (La, Ce)
Thermic (Sm)
…..

Rare Earth Metals



Data from Liang et al., 2014

A group of 17 elements:
The lanthanide group
and yttrium and scandium

Soil contamination reaches magnitudes of mg/g

Reported anthropogenic anomalies in water bodies (Tepe, Romero et al. 2014)

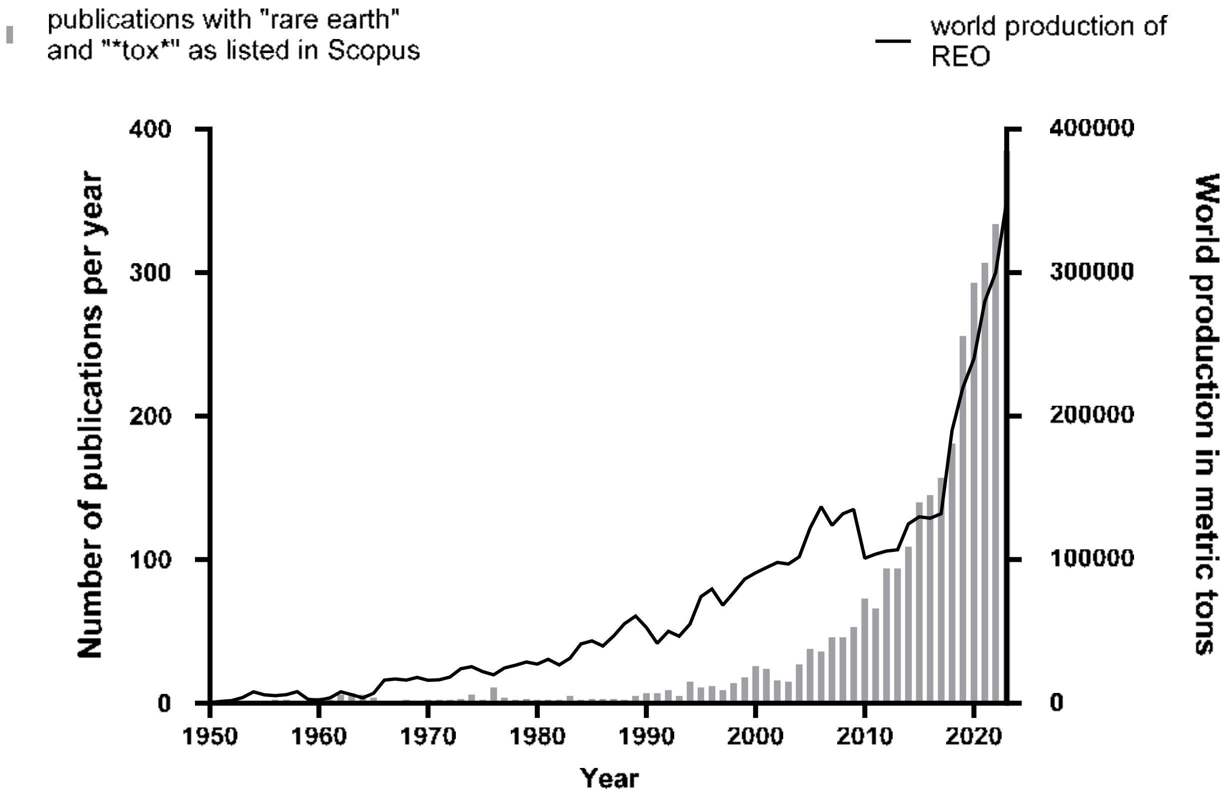
River / Water Bodies	Country	REE	Source
Weser	Germany	Gd	Kulaksiz & Bau, 2007
Rhine	Germany	La, Sm, Gd, Ce	Kulaksiz & Bau, 2013
Atibaia River	Brazil	Gd	de Campos & Enzweiler, 2016
San Francisco Bay	USA	Gd	Hatje et al. 2016
Hérault River	France	Gd	Rabiet et al. 2009
Teltow Channel	Germany	Gd	Knappe et al. 2005
Wupper	Germany	Gd	Bau & Dulski 1996
Rhine Estuary	The Netherlands	Nd, Pr, Sm	Bakkenist & van de Wiel 1995
Tagus Estuary	Portugal	Y	Brito et al. 2018
Tokio Bay	Japan	Gd	Nozaki et al. 2000

Of concern?

Challenges in risk assessment for rare earth elements

- Number of publications increasing with world production (Revel, van Drimmelen et al. subm)
- Still relative few bioassay data available
- Complexation of REE with e.g. phosphate complicate ecotox tests (e.g. algae tests)
- Not clear, how water chemistry relates to REE toxicity
- What is the bioavailable species? (Ln^{3+} ?)
- Accumulation in sediments → sediment toxicity and impact on bentho-pelagic coupling?

(2020 – 2024)

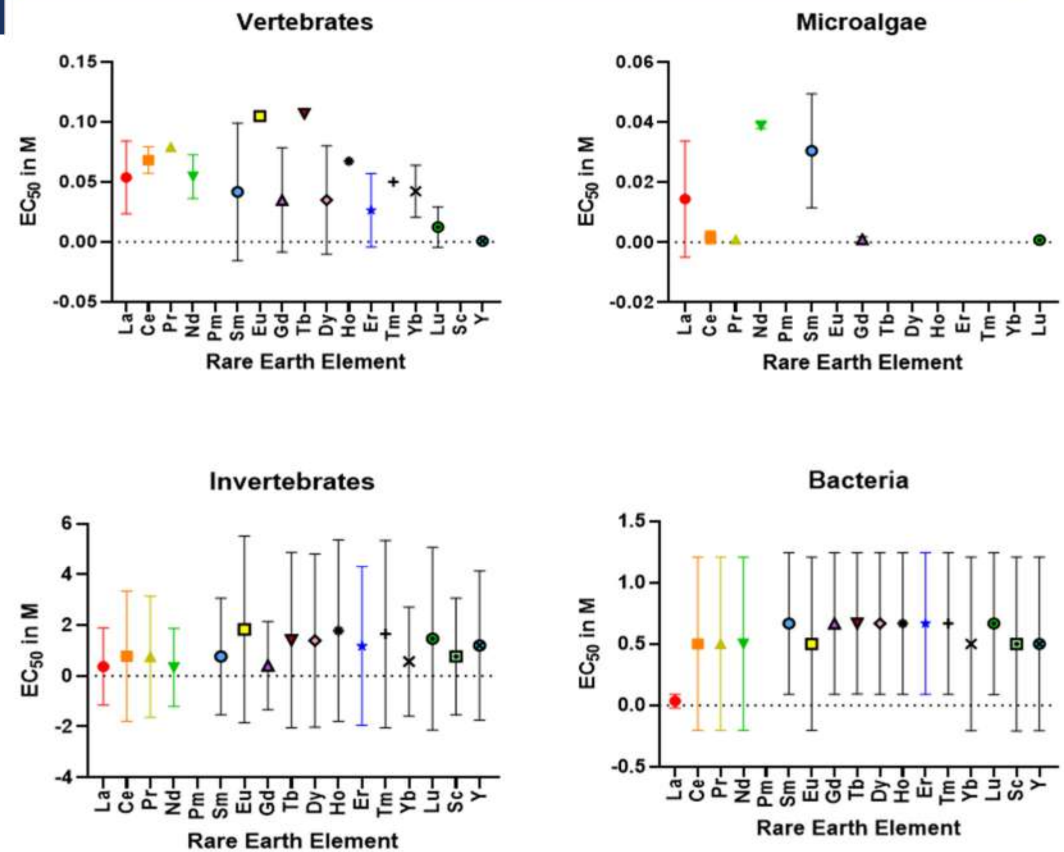


(Revel, van Drimmelen et al. , subm)

Ecotoxicological data on REE (Revel, van Drimmelen et al, subm.)

(Publications, validated acc. to Klimisch criteria)

- 26 studies were performed on freshwater, only few on sediment
- Testorganisms were mostly invertebrates (crustaceans)
- Variations in EC_{50} are large
- Data on microalgae are scarce→ Complexation with phosphate masks REE toxicity (our data, pub. in prep)



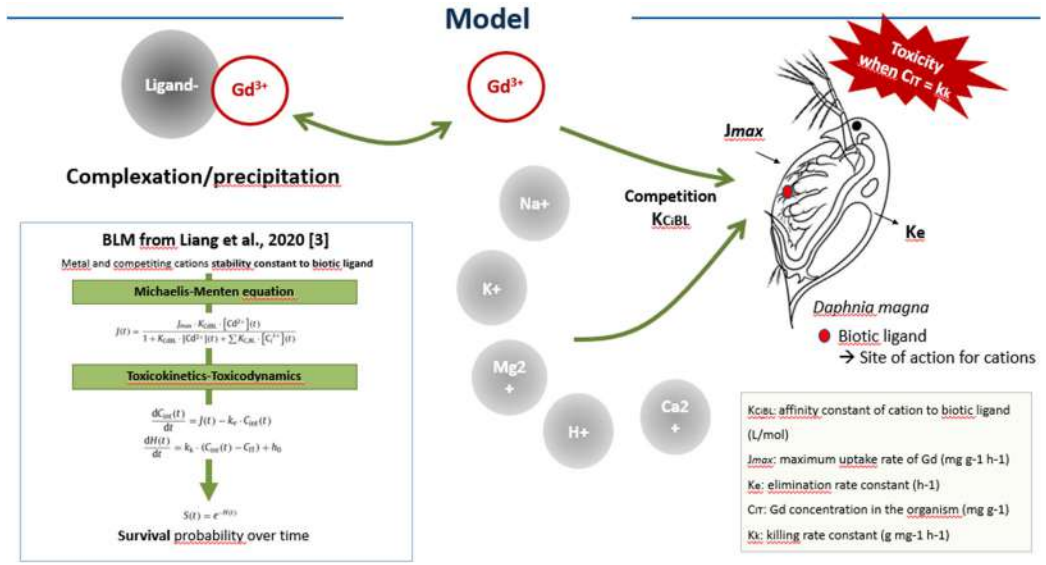
Range of EC50 values for REE (freshwater)

The influence of water chemistry on REE toxicity:
Development of a Biotic Ligand Model for gadolinium (Revel et al, in prep)

- pH above 7.7 reduces Gd toxicity
- Ca^{2+}, Mg^{2+}, **and K^{+}** compete with Gd
- Free ion concentration was the available fraction.

The model predicted toxicity in most contaminated, natural water samples well.

→ The model could improve risk assessment of REE.



Difference in mode of action in Daphnids when short-term exposed (72 days)

- La (low toxicity): confined to the intestinal tract
- Gd (elevated toxicity): distributed throughout the tissue

La less soluble than Gd:

→uptake of solid substance or precipitate formation in the gut.

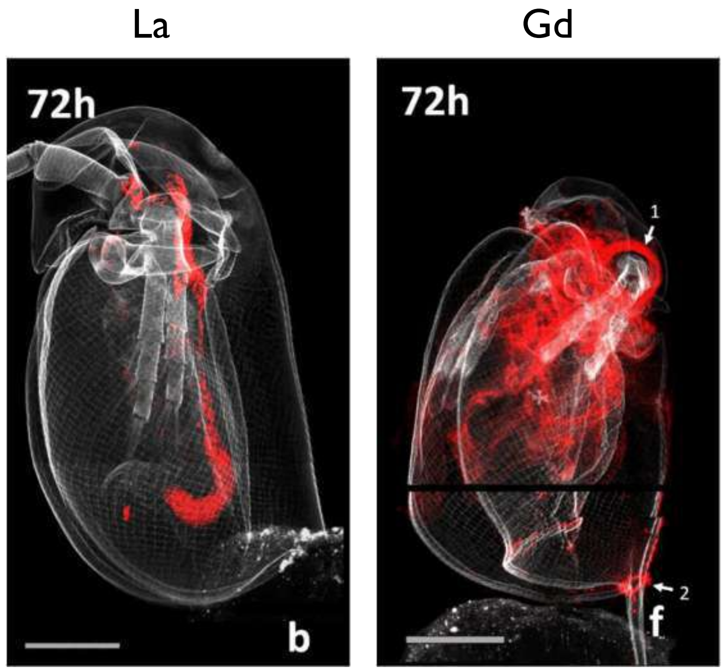
→ lower toxicity of precipitates

→ Free ions are more effective over 72 hours. (Revel et al. 2023)

BUT:

Exposure studies for 7 days showed, that also precipitates in the gut can adversely affect the organisms (Revel et al. 2024)

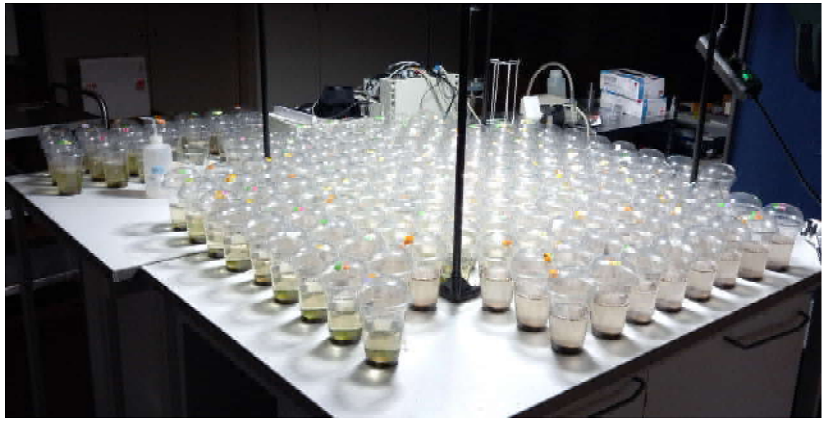
→ **Implications for the risk for sediment organisms?**



Impact of REE on sediment organisms and bentho-pelagic coupling? (van Drimmelen et al., subm.)

Open questions:

- Toxicity of sediment-bound REE?
- Do sediment organisms incorporate REE precipitates?
- Fate of REE during resuspension/sedimention cycles?
- How do REE affect multi-species systems?



Summary

Emerging substances in the light of the energy transition are metals.

TCE are increasingly mined and will therewith end up in the environment.

Major TCE are the PGE and the REE (and a few others)

Of these, PGE, thallium and REE might be most important to look at, but toxicity data are scarce.

Complex speciation complicates risk assessment.

Toxicity even differs between chemically similar elements (e.g. lanthanides)

Very little is known on sediment toxicity – e.g. uptake of precipitates by benthic organisms.

With TCE – we have more questions than answers. It‘s time to start working on it!

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Impact of (emerging) substances on the BU of sediments

Different approaches taken within different programs within the USA and the EU

Dr. Arjan Wijdeveld

04-06-2024

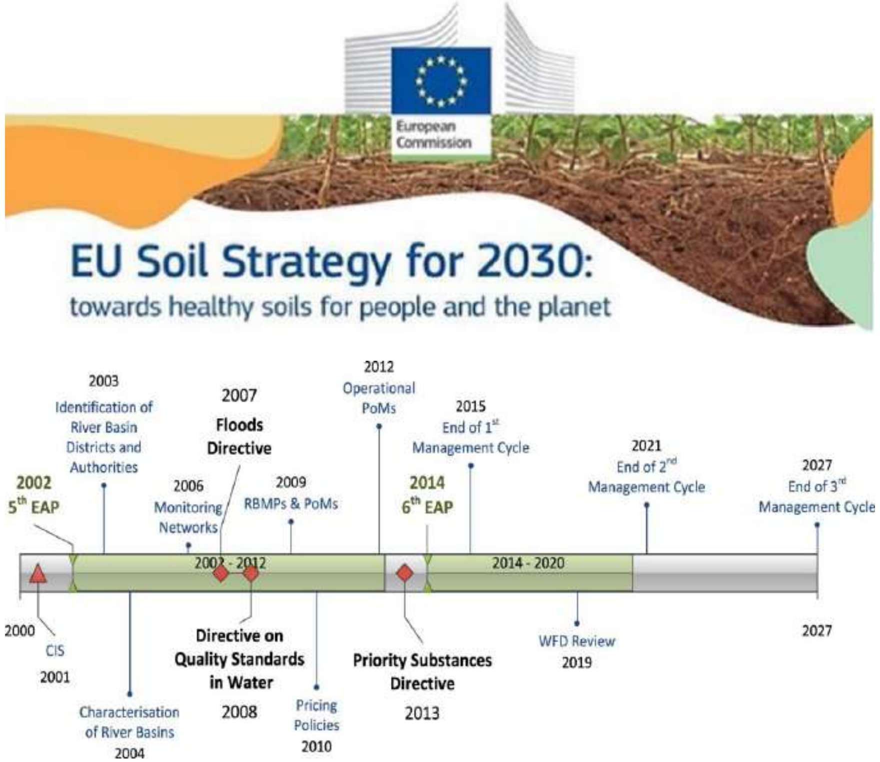
Why now?

High ambitions for 2030 in the USA when it comes to BU of sediment.

Recent discussion (March 2024) on state of science/industry on how to deal with contaminants.

EU Soil Strategy (2030) and WFD end of 3rd management cycle.

Impact of substances of possible concern



Contaminated Sediment Beneficial Use Workshop
Washington, March 2024

Observations for the **Superfund sites**[1]: BU of sediments, when remediation takes place, is not a specific criterium:

EPA

- Threshold Criteria: All alternatives must meet threshold criteria (except for the no action alternative)
  - Overall protection of human health and the environment
  - Compliance with ARARs (Applicable or Relevant and Appropriate Requirements)
- Balancing Criteria:
  - Used to compare each alternativeLong-term effectiveness and permanence
  - Reduction of toxicity, mobility or volume through treatment
  - Short-term effectiveness
  - Implementability
  - Cost
- Modifying Criteria
  - State acceptance
  - Community acceptance

[1)] As solution under the Comprehensive Environmental Response, Compensation, and Liability Act **(CERCLA)**

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Contaminated Sediment Beneficial Use Workshop
Washington, March 2024

Observations for the **Superfund sites**: Beneficial Use can conflict with treatment:

EPA

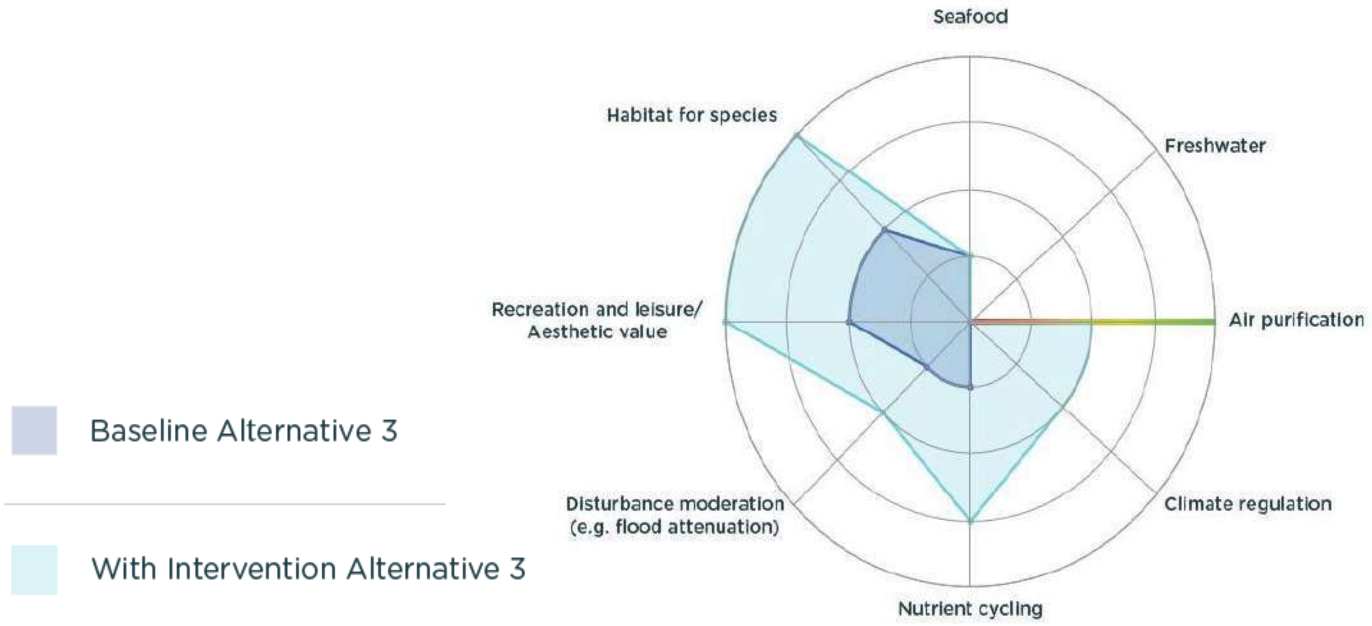
- If beneficial use is being considered, any treatment or other technologies should be discussed at this time so that treatability studies can be scoped and conducted.
- Treatability studies can also be performed during the remedial design or remedial action phases. If the results of the treatability studies lead to changes in the remedy selected in the Record of Decision, a modification of the ROD (Explanation of Significant Differences or ROD Amendment) may be needed.

What makes emerging compounds (or substances of possible concern in the EU) even more scary for BU of sediments on superfund sites is that *not removing* contaminated sediment from the site might lead to *a follow up responsibility* for the parties when an emerging compound is exceeding a (new) threshold (no ‘ne bis in idem’).

Contaminated Sediment Beneficial Use Workshop
Washington, March 2024

Observations for the **Superfund sites**: Cost is only one of nine criterium, alternative benefits like Ecosystem Services (LCA) are hard to justify.

In Conclusion: *Superfund sites*, regulated by the nine EPA criteria, *might not be the best place for BU of contaminated sediments*, since there is a limited incentive for BU benefits and emerging compounds are a risk.



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But there are USA projects with BU of contaminated sediments as an alternative solutions for clean up, often under state regulation.

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Major Conservation Benefits:

- Over 250 vascular plant species (170+ native)
- 200% cover
- Productive and complex habitat
- Dozens of wildlife species
- Locally-significant pollination source

RAMBOLL ERDC

Integrating ecosystem functions and biological conservation into the remedy benefits

- Estimated savings greater than $10M
- Avoided import of 3M CY of offsite cover material
- Equivalent leachate minimization performance
- Enhanced landscape diversity
- Restored rare plant communities
- Renewable biomass energy sources
- Eliminated environmental impacts and costs associated with mining and moving 3MM CY of sediment

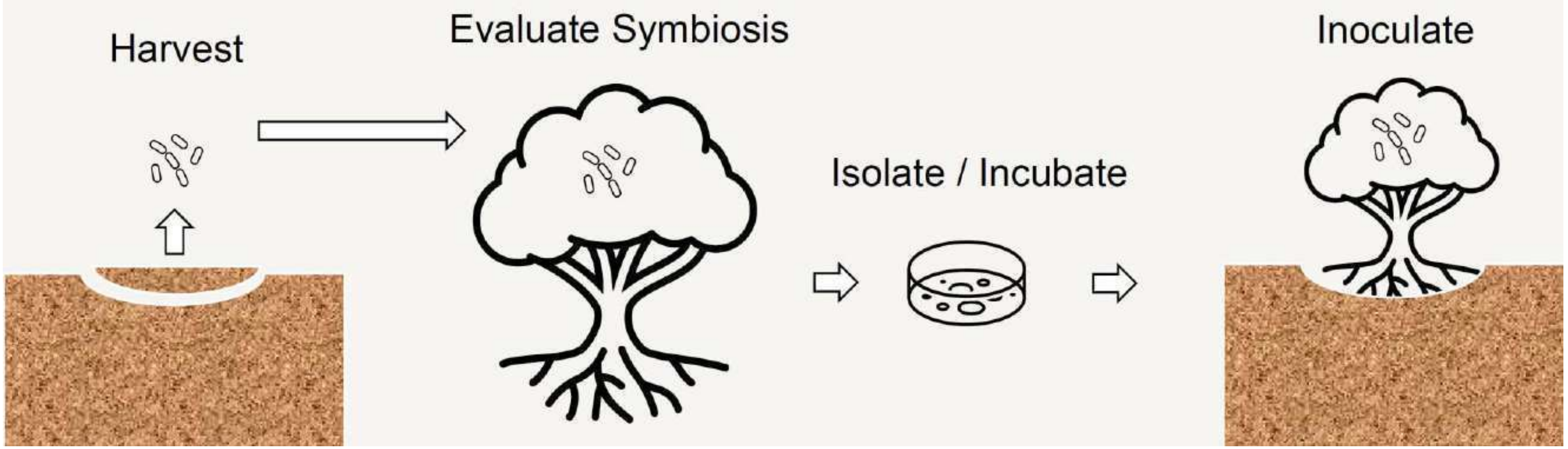
Maximum benefits are realized when habitat and restoration values are fully integrated with site-wide design

Contaminated Sediment Beneficial Use Workshop
Washington, March 2024

The U.S. Army Engineer Research and Development Center (ERDC) sponsors programs on the remediation of sediments within BU projects.

One such project focuses on contaminant-specific degrading bacteria residing in dredged sediment to adapt them for use as plant inoculants.

If bacteria that can degrade emerging substances like PFAS are found and isolated, enhanced rhizo-degradation in BU sediment applications (wetlands, meadows, shallow lakes) can accelerate clean up.



Contaminated Sediment Beneficial Use Workshop
Washington, March 2024

The program that was mentioned most as a stimulant for BU of sediments was the Great Lakes Legacy Act.

32 Great Lakes Legacy Act Cleanups Completed

Indiana

- East Branch - Grand Calumet River AOC
- Roxana Marsh - Grand Calumet River AOC
- Stateline - Grand Calumet River AOC
- West Branch - Grand Calumet River AOC

Michigan

- Black Lagoon - Detroit River AOC
- Division Street Outfall - Muskegon Lake AOC
- Former MGP Site - St. Marys River AOC
- River Raisin - River Raisin AOC
- Ruddiman Creek - Muskegon Lake AOC
- Tannery Bay - St. Marys River AOC
- Zephyr Site - Muskegon Lake AOC

Minnesota

- Minnesota Slip - St. Louis River AOC
- Slip 3 and Slip C - St. Louis River AOC
- SLR Interlake/Duluth Tar - St. Louis River AOC

New York

- Buffalo River - Buffalo River AOC

Ohio

- Ashtabula River - Ashtabula River AOC
- Jack's Marine North Slip - Ashtabula River AOC
- Ottawa River - Maumee River AOC

Wisconsin

- Hog Island Inlet - St. Louis River AOC
- Kinnickinnic River - Milwaukee Estuary AOC
- Lincoln Park Phase 1 - Milwaukee Estuary AOC
- Lincoln Park Phase 2 - Milwaukee Estuary AOC
- Sheboygan River - Sheboygan River AOC
- Tyco - Menominee River AOC

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Contaminated Sediment Beneficial Use Workshop
Washington, March 2024

What was a bit of a surprise was that *emerging components* like PFAS where well known and regulated for human consumption:

U.S. EPA Announces New National Primary Drinking Water Regulations for PFAS

APRIL 25, 2024

DRINKING WATER, EPA, PFAS, PFAS STRATEGIC ROADMAP

Read Time: 2 mins

On April 10, 2024, the U.S. Environmental Protection Agency (EPA) announced the first-ever legally enforceable drinking water standards for per- and polyfluoroalkyl substances (PFAS). PFAS are a group of thousands of manmade chemicals that have been manufactured and used globally since the 1940s. They are commonly found in textiles, cookware,

… both governmental parties and industry shied away from surface water and sediment regulation.

One comment was that the legacy pollutants like PCB would still take decades to clean up, another was the risk that BU would back-claw due to the need for a second clean up (no ‘ne bis in idem’).

Contaminated Sediment Beneficial Use Workshop
Washington, March 2024

Wrap up of the status of BU of contaminated sediments in the USA:

- Even contaminated there is potential as a resource,
- LCA's and sustainability goals are positive drivers,
- Regional programs offer opportunities
- There is a lack on upscaling experience with BU contaminated sediment applications.

Where are we now?

Beneficial Use of Contaminated Sediments – A White Paper
By - Barr Engineering Co., Deltares, & Windward Environmental LLC

Key observations based on the literature:

- Sediment increasingly is seen as a resource, not a waste
- Treatment or pre-treatment facilitates/expands beneficial use options
- Beneficial use of contaminated material more common in upland settings than aquatic
- End use affects both risk and risk acceptability
- Regional sediment management/planning facilitates programmatic approaches to beneficial use
- Techniques and applications are advancing
- Beneficial use aligns with sustainability principles
- Sustainability evaluations are becoming more common
- Approaching management options through sustainability evaluation creates opportunities
- Calculating lifecycle costs facilitates beneficial use
- Stakeholders may draw valid but contradictory conclusions regarding acceptability
- Improved communication/engagement can reduce stigma
- Regulatory flexibility to allow adaptive management (to control risks and enhance rewards over time) is foundational to achieving the social, economic and environmental benefits of beneficial use
- Questioning conservative biases in screening-level risk assessments will enable risk characterization and management decisions that provide greater social, economic, and environmental benefits.

US Army Corps of Engineers • Engineer Research and Development Center

Recent EU policy developments – Soil monitoring law

The EU Soil strategy (2030) is covered by Julia Gebert.

But good to recap that there will be a Soil monitoring and resilience directive, to be implemented in law.

The status of sediments in the soil strategy and soil monitoring are not yet clear (only mentioned under management of flood risks and the impacts for the soil-sediment-water system), so if and what components to monitor in sediments is not yet defined.

Sediments?

Figure 1: links between the EU Soil Strategy and other EU initiatives

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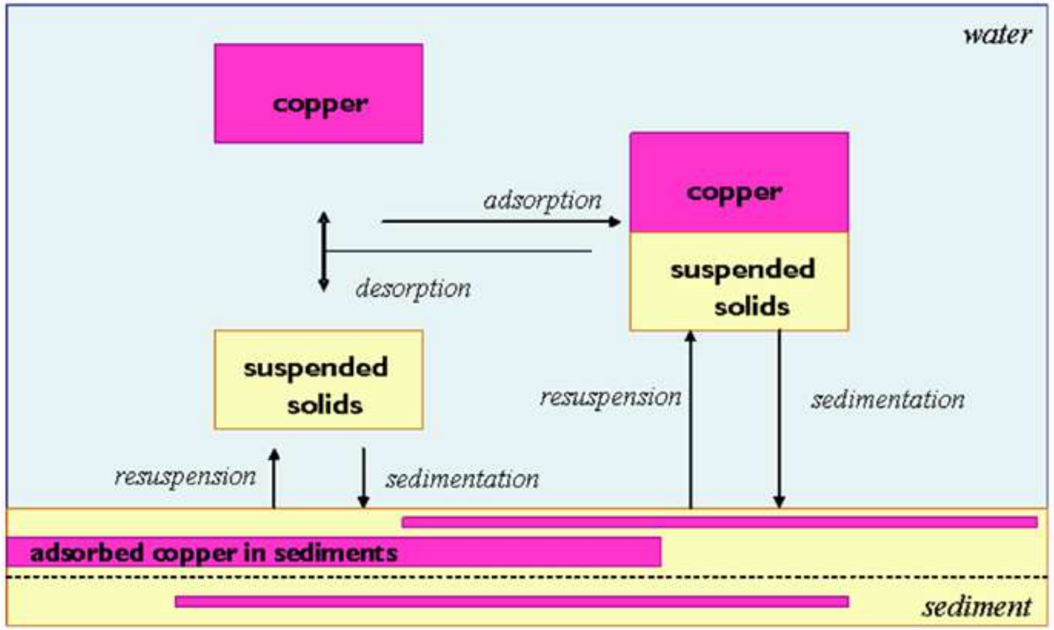
Recent EU policy developments – WFD

However, getting towards the end of the 3rd WFD management cycle in 2027, meeting the WFD water criteria is becoming more and more important.

Sediments are seen as a source for uptake and release of contaminants, therefore contaminant concentrations in sediments are deemed relevant.

A recent (November 2023) EU committee decision to set an *EQS for TBT in sediment based on the WFD EQS in surface water* illustrates that sediments, and therefore the BU of sediments, can be impacted by the WFD.



Equilibrium partitioning between water and suspended solid and water and sediment

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Recent EU policy developments – WFD

Deltares is now screening the potential impact of contaminants in sediments for:

- All 33 priority substances
- 70 Dutch specific WFD substances
- 33 PFAS components
- 8 new substances of possible concern
- 5 types of waterbodies

What helps is that in the Netherlands there is a WFD covering model to assess the impact of contaminant sources (https://www.immissietoets.nl/berekening/immissietoets#/berekening/immissietoets).

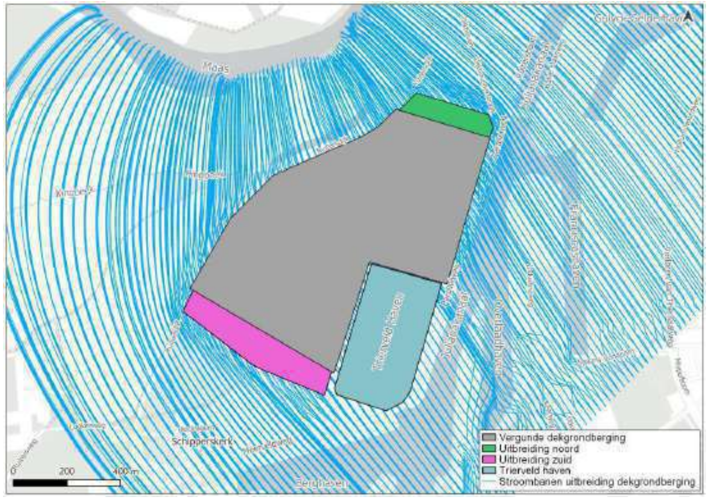
The outcome of this screening could be that the quality of sediments suitable for BU can be waterbody specific.

Recent EU policy developments – WFD

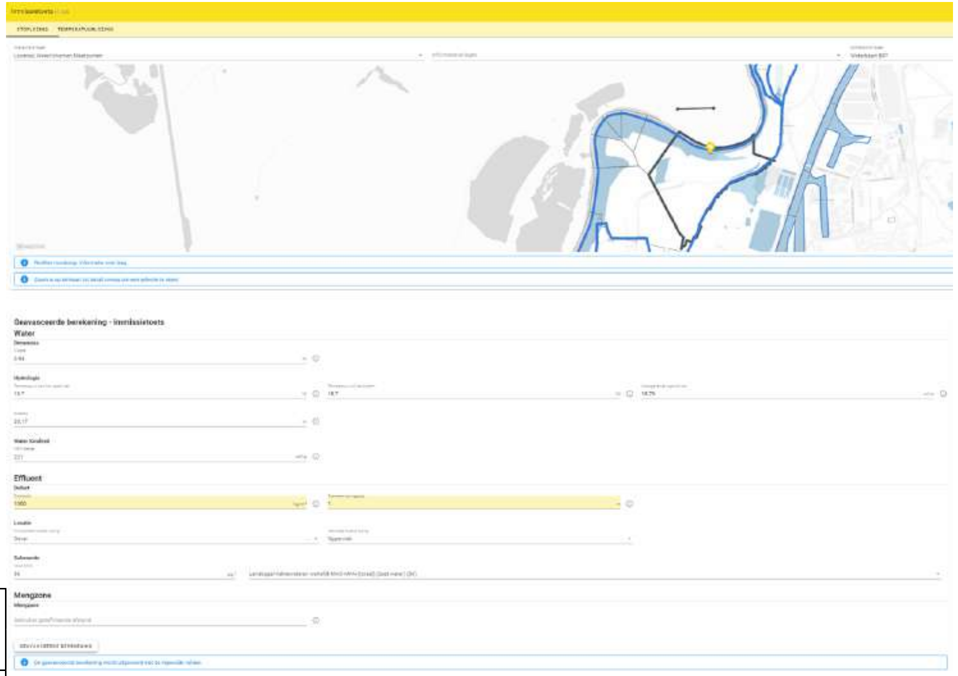
An example for BU of sediments (and soils) with PFAS near a riverbank:

The site

Groundwater flow



Immission -> assessed



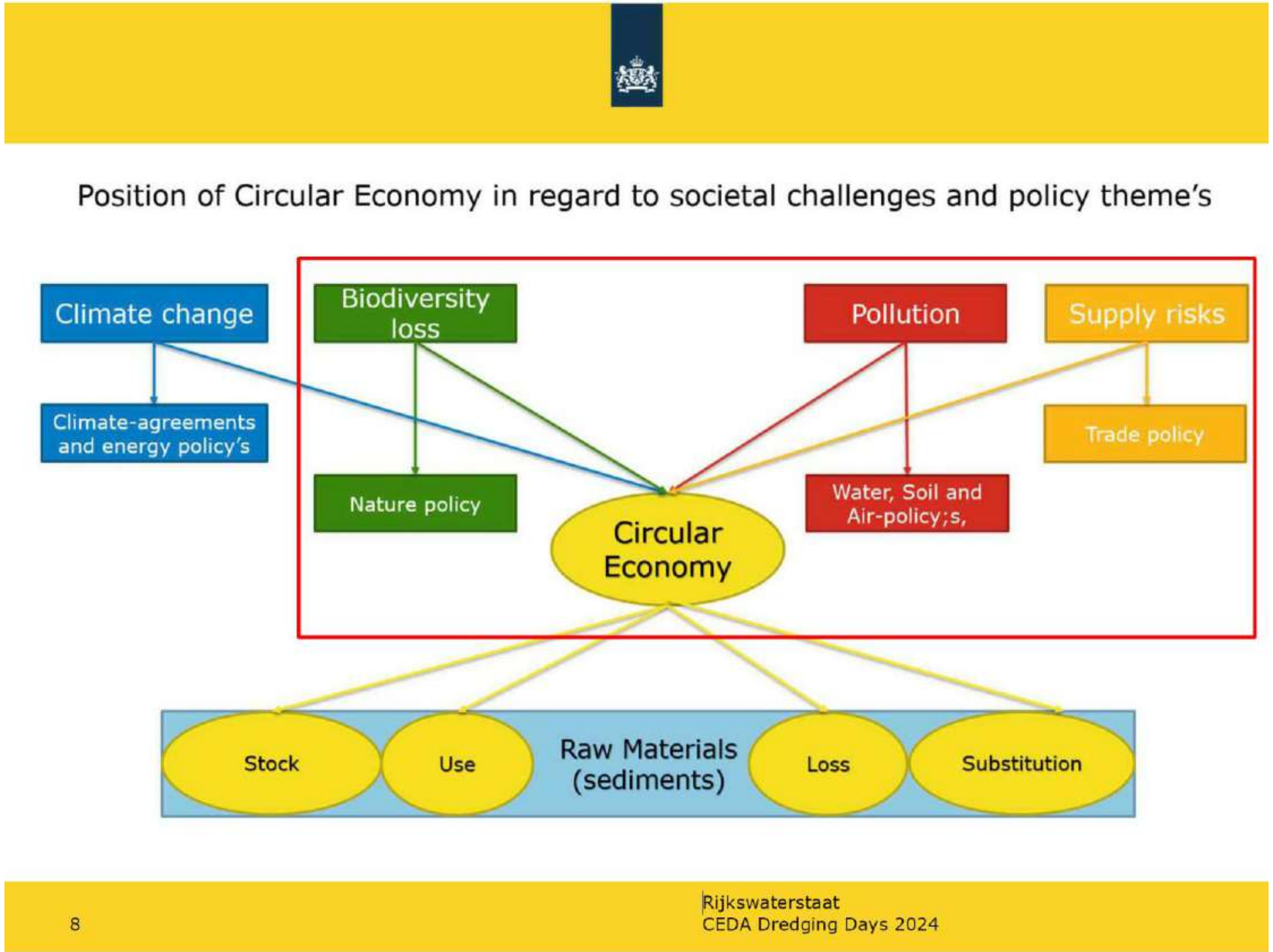
Immission -> approved

Overzicht voor	**Tmax =**	**600**			
achtergrond conc. =		0.00160	(ref. Eijsden)		
Maximum immissietoets		**PFOS**		**JG-MKN**	**MAC**
	jaarvracht	conc.	µg/l	**0.00065**	**36.0**
Tijd (Jaar)	gram/jaar	µg/l	significantietoets	**normtoets JG**	**normtoets MAC**
600	1.13	0.00119	-0.000004	0.00160	
		voldoet?	ja	achtergrondwaarde	ja

Recent EU policy developments
BU of sediment from an end user perspective (RWS)

At the CEDA dredging days (May 2024)

Pieter de Boer presented the following slides



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Recent EU policy developments
BU of sediment from an end user perspective (RWS)

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Pieter de Boer presented the following slides

2. Circularity of sedimentmanagement and dredging

- CE is **a tool** for reaching our global goals for sustainability.
- CE addresses the scarceness (of resources) of raw materials as well as the environmental effects of mining (dredging) and use of those materials.
- CE is about the use and lifecycle of (raw) materials. The general goals are:

  1. Protection of **stocks**;
  2. Reduction of negative environmental **impact** of mining (dredging) stocks;
  3. Retention of the **value**. High quality use of the material (maximise the value).
- Action is needed to reach the general goals of CE and for improvement of the sustainability of sediment management and dredging projects.

Recent EU policy developments
BU of sediment from an end user perspective (RWS)

At the CEDA dredging days (May 2024)

Pieter de Boer presented the following slides

3. Conclusions and outlook.

- The concept of Circular Economy is a framework that can help to improve the sustainability of sediment management and dredging projects.
- EU Regulations such as the The WasteFD and WaterFD already are in place to facilitate sustainable sediment management, but need to be elaborated.
- Knowledge of “the sector” on beneficial use of DM and on waste management options is available for this elaboration of the regulations!

- No time to waste!

Recent EU policy developments
SedNet contribution

To close this session:

Several SedNet members have contributed to the common implementation strategy for the Water Framework Directive on **Integrated sediment management** - Guidelines and good practices in the context of the Water Framework Directive.

The principles here should be leading for BU, including the evaluation of the risk of contaminants.

https://environment.ec.europa.eu/system/files/2022-09/CISdocumentsedimentfinalTO_BE_PUBLISHED_1430554724.pdf

COMMON IMPLEMENTATION STRATEGY
FOR THE WATER FRAMEWORK DIRECTIVE
(2000/60/EC)

Integrated sediment management
Guidelines and good practices in the context of the Water Framework Directive

Hamburg Port Authority

LD

Landside Treatment and Disposal

Karsten Lehmann, HPA

05.06.2024

01 Sediment management

02 Landside treatment

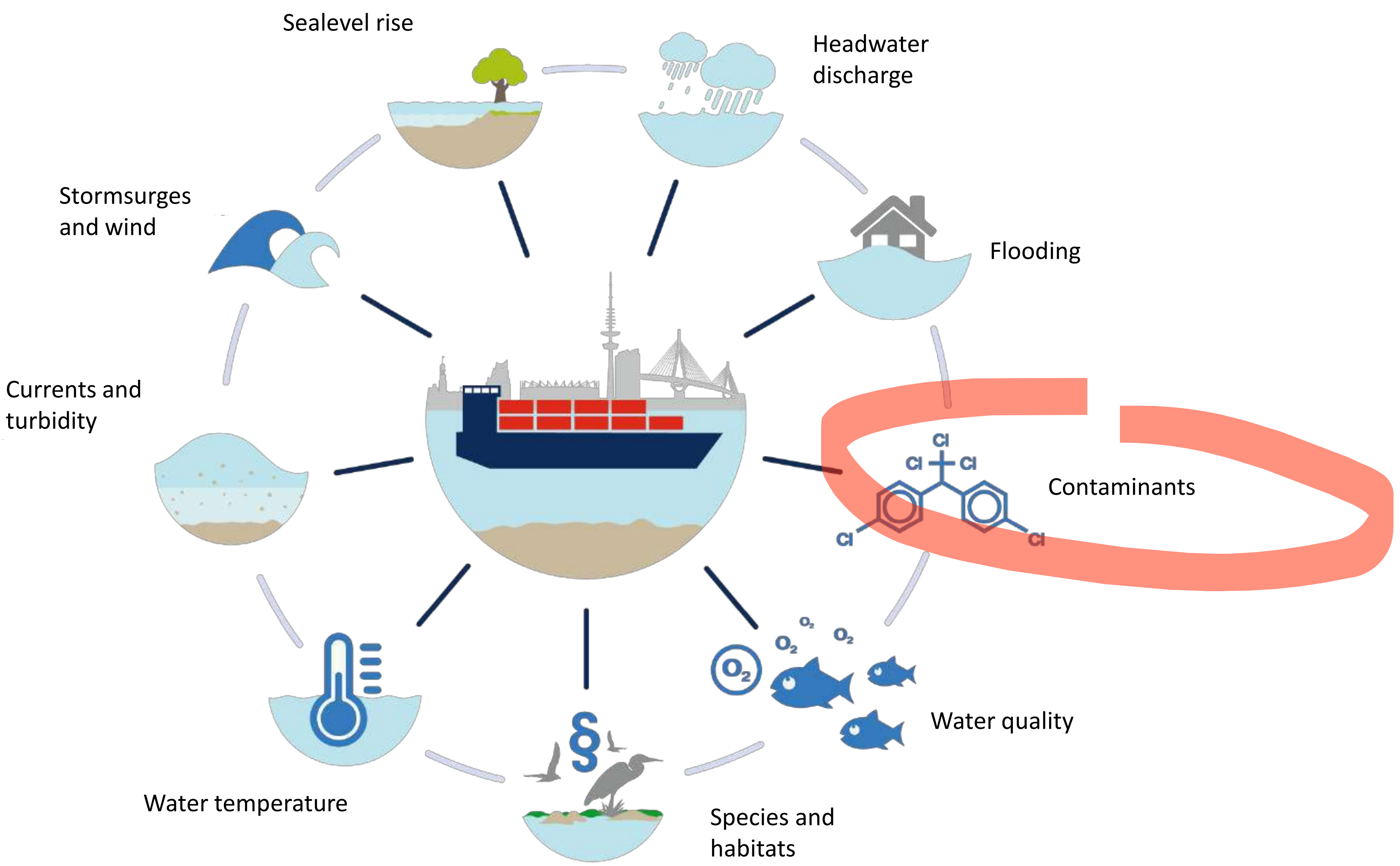
03 Disposal and beneficial use

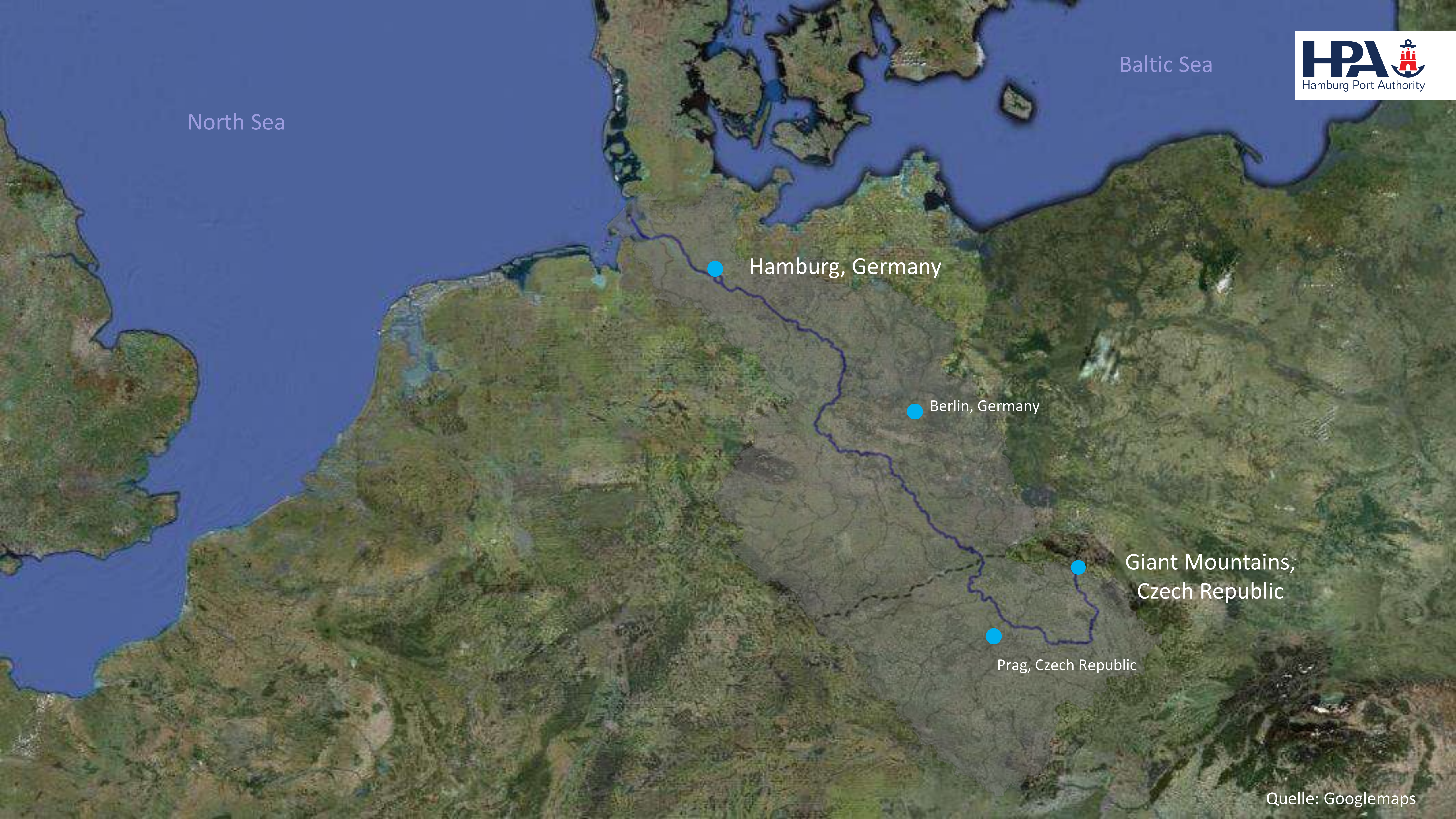
01

Sediment management in the Port of Hamburg

Accessiblity to the port

Influencing Factors




North Sea
Baltic Sea
HPA
Hamburg Port Authority
Hamburg, Germany
Berlin, Germany
Giant Mountains,
Czech Republic
Prag, Czech Republic
Quelle: Googlemaps

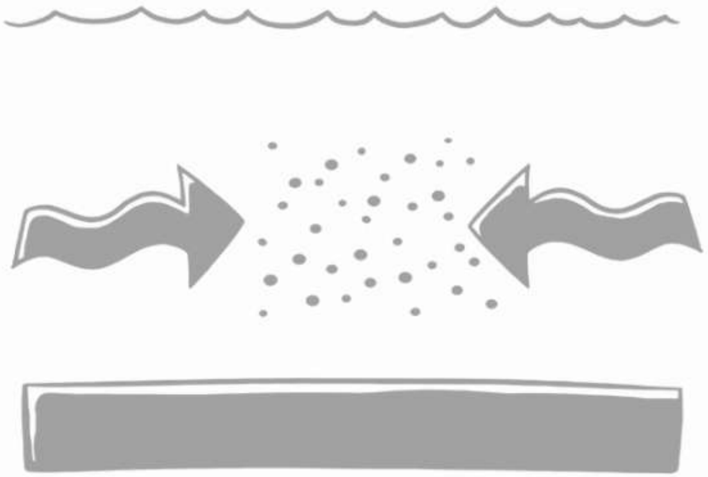
Hamburg Port Authority

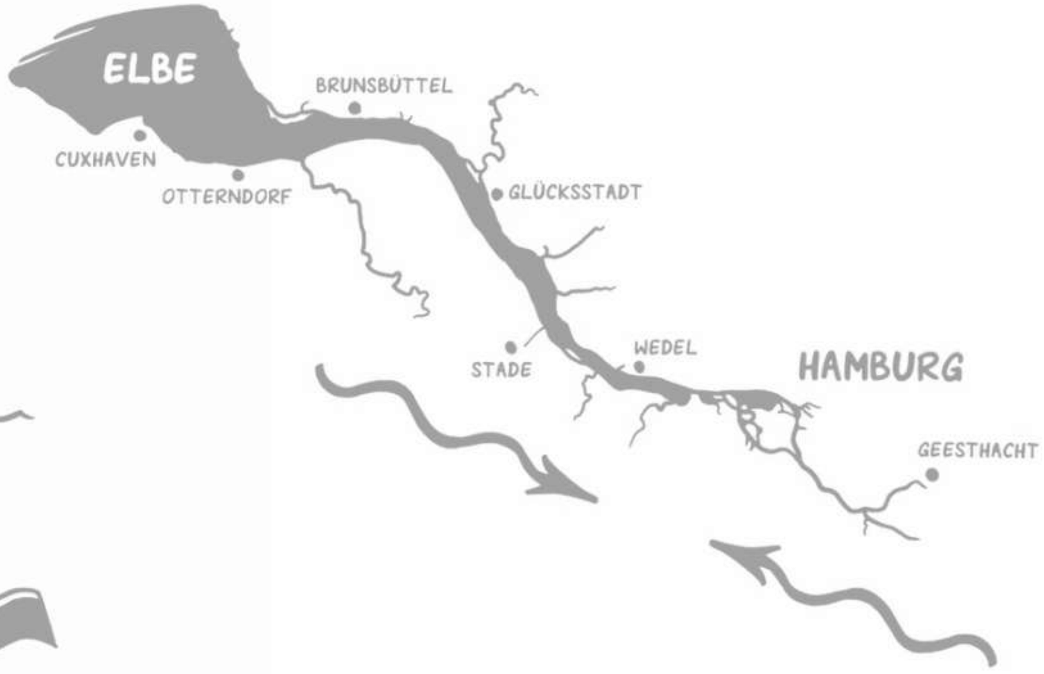
Sediments from the upper course of the Elbe river and the north sea

Flow rate of the upper course

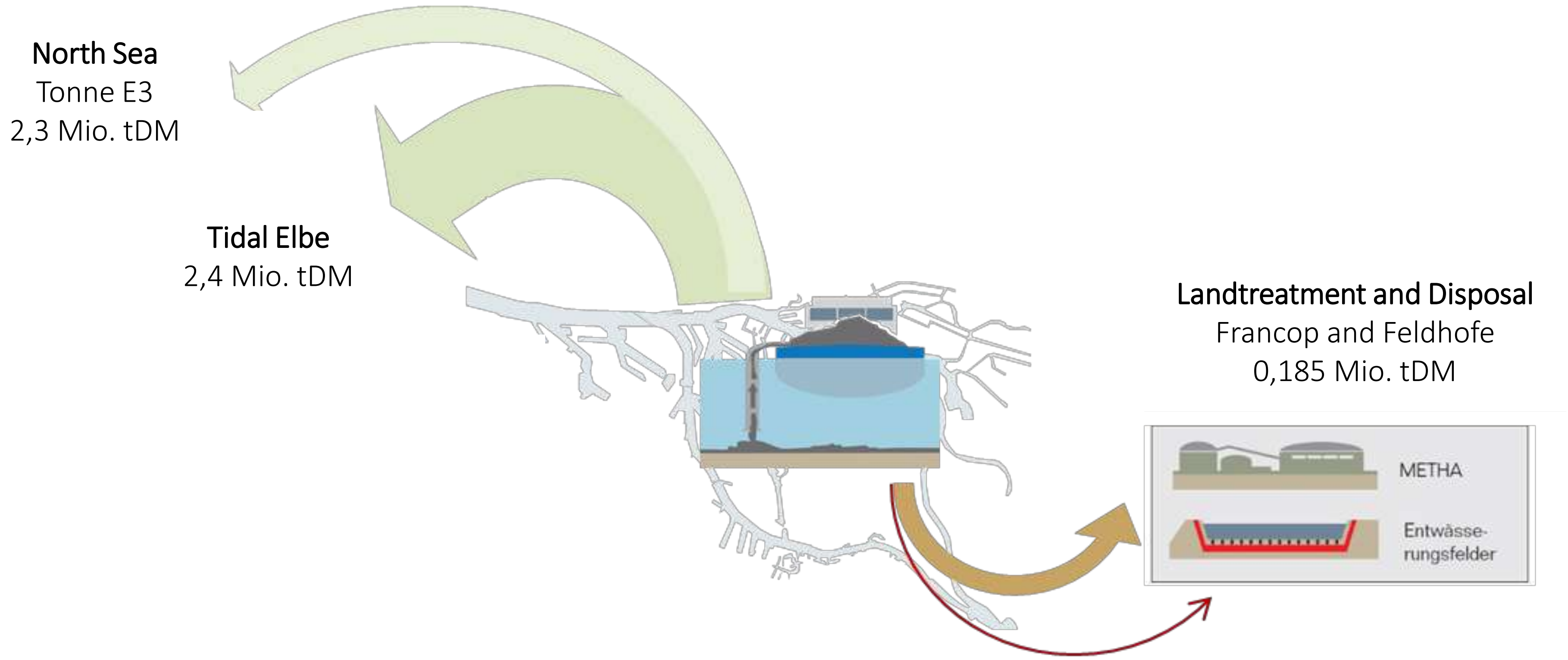
average 2023:
488 m³/s

longterm average
675 m³/s





Sediment fluxes in 2022 – Port of Hamburg



02

Landside treatment

Reciving of dreged material

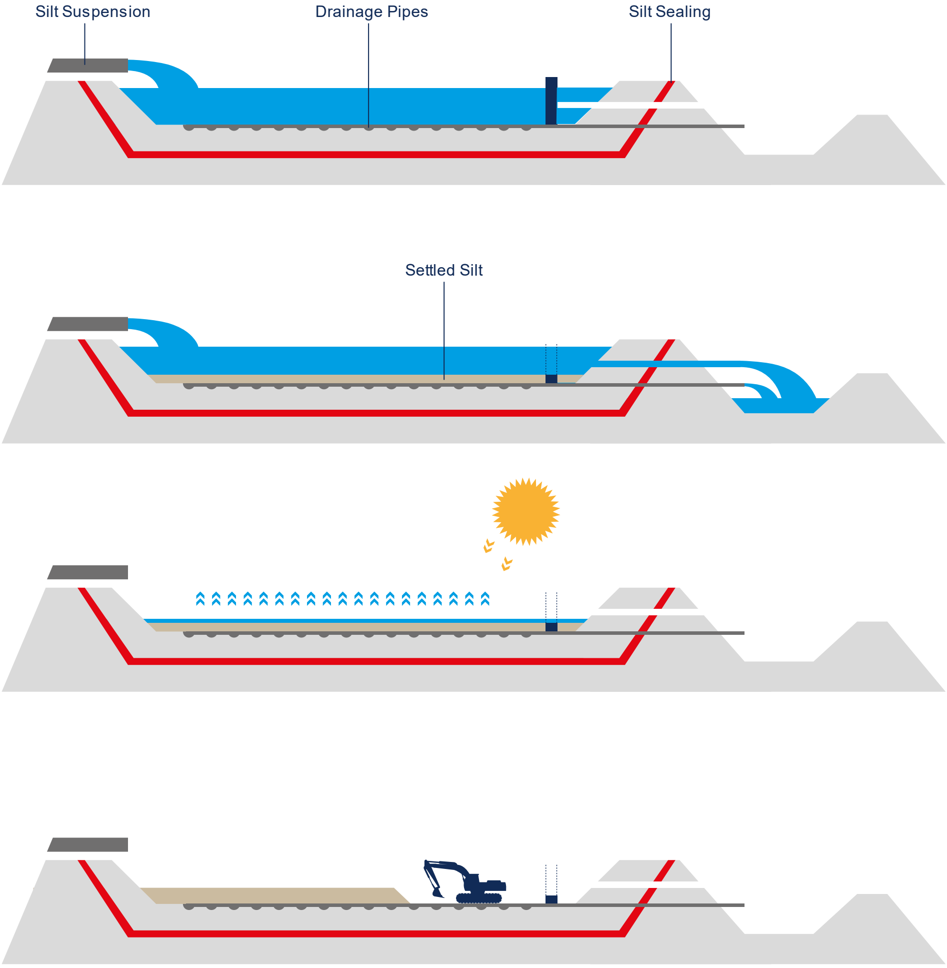
Treatment of habour sediments

Beneficial use or disposal of treated sediments

DM Treatment - Dewatering Fields Moorburg

- Area size of dewatering fields: about 100 ha
- Field size: 2 - 4 ha
- Throughput capacity: up to 250,000 m³/a

Operation Principle of the Dewatering Fields

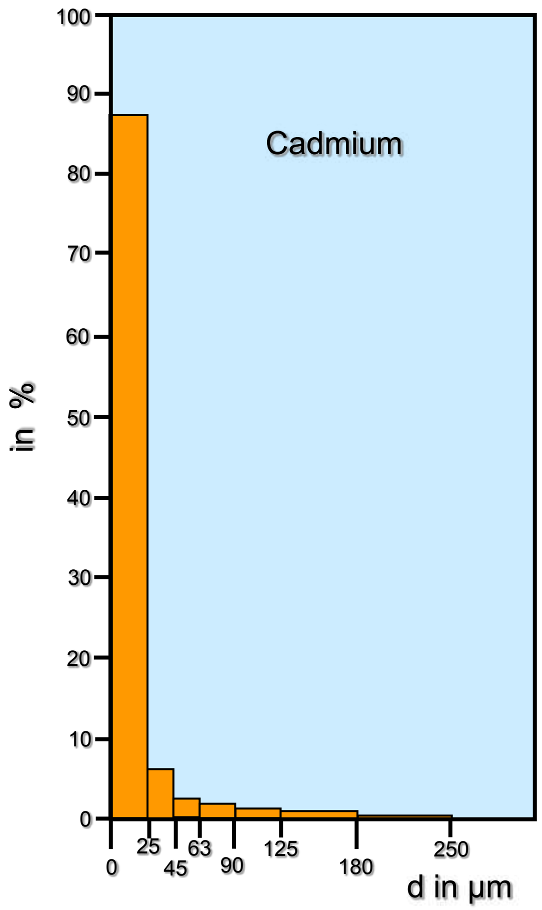


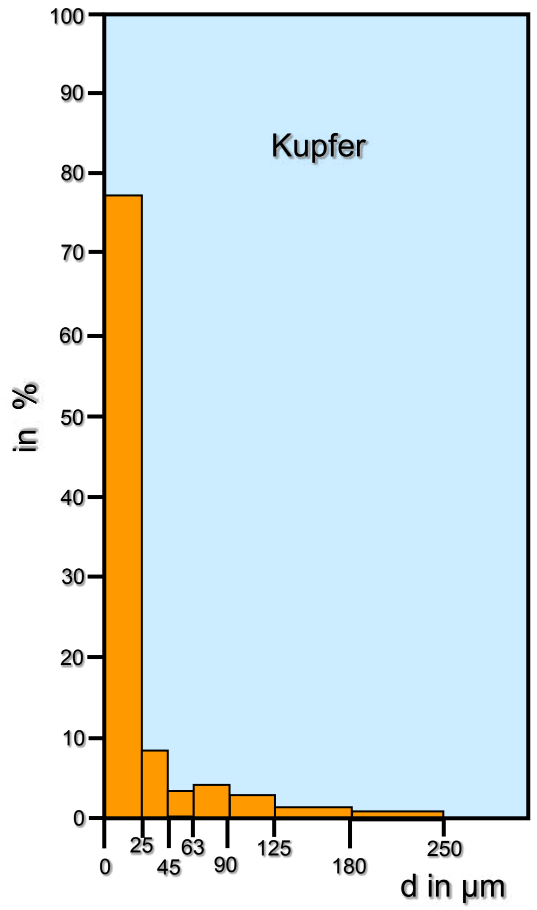
- Filling of dewatering fields
- Remove Supernatant water
- Natural dewatering by sun and wind
- Remove and transport to final use

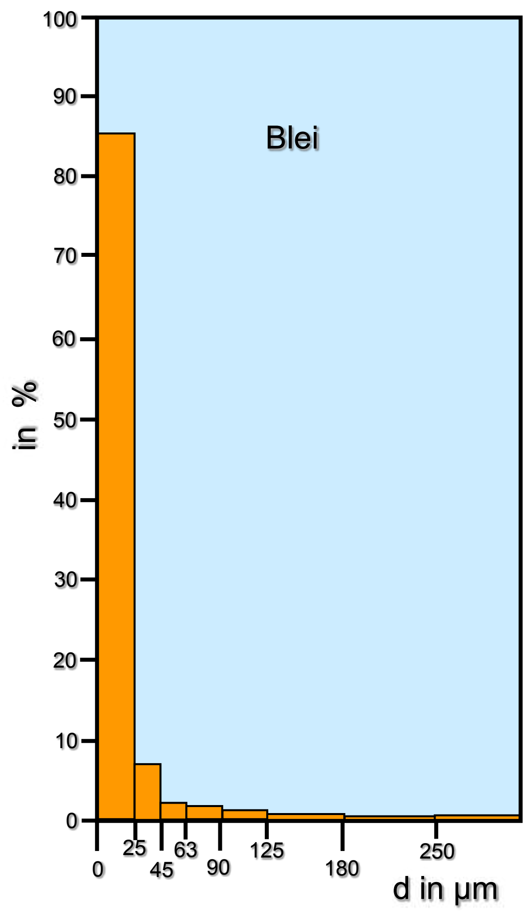
Dredged Material Treatment Plant - METHA

- Operation phase since 1993
- Annual throughput up to 230.000 tDM/a

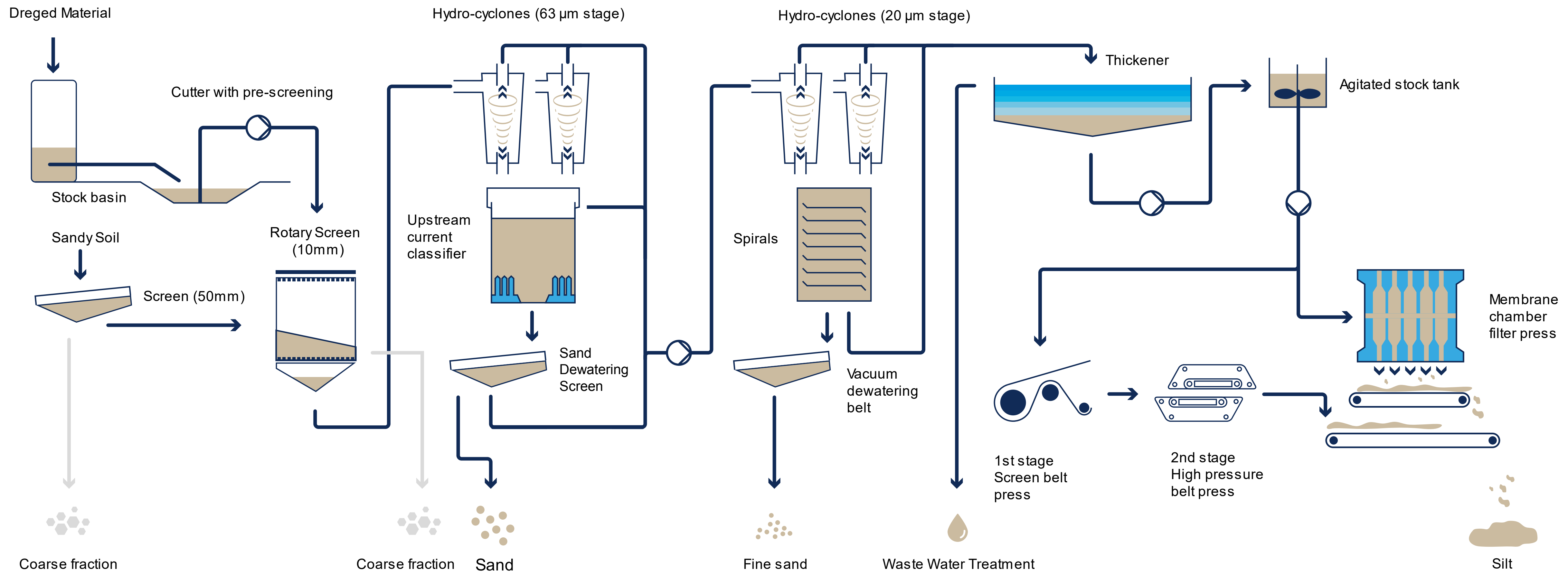
Classification of dreged sediments





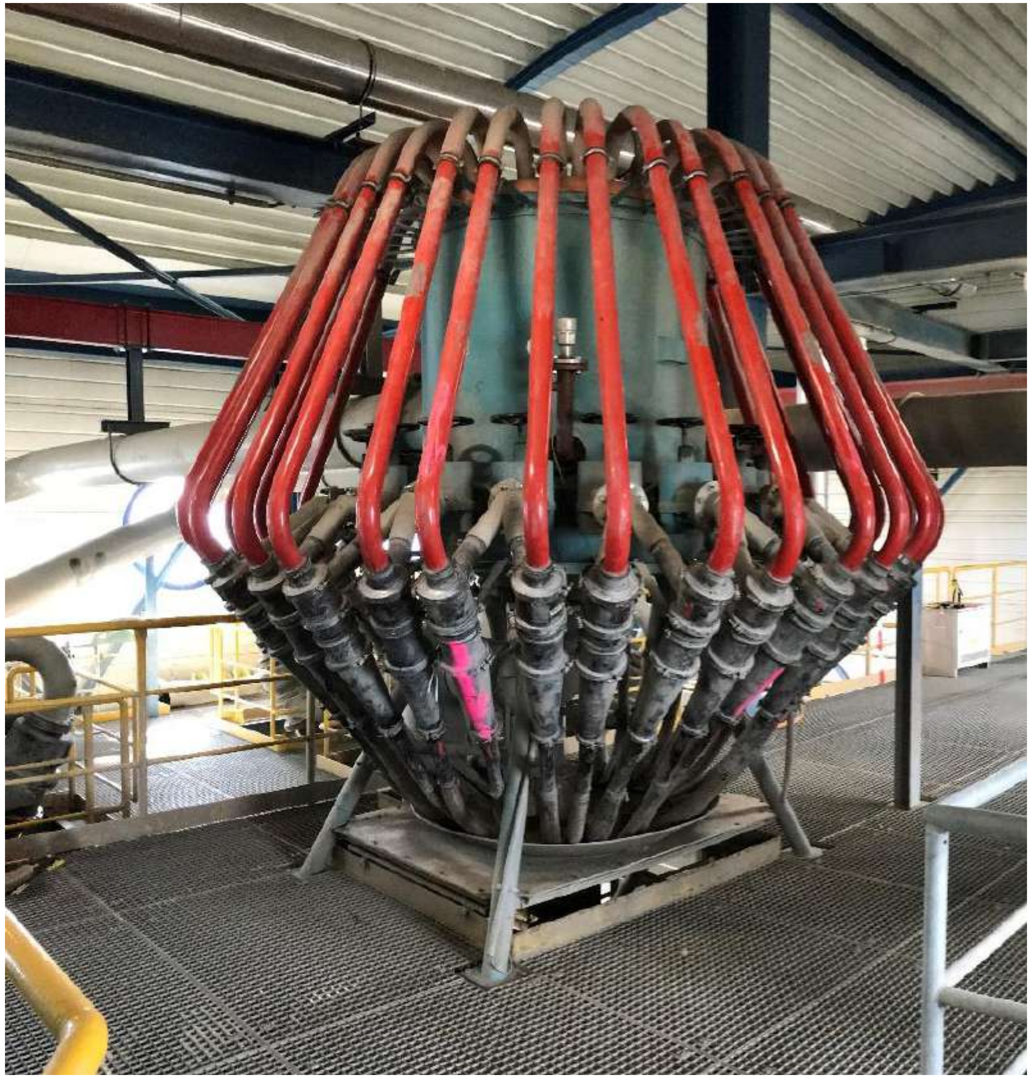


Operation Principle of the METHA



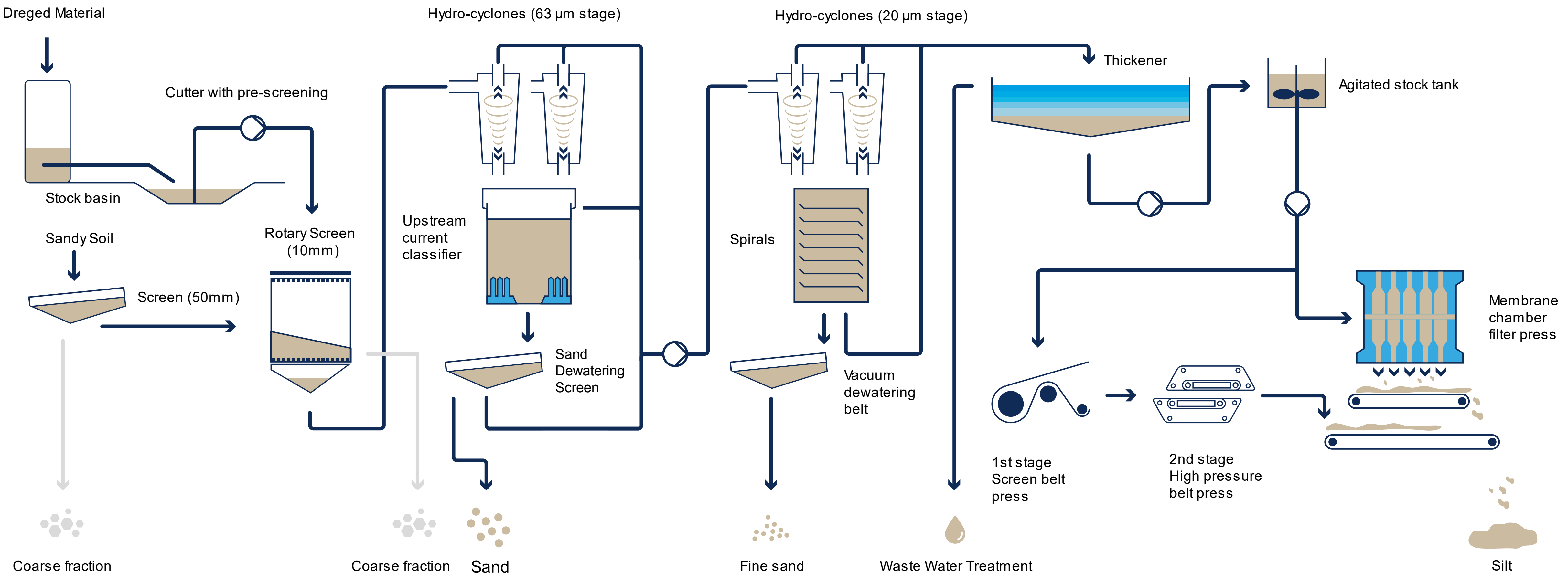
Classification

Classification - Hydrocyclones and upstream classifiers



Classification - Sand dewatering screens

Operation Principle of the METHA



Classification - Thickener

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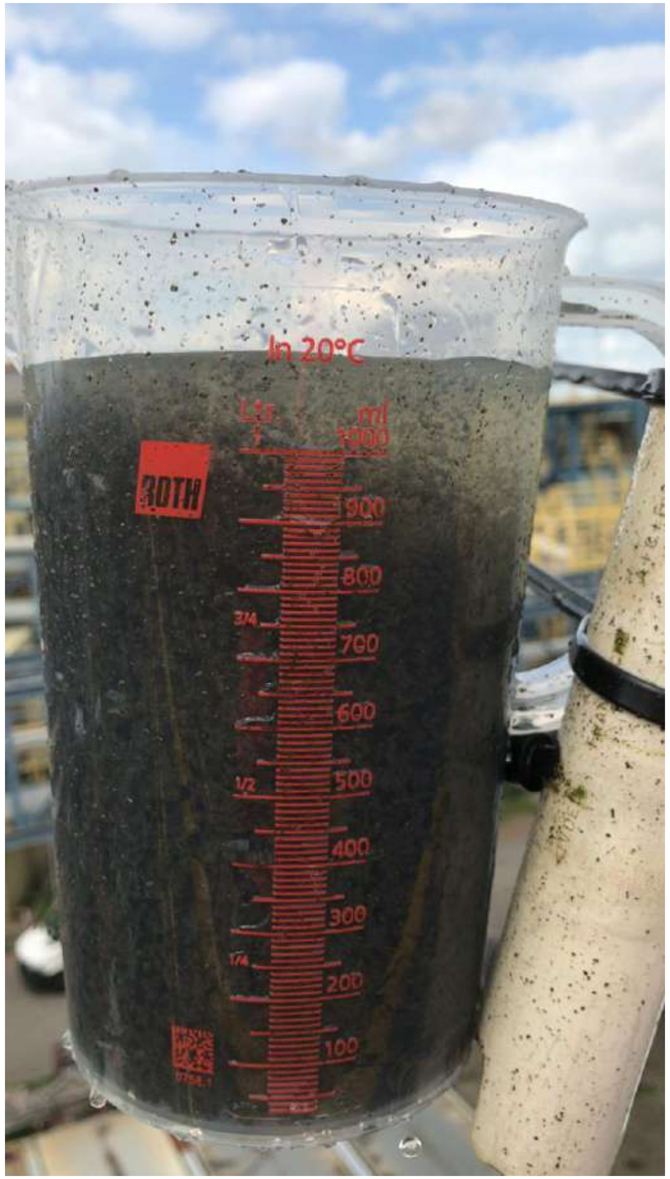
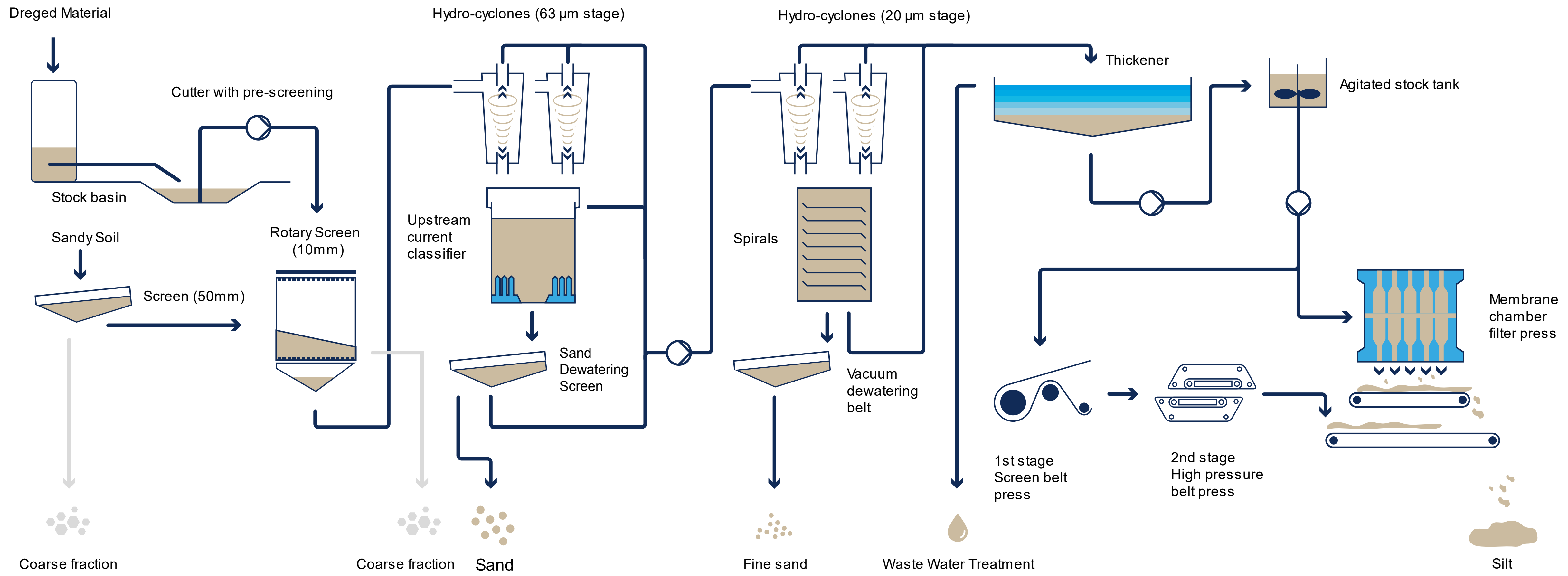
Classification - Thickener



Operation Principle of the METHA



Dewatering

Hamburg Port Authority

Dewatering - Belt press

Dewatering - High pressure belt press

Basic and costs

- Development of the technology: 1987 - 1992
- Commissioning: March 1993
- Annual throughput: 230.000 tDM
- Investment costs: about 70 Mio. € (1993)
- Operation costs: about 14 Mio. €/a
- Staff: 96 employees
- For nearly 20 years the METHA plant had been the one and only dredged material treatment plant worldwide. Since 2011 there is a comparable facility in Antwerp in operation.

03

Disposal & Beneficial Use

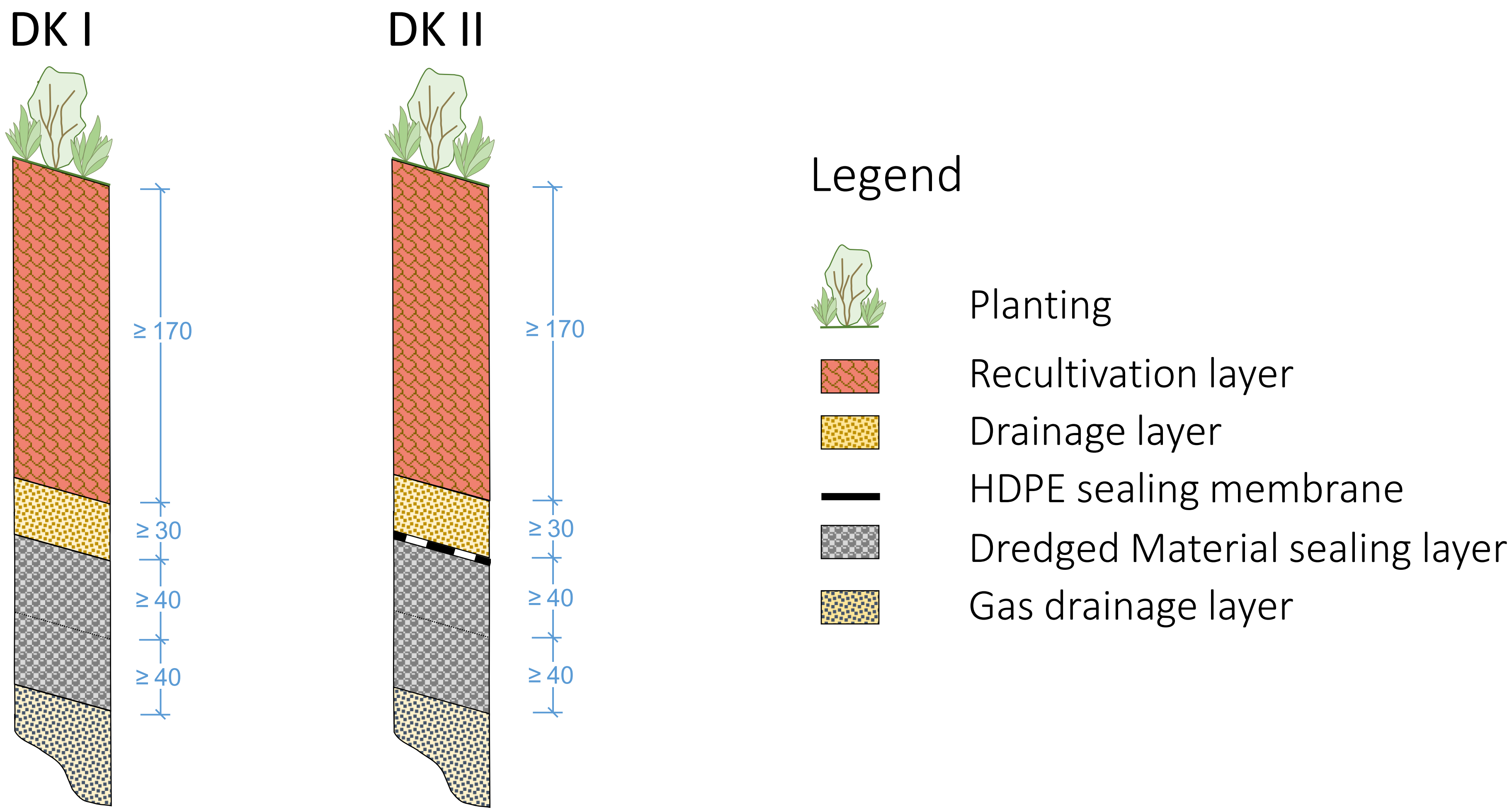
DM as sealing material on disposal sites

- Disposal site Francop
- Capacity ca. 9.000.000 m^3
- Future use public park
- Closed in 2020

DM as sealing material on disposal sites

- Disposal site Feldhofe
- Capacity 7,000,000 m^3 DM

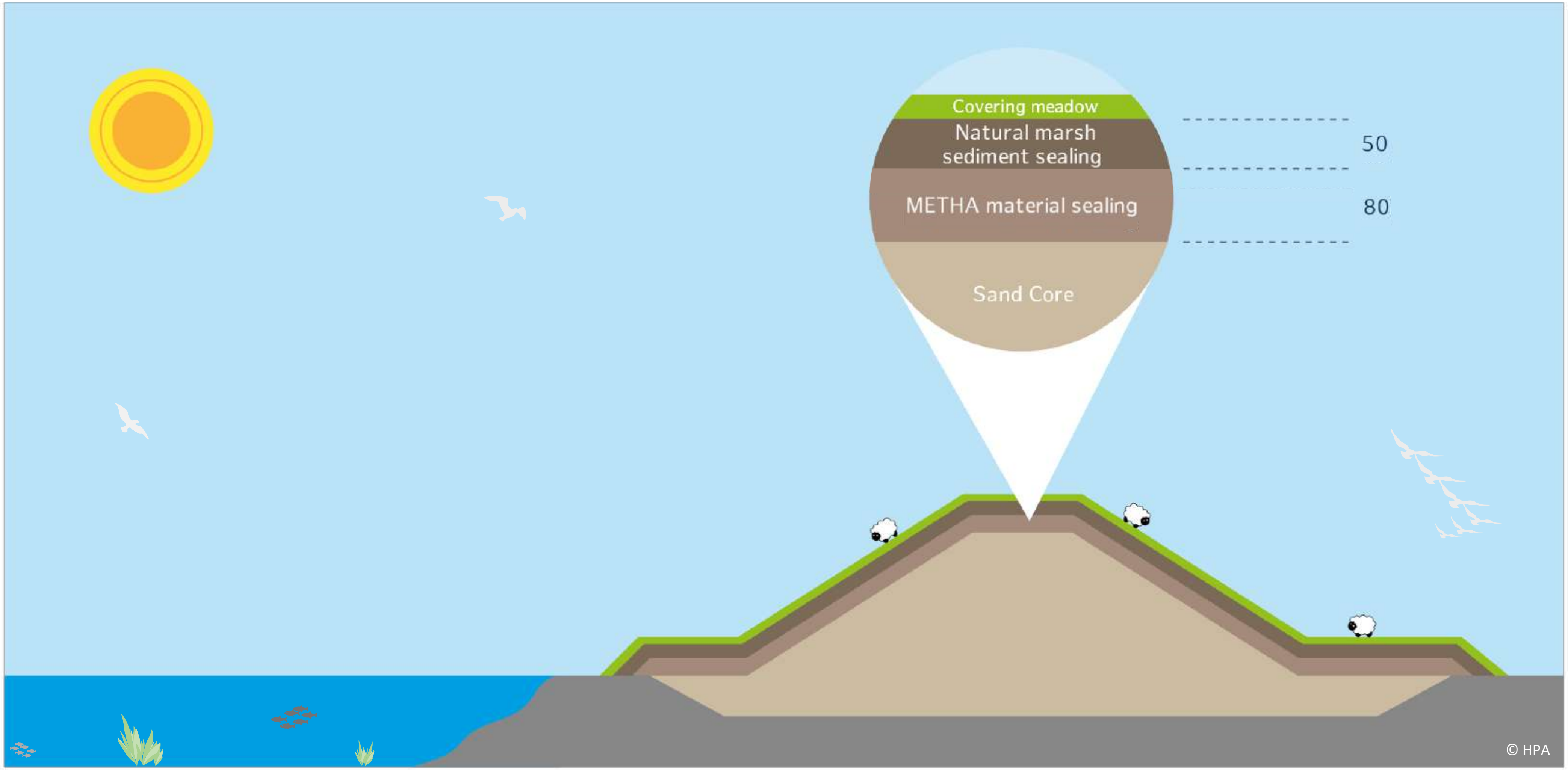
DM as sealing material on disposal sites



DM as clay substitute in dike construction

- Pilot dike construction using METHA Material below a layer of natural marsh sediment at Ellerholzkanal, Hamburg
- Built in 2004

DM as clay substitute in dike construction



Silty and sandy DM in backfilling measures

- Area: 8 ha
- 290,000 m³ METHA-Material
- 420,000 m³ Sand
- Target Hight: + 8.00 m
- Built in 2013 - 2016

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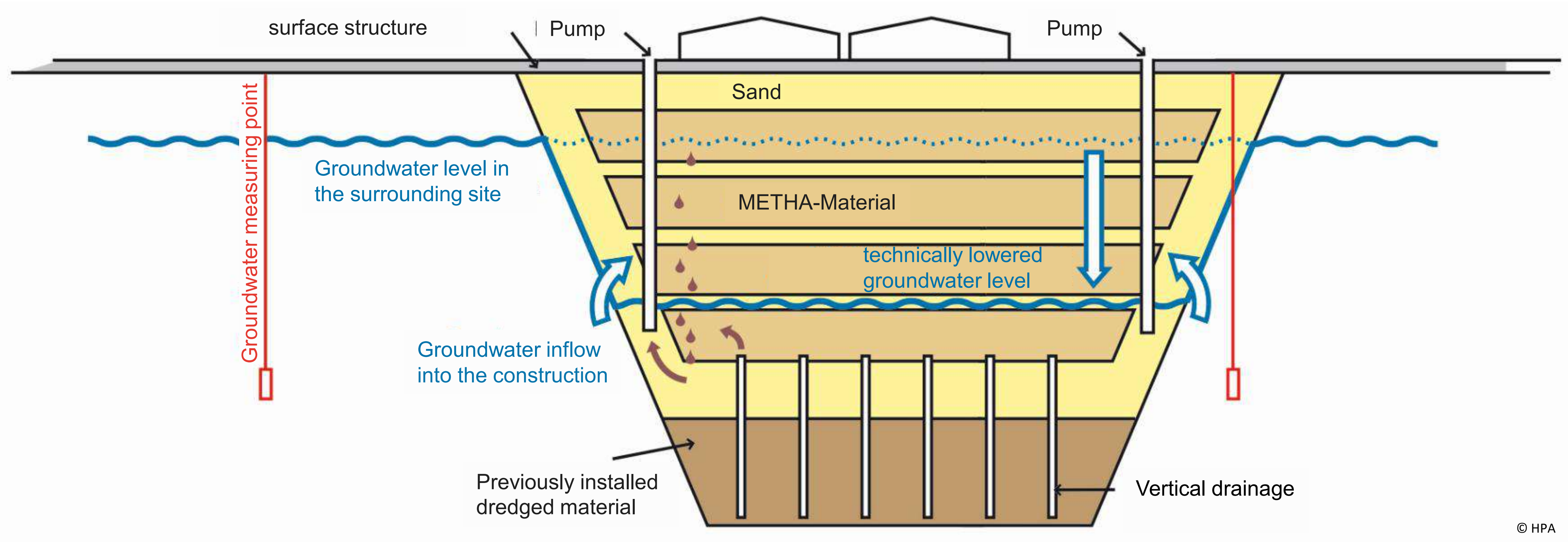
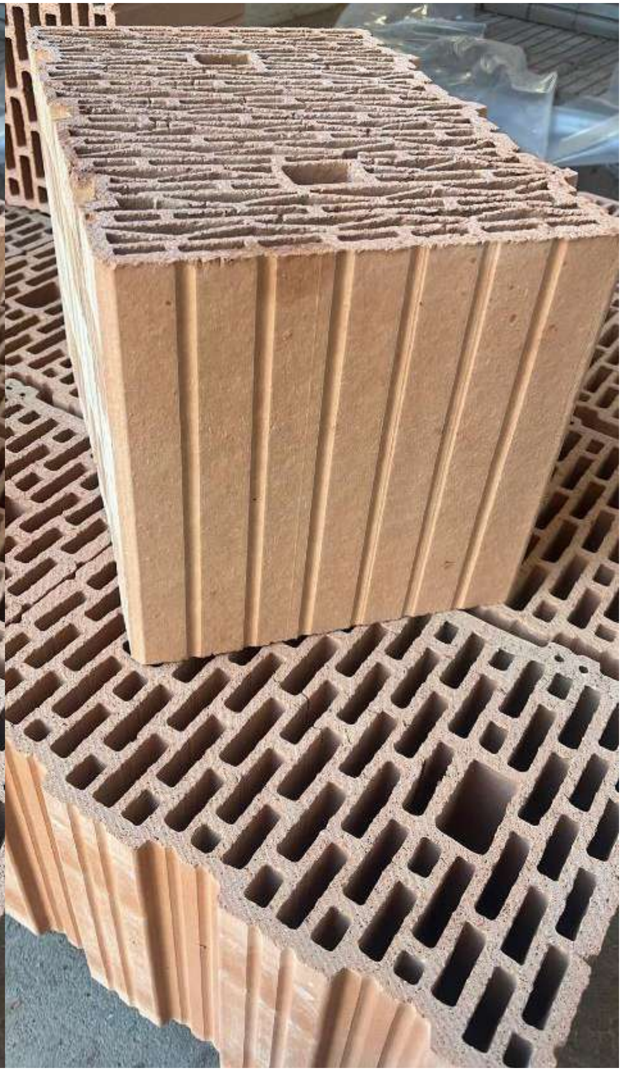
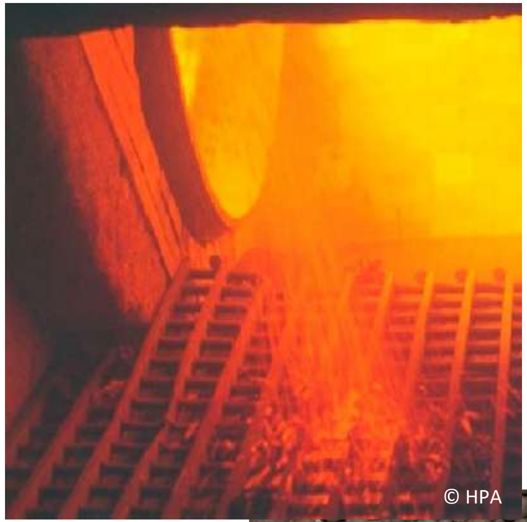
Silty and sandy DM in backfilling measures



Silty DM material in the ceramic industry





Leightweight
Aggregat Production

Karsten Lehmann

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