Practical Aspects of Sediments and Their Treatment - an Example

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Short history of Sediments

- Sediments have been regarded a valuable source for men (agriculture, dikes, dike foreland) and nature until the 20^{th} century.
- Floods (Odra, Elbe, Rhine) revealed a wide spectrum of problems with contaminated sediments.
- Sediments are disqualified from source to hazardous waste.

Contaminants

- In Hamburg harbour
  - Metals (Copper, Cadmium, Lead, Zink, Arsenic,...)
  - TBT
  - PAH
  - Hexachlorobenzol
  - Chloropestizides
  - Estrogenes ?
- Contaminants can be remobilised and harm the aquatic environment

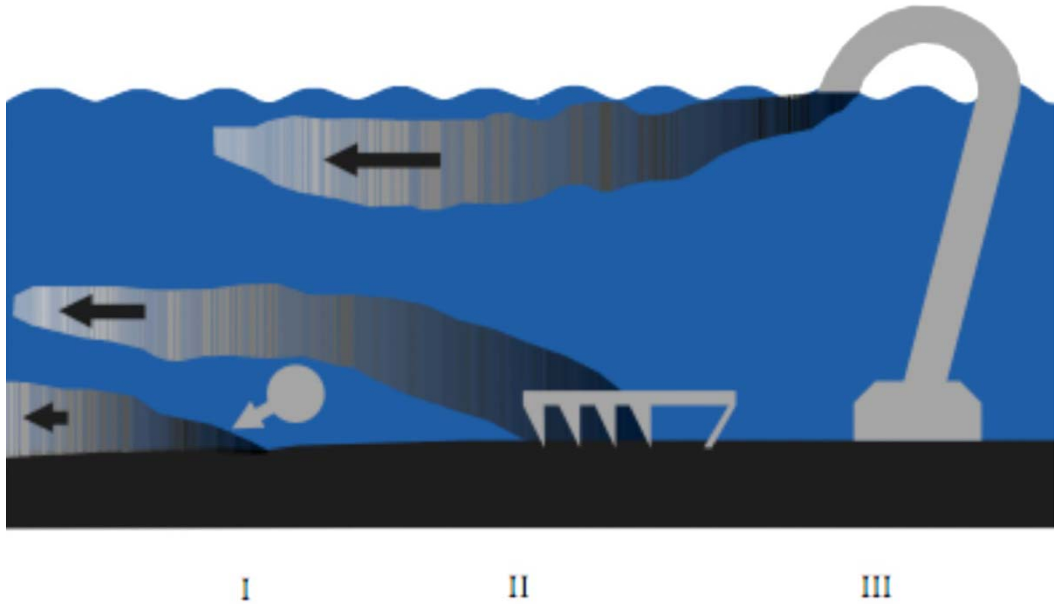
Remedial options

1. No action, which is only appropriately applied of if is determined that sediments pose no risk,
2. Monitored natural recovery, based on the assumption that, while sediments pose some risk, it is low enough that natural processes can reduce risk over time in a reasonably safe manner,
3. In-situ containment, in which sediment contaminants are in some manner isolated from target organisms, though the sediments are left in place,
4. In-situ treatment, and
5. Dredging or excavation (followed by ex situ treatment, disposal and/or reuse).

Remediationtechniques for sediments

	in place	excavated
containment	in-situ-capping	confined aquatic disposal/capping
	contain/fill	land disposal
		beneficial use
treatment	bioremediation	physical separation
	immobilisation	chemical extraction
	chemical treatment	biological treatment
		immobilisation
		thermal treatment

How to remove Sediments - conventional relocation of harbour sediments I



1. water injection
2. agitation (mud harrow)
3. side casting

Relocation of sediments, no removal!

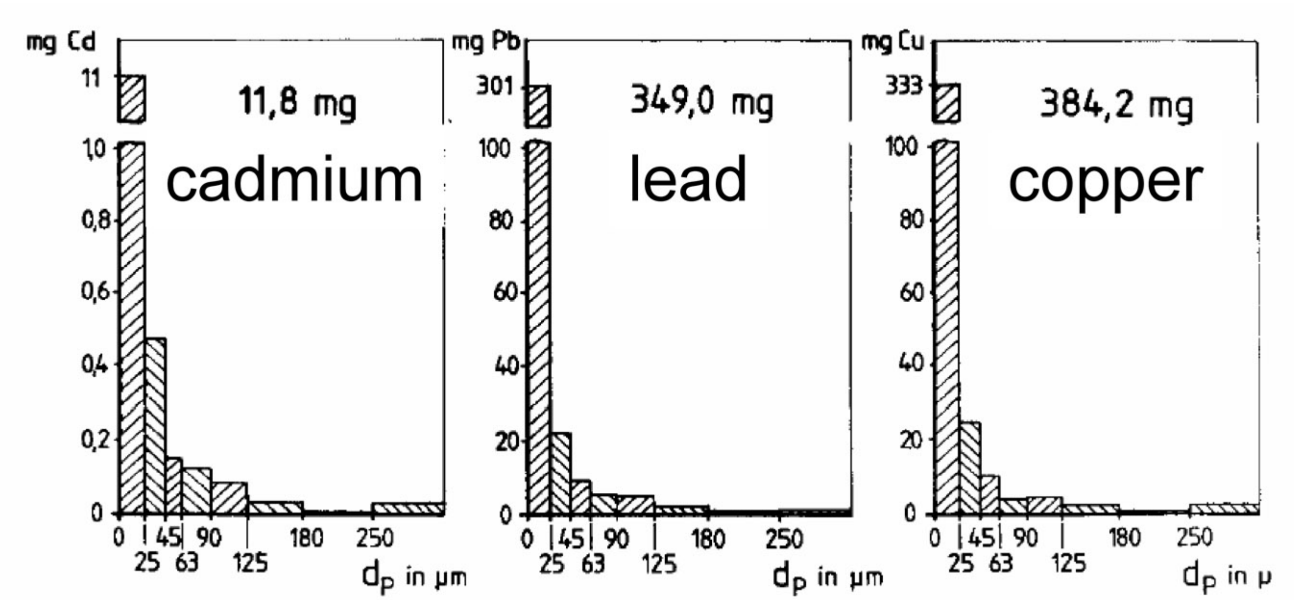
How to remove Sediments - conventional relocation of harbour sediments II

- Other conventional techniques:
  - Bucket excavator
  - Shovel excavator
  - Suction excavator
- Removal of sediments, external storage possible
- Storage on fields
  - treatment of sediments from fields ?
  - treatment of excess water from fields ?

How to treat removed Sediments

- large scale:
  - e.g. mechanical separation
  - low costs per unit of residue
  - low sensitivity to variations
  - can be applied to mobile plants
- small scale:
  - decontamination, e.g. biological treatment, acid leaching, solvent extraction
  - higher costs per unit of residue
  - specific experience needed
  - usually stationary

Particle size dependent contamination



classification of sediments (DIN 4022)

63 mm	stones
20 mm - 2 mm	gravel
632 µm - 63 µm	sand
20 µm - 2 µm	silt
0,6 µm - 0,2 µm	clay

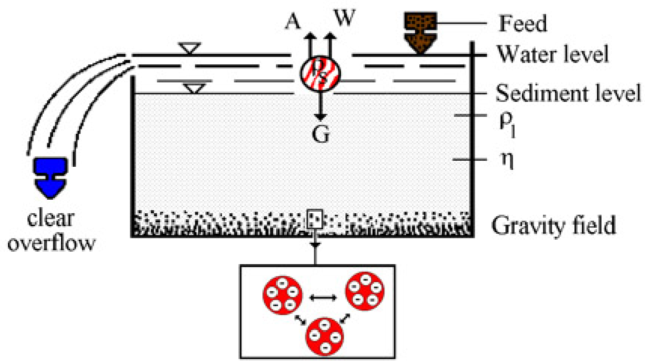
contaminants predominantly in middle silt fraction (d_p < 20 µm)

sand (d_p > 63 µm) minor contaminations

mechanical separation (particle size) reasonable

Sedimentation and Filtration < 0.1 mm

Sedimentation



Stokes´s Law:

$$v_s = \frac{d^2(\rho_s - \rho_l)g}{18\eta}$$

d = 1 µm → ν_s = 1 m / month
d = 0,1 µm → ν_s = 1 m / a

ν_S = velocity of sedimentation
d = diameter of particle
φ = density **g** = gravity η = viscosity

ν_s decreases with increasing Re and with equal polarities of particles

Karman and Kozeny:

Filtration:

Nanoskale-particles

problematic

$$\alpha_H = 5 \cdot \frac{(1-\varepsilon)^2}{\varepsilon^3} \cdot \frac{36}{d^2}$$

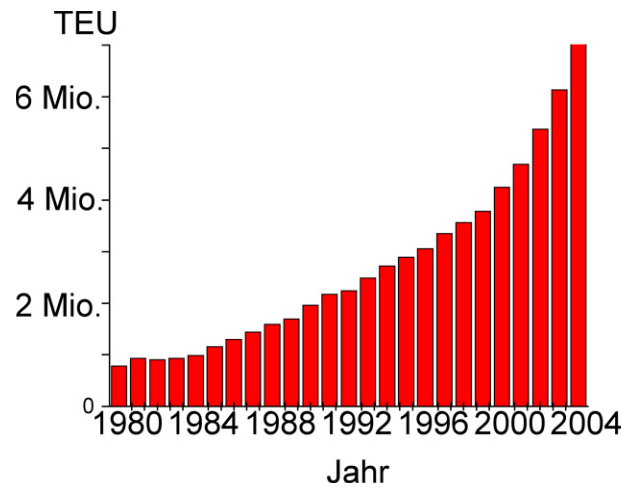
α_H = resistancy of filtration
d = diameter

$$v_F = \frac{\Delta P \cdot r^2}{8 \cdot \eta_{Fl} \cdot z}$$

ν_F = velocity of filtration
ΔP = difference of pressure
r = pore-diametre
η_{Fl} = viscosity of liquid
z = length of pore

Example Hamburg Harbour

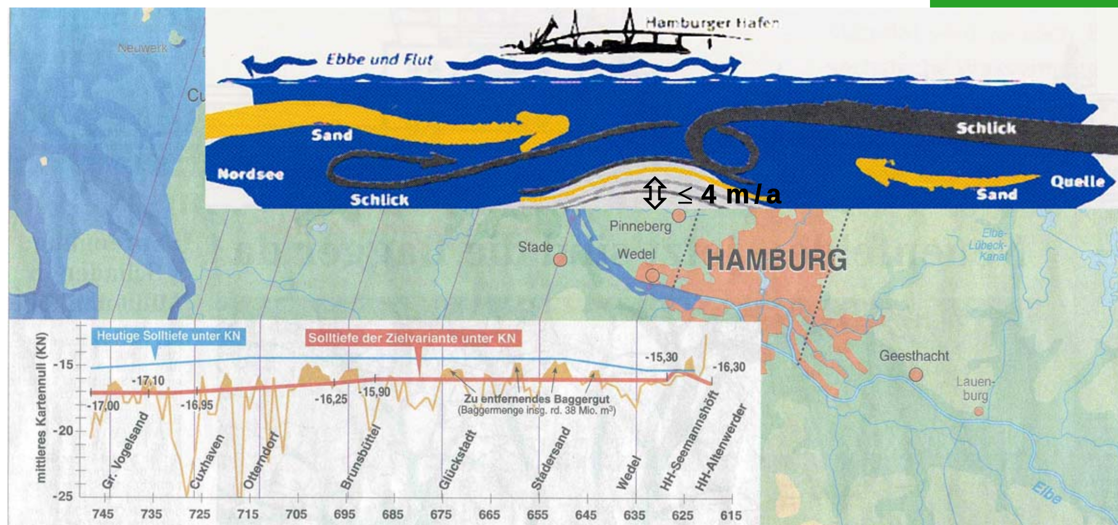
	2004
Rotterdam	8,2 Mio TEU
Hamburg	7,0 Mio TEU
Antwerpen	6,0 Mio TEU



TEU: Twenty-Feet Equivalent Unit
(Standard-Container)
L 6,1 m; B 2,5 m; H 2,6 m

Keeping free the waterway and the Elbe

Hamburg Harbour lower Elbe:



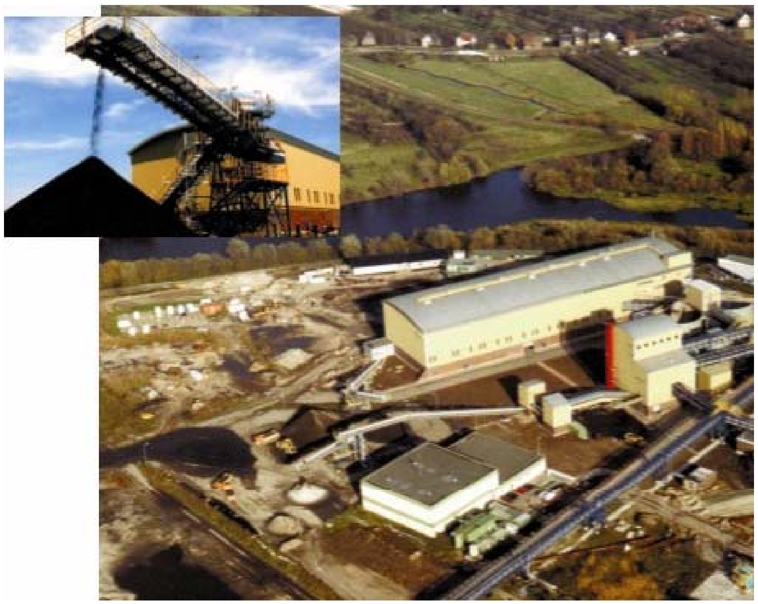
Depth of waterway: 13,80 m (independent of tidal: 12,50 m)

8,1 Mio m³/a dredged material, with 5,35 Mio m³/a silt and fine-sand sediment

4,25 Mio m³/a with low contaminations ⇒ relocation/dumping/harrowing in the current

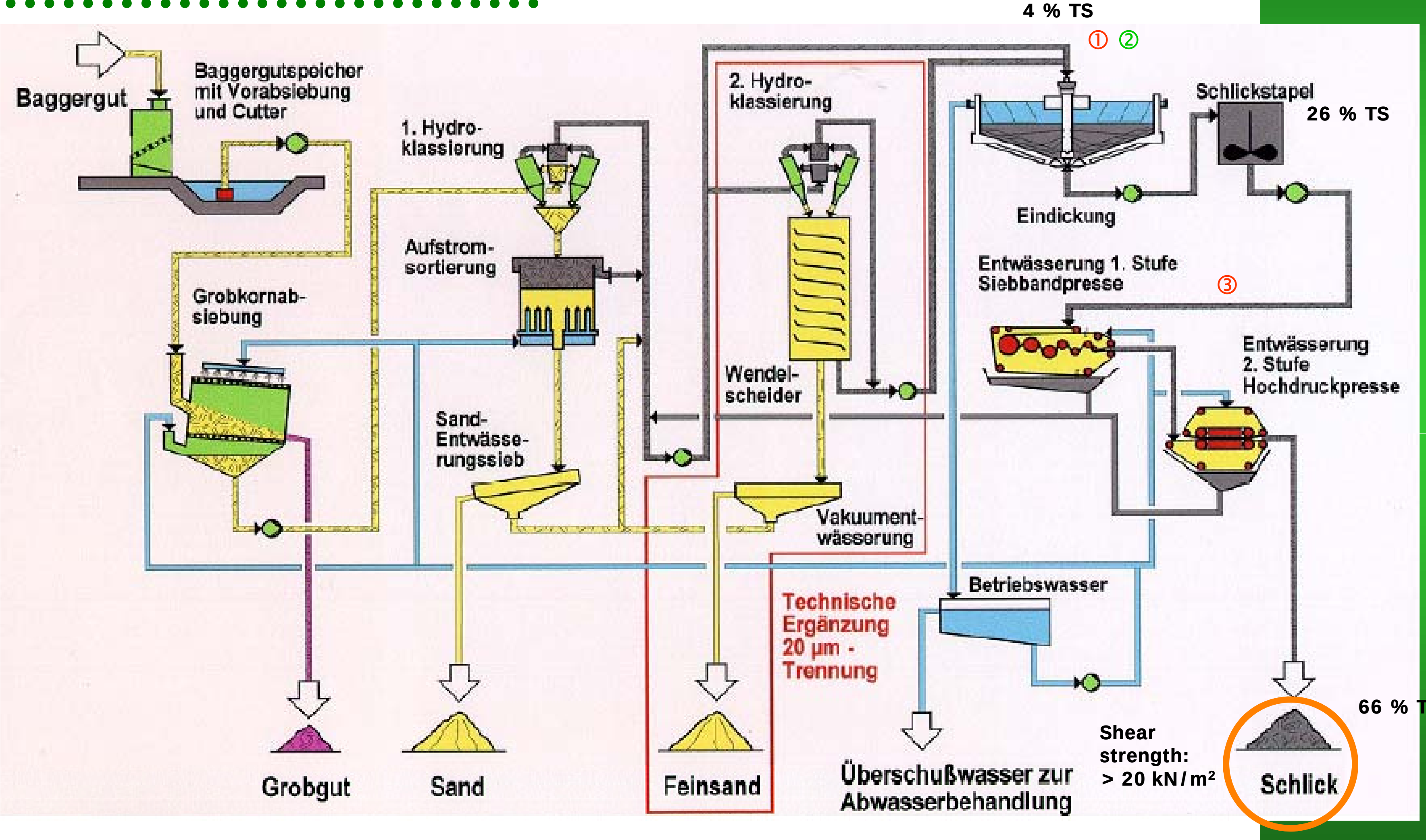
1,1 Mio m³/a contaminated ⇒ disposal

METHA III



- Since 1993 separation of dredged material in low contaminated sand (> 63 µm) and contaminated mud
- Production of 400 000 t/a dewatered mud
- Invest: approx. 68,5 Mio €
- Annual costs: approx 5,5 Mio € (approx 1,3 Mio € for flocculants)

Principle of sediment dewatering (METHA III)



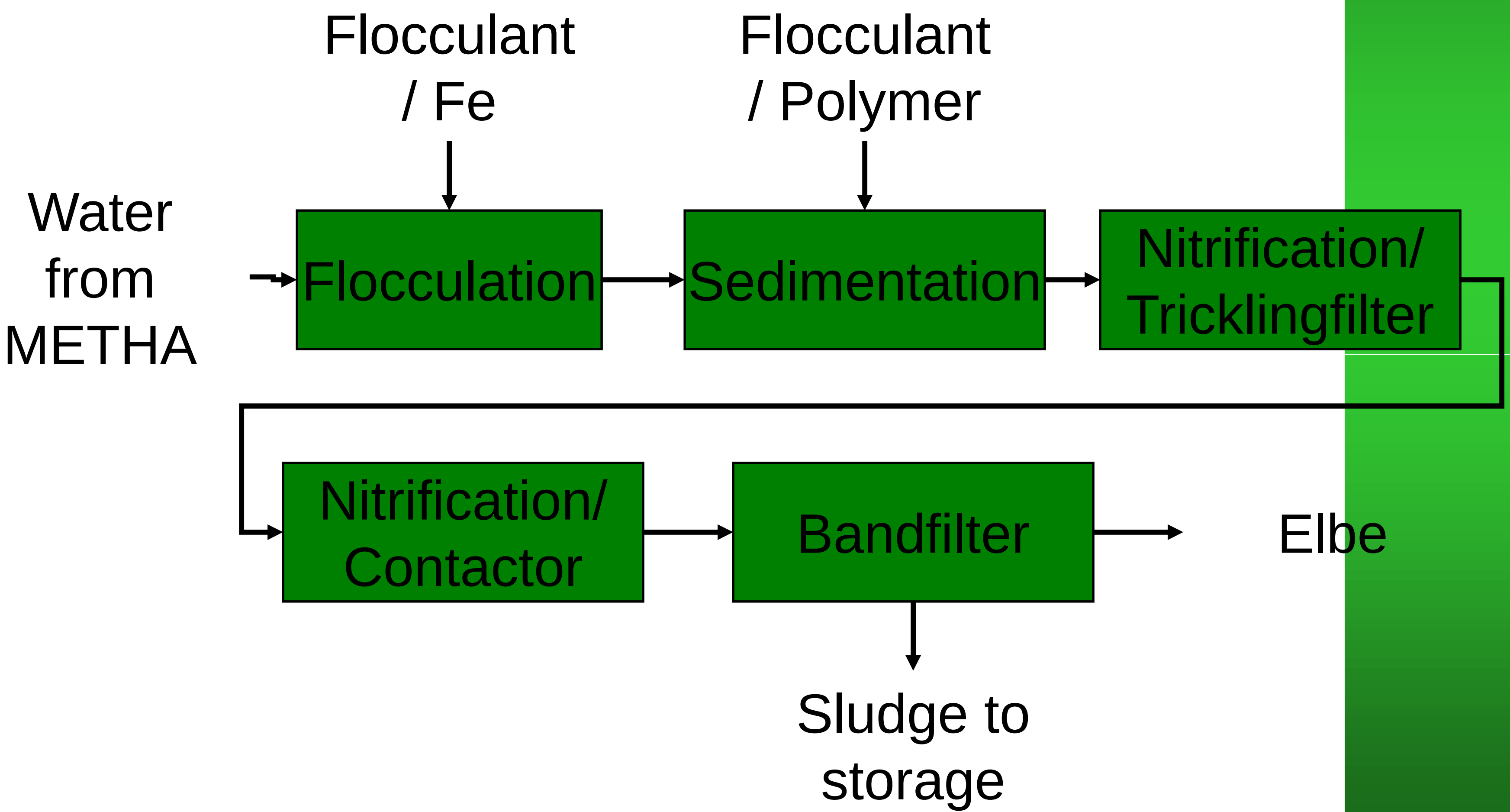
CUTEC: tests on dewatering of mud

contaminants (disposed)

What about sand, mud and water?

- gravel:
  - usage as usual
- sand:
  - usage as usual
- mud:
  - usable (and used as sealing (e.g. landfill) if contamination OK in sealing concept
  - disposal
  - remediation
  - incineration if organics (humic substances) in good concentration
- water from fields:
  - biological treatment
  - lagoons

Treatment of excess-water from METHA (SARA)



Conclusion

- Treatment of sediments are state-of-the-art
  - In-situ
  - Ex-situ
- Mechanical classification of sediments are reasonable
  - Large-scale classification into contaminated fraction and non-contaminated fraction
  - Smaller scale treatment of contaminated fraction reasonable
- Treated sediments can have a benefit