REPORT ON THE

WORKSHOP ON SEDIMENT CLASSIFICATION AND MANAGEMENT DECISIONS - IN SITU AND EX SITU,

HAMBURG, SEPT. 20-21, 2018

THE INCENTIVE

Many countries face the similar problems with regard to sediment and dredged material management:

- How to decide when a sediment is „polluted“?
- When should the sediment be taken out of the environment for ecological reasons (due to an assessment of sediment quality „in situ“?
- How to decide on management options for dredged material (ex situ)?

In 2003, den Besten, de Deckere [1] provided an overview over different biological effect-based sediment quality assessments in Europe and concluded that there was a considerable difference between European countries in the way sediment quality guidelines (SQGs) were derived and implemented. Furthermore, the extent to which biological data were integrated in frameworks varied a lot and ranged with regard to dredged material assessment from “none” (e.g. Belgium and Italy) to “part of a decision support system” (e.g. Netherlands and United Kingdom). Between 2003 and today, decision making frameworks may have changed in countries due to new information on SQGs, new analyses methods, or due to different political incentives. The workshop was initiated to identify whether the topic of sediment quality assessment – ex and in situ – continues to be a relevant topic.

THE OBJECTIVE

The objectives of the workshop were (1) to compare existing regional or national regulations with regard to their components, decision making and consequences for the catchment management, and (2) to exchange experiences and difficulties with the different frameworks.

THE BACKGROUND

The workshop was co-organized by the European Sediment Network SedNet (www.sednet.org) and by the Interreg Project "Sullied Sediments" which aims at developing an improved sediment assessment framework taking currently non-regulated watch list chemicals into account.

PARTICIPANTS

The following participants joined the workshop:

Surname	first name	affiliation	country	Interest / Expertise	
				Environment	**in situ / ex situ?**
Vanacker	Goedele	OVAM	Belgium	freshwater	in situ/ex situ
van de Wiele	Katrien	OVAM	Belgium	freshwater	in situ/ex situ
Teuchies	Johnny	Univ. Antwerp	Belgium	freshwater	in situ/ex situ
Hetjens	Hanne	Univ. Antwerp	Belgium	freshwater	in situ/ex situ
Bervoits	Lieven	Univ. Antwerp	Belgium	freshwater	in situ/ex situ
van Gestel	Stien	AECOM	Belgium	freshwater	in situ/ex situ
Bataillard	Philippe	BRGM	France	freshwater	in situ/ex situ
Krüger	Frank	HPA	Germany	Freshwater/marine	ex situ
Kramer	Annette	HPA	Germany	Freshwater/marine	ex situ
Roeper	Henrich	HPA	Germany	Freshwater/marine	ex situ
Oing	Katja	HPA	Germany	Freshwater/marine	ex situ
Carls	Ilka	Environment Ministry Hamburg	Germany	freshwater	in situ
Breitung	Vera	BfG	Germany	fresh and marine	ex situ
Hoess	Sebastian	ECOSSA	Germany	freshwater	in situ/ex situ
Faetsch	Sonja	Hamburg Applied University	Germany	Freshwater	in situ/ex situ
Heise	Susanne	Hamburg Applied University	Germany	Freshwater/brackish	in situ/ex situ
Romano	Elena	ISPRA	Italy	marine	ex situ
Ausili	Antonella	ISPRA	Italy	marine	ex situ
Pellegrini	David	ISPRA	Italy	marine	ex situ
Regoli	Francesco	Università Politecnica delle Marche	Italy (Ancona)	marine	ex situ
Wensveen	Marco	Port of Rotterdam	Netherlands	brackish water	ex situ
Postma	Jaap	Ecofide	Netherlands	marine	ex situ
Castro Uranga	Raul	AZTI	Spain (Pasaia)	marine	ex situ
Casado	Carmen	Ökotoxzentrum	Switzerland	freshwater	in situ
Mason	Claire	CEFAS	UK	marine	ex situ
Rotchell	Jeanette	University of Hull	UK	freshwater	in situ/ex situ

WORKSHOP STRUCTURE

To facilitate comparison of different frameworks, all participants were asked to apply their regional/national frameworks on provided data, using a fictitious case study, the „River Nimrodel“ (see attachment). The provided data were supposed to characterize 3 different sediments:

Sediment/Dredged material (DM)A: high content of medium sand (56 %), high concentration of heavy metals (esp. Cd) in the fine fraction, but Cd, Hg and Ni high in the total fraction. High concentrations of PAHs, PCBs and DDX and Dioxin.

Sediment/DM B: Finer than sample A (30 % less than 20 µm; 30 % 200-360 µm); lower concentrations of heavy metals in the fine fraction but higher concentrations for As and Zn in the total fraction. Intermediate concentrations of PAHs and PCBs, DDX and Dioxins. Highest concentrations of HCB and Hexachlorobutadiene and TBT-Sn

Sediment/DM C: Very fine material (65 % in the less than 20 µm fraction). Heavy metal concentration in the fine fraction apart from high Zn concentrations similar to Sediment B. Pb concentrations in the total fraction highest of all samples. Concentrations of organic contaminants are low with the exception of TBT and hexachlorobutadiene. For a better overview, table 1 summarizes the trend in chemical composition, colour scheme refers to the relative concentrations in the 3 samples.

Table 1: Overview over relative contamination in the different samples

	Sample A	Sample B	Sample C
Major grain size fraction(s)	200-630 µm (56 %)	<20 µm (31 %); 200-630 µm (35 %)	< 20 µm (65 %)
Metals in <20 µm Fraction			
Metals in total fraction			
PAHs, PCBs, DDX, Dioxin			
HCB			
TBT-Sn			

The provided data were used to demonstrate different assessment approaches. Outcomes with regard to the respective management decisions were compared.

THE DIFFERENT FRAMEWORKS

FLANDERS/BELGIUM_FRESHWATER, IN SITU

Three different evaluation systems are applied for freshwater/in situ, of which only VLAREM and VLAREBO are currently implemented:

(a) VLAREM: use of existing environmental quality standards for sediments. Measured chemical concentrations are corrected for grain size and organic matter content (c). They are then compared to a reference sediment (µ). Classification is based on the deviation from the reference material. Classes are defined according to the logarithm of the quotient (c/µ). Classes are set as follows:

Quality Class	Log-Index	Class description
1	<0.4	not deviating from reference
2	0.4 - <0.8	slightly deviating from reference
3	0.8 - <1.2	deviating from reference
4	1.2 < 4	strongly deviating from reference

Hence, class 4 refers to an enrichment factor of 15.8 to less than 100. Decision on the final class is made on a one out, all out decision.

These measurements are part of a monitoring and evaluating framework following the triad method. However, the ecotoxicological and biological data are not used for regulatory purposes.

With the current examples, site A and B would have been considered class 4; site C as class 1

(b) Threshold values: Based on a combination of chemistry, biology, toxicology
According to de Deckere, De Cooman [2]), chemical quality criteria are determined based on biological responses.

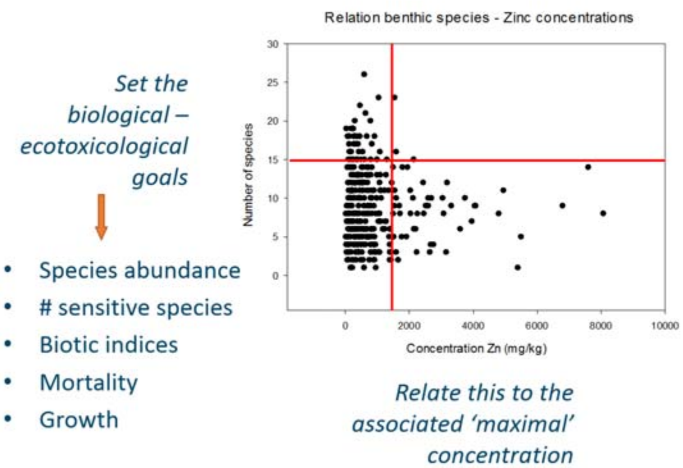

Figure 1 Derivation of ecotox-based SQC (Slide L. Bervoets)

Using this calculation method, new sediment threshold values for Flanders are being developed at present. These values are based on the relation of a biotic index (Sediment Biotic Index described by De Pauw and Heylen [3]) and concentrations of contaminants. The values will be used to decide whether further investigation is needed.

(c) Reuse as soil (VLAREBO)

In these scenarios, no reuse would be permitted due to high PCB (case A), and high heavy metal concentrations (in total fraction): Cd and Hg at Site A; Cd and Zn at Site B and C.

FLANDERS/BELGIUM_FRESHWATER, IN SITU – SPECIFICALLY FOR PORT OF ANTWERP "ECODOCKS"

The aim of this approach, which is in development, is to achieve a good chemical status in the environment of the Antwerp harbour docks and to support in management decisions. The basis is a mathematical risk model. Based on extensive datasets, pollutant fluxes and the impact of dredging and navigation on pollutant dynamics are calculated. An exposure model allows calculation of changes in water and sediment concentrations (Fig. 1). Also, speciation of metals is addressed in order to better comply with ecotoxicological risks. Bioassays are not included.

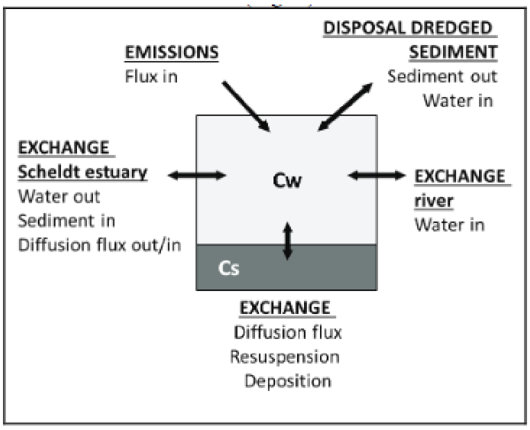

Figure 2 Calculated fluxes within the exposure model (Teuchies et al. 2015; SedNet conference Krakow)

The Ecodocks approach does look broader than just into the sediment sample as it also takes into account the specific geography and hydrology of the area of interest, spreading of contaminants (e.g. as a consequence of navigational dredging) and also the speciation of metals. Its intention is an integrated risk assessment for prioritizing of sediments and measures.

With regard to the scenario, the ecodocks-model was only applied to sediment A (highly contaminated) with the additional condition of having 1000 m³ of sediment removed (nautical dredging) by a trailing suction hopper dredger. The program would supply the following information:

- Sediment A would provide a hotspot for some contaminants within the already contaminated docks and compared to the Scheldt estuary. Local ecotox effects would be expected.
- The release to the surface water would be very limited. Also, during resuspension coming from shipping.
- The contaminants would not be spread to the Scheldt estuary.
- The impact of dredging would be limited. It would lead to removal of contaminants, from which 0.1% would be discharged into the water again due to dewatering processes.

So this is not a tool to classify sediments but a custom made approach to perform a risk assessment of sediments.

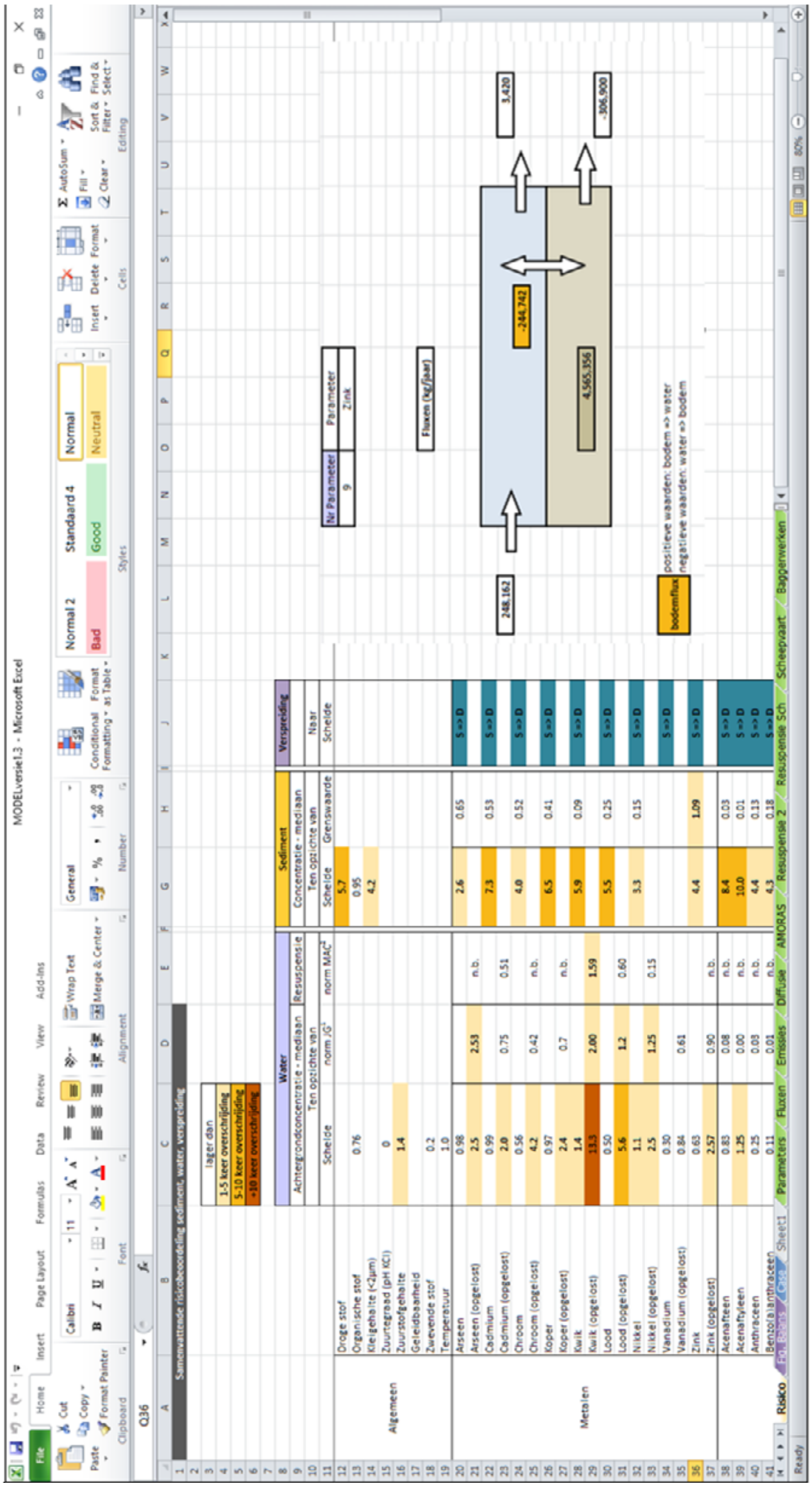

Figure 3: view of the „Ecodocks"-Model. Slide provided by Johnny Teuchies during the SuSe-SedNet workshop.

FRANCE_ENVIRONMENTAL CODE, FRESHWATER AND MARINE, EX SITU

For sediment dredging or relocation, the following criteria have to be considered in the first step:

- **Two lists of pollutants** including limit values to judge the chemical quality of the sediment (bulk content) for trace elements (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn), PCB (sum and/or each 7 PCBs taken individually), PAH (sum of 16 USEPA PAH - only for fresh sediment) and TBT (only for marine sediments) [4]. **These lists are known in France as the "S1" criteria for fresh sediments and as the "N1" and "N2" criteria for marine sediments**.

- **The quantity of sediment that will be moved during the operation** (in m^3 or m^3/year – differences exist according to the seaboard (Atlantic or Mediterranean)) and, for rivers and canals, the length of the area that will be dredged [5].

- **The distance between the operation and a possible growing area of shellfish**.

- **The statute of the site where the operation will take place** (e.g. Natura 2000).

The fate of the dredged material at sea depends on the exceedance of sediment quality criteria N1 and N2 for chemical compounds (metals, PCB, TBT). These "N"-criteria define the exceedance of background values which have been derived from statistical analysis samples. If N1 is not exceeded, dredging and relocation activities can be authorized without further studies. If levels are between N1 and N2, a more extensive analysis has to be done and the material is tested for ecotoxicity.

If N2 values are exceeded, relocation activities should not be carried out unless their impact on the environment is the least harmful of all options. This requires an in depth analysis.

S1 levels as opposed to the N limits are based on ecotoxicological data. They are applied to freshwater systems.

Ecotoxicology: Then, **for relocation in river**, *Brachionus calyciflorus* is often used by stakeholders like French Waterways (VNF) and the National Company of the Rhône River (CNR), to judge of the hazard of the sediments. VNF includes this bioassay in a larger protocol based on the calculation of the QSM, an indicator of the degree of multi-contamination of the sediments derived from MacDonald et al. (2000) [6] (Figure 4) ([7], personal communication VNF).

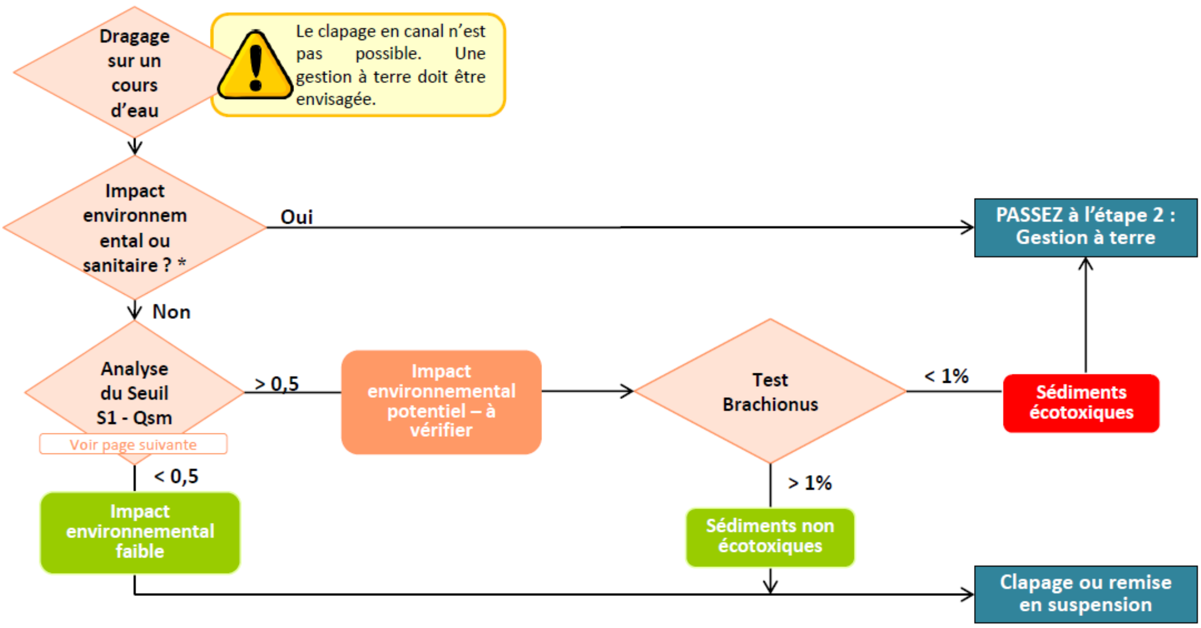

Figure 4: VNF's procedure, using the Brachionus calyciflorus bioassay and the Qsm, to decide if relocation in river is possible or not (fig. provided by P. Battaillard)

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For disposal at sea, microtox® and bioassays based on bivalve, copepod and *Corophium* are used to evaluate the hazard [8]. As for rivers, these tests are included in a global procedure, which permits the calculation of a score of risk. This procedure is well known in France and can be considered as a national tool, used in every port of the country. All these tools (rivers and ports) use the threshold values S1, N1 and N2, mentioned above, as trigger values.

FRANCE_FRESHWATER, IN SITU (IN DEVELOPMENT)

A 3-step approach is currently under development, which integrates ecotoxicological data to a larger extent and which shall be more accurate in the characterization of the hazard of fresh sediments (Marc Babut, IRTSEA). The aim of this approach is to manage contaminated sediment and/or to assess the environmental consequences of (environmental) dredging.

In most cases within the decision matrix (unless toxicity is very low or very high in Step 1), Step 2 will be carried out as well. If only one of the lines of evidence (bioaccumulation, biotest battery or IOBS (oligochaete diversity index)) indicates toxicity, the sediment is considered hazardous. Based on the integrated assessment of these criteria, works are carried out, a more detailed analysis is necessary or the evaluation is stopped and other management options are considered.

Table 2: Concept of a new method to characterize the hazard of fresh sediments (Original: M. Babut, IRTSEA, translated by Philippe Bataillard, modified by S. Heise) (*italic, purple: criteria of interpretation*)

Steps in chronological order	Steps	Bioaccumulation	Contamination	Ecotoxicity on benthic fauna	Impact on the macrofauna and benthic community
	0 – preliminary phase	➢ Compilation and synthesis of available data and information ➢ Adjustment: Consideration of specific management options of the project and early concertation with the operator and the regular authorities ➢ Plan of investigation: sets the variables to be measured (contaminants analysis; bioassays), the number and the location of samples; and considers the readily available data.			
	Step 1: Screening	Analysis of priority and contextual substances (bulk sediment ≤ 2 mm)		**Battery of bioassays:** testing of nematodes, ostracodes and bacteria, to reduce type II errors due to the variation of bioavailability or to the presence of other pollutants not analysed	
		EQS-threshold transposed to biota	*Predictive contamination-threshold of ecotoxicological effects*	*Threshold value and indices of ecotoxicity*	
	Step 2: detailed assessment	Analysis of bioaccumulative pollutants in local or caged organisms (oligochaete, *Chironomus, Gammarus*)		**Battery of bioassays:** measurement of different traits relative to survival and reproduction of diptera, a crustacean and an oligochaete.	**IOBS – index** Toxic effects measured at the community level of oligochaetes, And degradation of organic matter.
		EQS biota or tissue-toxicity threshold		*Level of biological significance*	*Quality classes*

ITALY_MARINE, EX SITU

(FRANCESCO REGULI, DAVID PELLEGRINI, ELENA ROMANO, ANTONELLA AUSILI, WITH CONTRIBUTIONS OF ANDREA BARBANTI, CRISTIAN MUGNAI)

Two different evaluation systems are applied for evaluation of sediment quality in accordance with two different legislations:

1) A law for sediment dredging at National Relevance Sites (high anthropogenically impacted marine areas): The management options for dredged marine sediments are based on an integrated chemical-physical and ecotoxicological approach. For the evaluation of sediment quality specific chemical values have been defined, based on ecotoxicological effects, corresponding to the Probability Effect Level (PEL) according to international literature [9-12]. Three different options for sediment management, based on analytical results and ecotoxicological responses, can be considered: dumping at the sea (i.e. beach nourishment, etc.), disposal on land or in a CDF (Confined Disposal Facility).
2) A regulation about methods and technical criteria for permitting the disposal of dredged marine sediments at sea in the other areas: It establishes criteria and methodological procedures for dredging sediment characterization, sediment classification and identification of appropriate management options and monitoring. Among others, the major novelties were (1) Weight of Evidence (WOE) approach for hazard

assessment; (2) a priority role of ecotoxicology in the characterization; (3) 5 sediment quality classes and corresponding environmental management options.
A simplified chemical characterization on sediments is allowed only for some areas (coastal areas or river mouths, small ports, etc.) that already showed low to absent toxicity. In all other cases a large set of contaminants has to be analysed (heavy metals, PAHs, hydrocarbons >12C, pesticides, TBTs, PCBs, PCDD/Fs+PCBs (T.E.)) together with the ecotoxicological analysis.

The chemical classification is based on the comparison of measured concentrations with predefined reference values L1 and L2. The Chemical Hazard Quotient (HQc) is based on the variation from the reference value. It takes the toxicity of a contaminant into account and ranges between absent to very high.

Ecotoxicological hazard	Chemical hazard	Quality classes
Absent	HQ_C (L2) ≤ Negligible	A
	Slight ≤ HQ_C (L2) ≤ Moderate	B
	HQ_C (L2) = High	C
	HQ_C (L2) > High	D
Slight	HQ_C (L1) ≤ Slight	A
	HQ_C (L1) ≥ Moderate and HQ_C (L2) ≤ Slight	B
	Moderate ≤ HQ_C (L2) ≤ High	C
	HQ_C (L2) > High	D
Moderate	HQ_C (L2) ≤ Slight	C
	HQ_C (L2) ≥ Moderate	D
≥ High	HQ_C (L2) ≤ Slight	D
	HQ_C (L2) ≥ Moderate	E

Figure 5: sediment characterization following the integrated approach in Italy (from Onorati et al, SedNet conference Genova, 2017).

The ecotoxicological characterization is based on a battery of bioassays (at least three organisms from different taxonomical groups: bacteria, algae, crustaceans, bivalves, echinoids). The results of ecotoxicological analyses are assessed as a whole at the level of "battery" (not of single bioassay), weighing the biological relevance of the measured effects (end-point), the statistical significance of measured results, the assay conditions in terms of tested matrix and duration of exposure.

A dedicated software (SediQualSoft 109.0®; Benedetti et al., 2012) is used to finalize the integrated classification and to assign the sediments to one of the five quality classes that correspond to different management options:

- Class A: nourishment, sea disposal in confined or not confined conditions;
- Class B: sea disposal in confined or not confined conditions;
- Class C: confined disposal in port areas;
- Class D: confined and sealed disposal;
- Class E: removal from the marine environment.

GERMANY_HABAB-WSV, FRESHWATER FEDERAL WATERWAYS, EX SITU

According to the German guideline for dredged material handling in federal inland waterways (HABAB-WSV 2017), sediment is not classified in absolute terms but relative to the contamination downstream of the relocation site. The reference value is the recent 3-year average of the pollutant concentrations of the suspended matter at the nearest downstream reference measuring station. In the assessment, three cases are distinguished:

Case I

All analysis results are ≤ 1.5-times reference value: Relocation is possible.

Case II

At least one parameter > 1.5-times reference value, all parameters ≤ 3-times reference value: Relocation is possible under the precondition that the relocation-related annual freight of each pollutant is ≤ 10% of the long-term mean annual freight at the reference measuring station.

Case III

At least one parameter > 3-fold reference value or the relocation-related annual load of at least one parameter is > 10% of the long-term mean annual load at the reference measuring station: No relocation except in specially justified individual cases weighing all potential risks.

In parallel to chemical investigations, ecotoxicological investigations are obligatory. The biotest data are assessed due how many dilution steps are necessary, before toxicity is reduced to below 20 % (pT value, Fig. 2). On the basis of these pT-values, the materials can be assigned to toxicity classes based on which management decisions are derived. If ecotoxicological data lead to a stricter decision than chemical data (e.g. forbid relocation) further investigations are required.

Table 3: pT values and responding management decisions (modified from BFG, 2011; HABAB-WSV 2017).

Highest dilution with effect	Dilution factor	pT-max value	Toxicity class		Result	Classification
Original	2^0	0	0	No toxicity measurable	Material not or only little hazardous	Relocation possible
1:2	2^{-1}	1	I	Very low toxicity		
1:4	2^{-2}	2	II	Low toxicity		
1:8	2^{-3}	3	III	Moderate toxicity	Material critically contaminated	Relocation possible on a case by case basis
1:16	2^{-4}	4	IV	Elevated toxicity		
1:32	2^{-5}	5	V	High toxicity	Material is hazardously contaminated	No relocation except in specially justified individual cases weighing all potential risks
≤ (1:64)	$\leq 2^{-6}$	≥ 6	VI	Very high toxicity		

GERMANY_GÜBAK, COASTAL/MARINE FEDERAL WATERWAYS, EX SITU

In Germany, there is a “Joint Transitional Arrangements for the Handling of Dredged Material in German Federal Coastal Waterways” (GÜBAK-WSV, 2009) which will be applied until a currently discussed revision will come into force.

GÜBAK states what data have to be gathered before deciding to relocate dredged material into marine waters, but it remains vague on how the final decision is made on the basis of chemical, biological and ecotoxicological data. Reference values are considered to be “guiding” values rather than strict “threshold values”.

Acc. to GÜBAK, chemical and ecotoxicological analyses have to be done unless the material consists of natural soil or is composed of more than 90 % sand or of coarse material (>63 %).

No chemical and ecotoxicological analyses are necessary, if contamination at the site is not expected (hazard can be ruled out) and the volume of dredged material is less than 10.000 t/a (dried substance).

For sampling, the size of the dredging area, the volume of dredged material and the horizontal and vertical variation of contaminant intensity at the riverbed have to be considered. The number of samples depends on the total volume. Samples have to be analysed individually, only in specific cases the analysis of a combined sample is possible. An ecotoxicological assessment shall be carried out for each dredging operation. However, biotests are not obligatory. If it is plausible that an ecotoxicological hazard can be ruled out (e.g. due to a lack of pollutant sources), bioassays do not have to be carried out.

The guiding values are derived from existing data about sediment contaminant concentration in the German part of the Wadden Sea, coastal sediments of the Northern Sea and Baltic Sea. RV (Reference value)1 is equivalent to the 90th percentile of the current regional contamination. RV2 is obtained by multiplying RV1 with a factor of 3. The only exception is TBT (defined guiding values). In the assessment, three cases are distinguished:

Case I
Analysis results below RV1: The material complies with the background contamination of the coastal area. Beneficial use/direct use is to be considered, relocation has to be carried out under consideration of physical and biological effects.
Case II
Analysis results in between RV1 and RV2: This material has a higher degree of contamination compared to the coastal zones (at least one parameter > RV1, no parameter > RV2). Beneficial use/direct use options need to be verified, and a full impact assessment has to be prepared. If necessary, go to Case III. Further monitoring is necessary (fish, benthos). Measures for impact minimization need to be considered.
Case III
Analysis results above RV2: This material is significantly higher contaminated compared to sediments in the coastal areas (at least one parameter > RV2). Procedure similar to Case II but additionally the source of contamination needs to be determined and if possible remediated. Safe disposal (landfill) and treatment options have to be considered.
In Case III biotests are obligatory. These tests are used to access the toxicity of the dredged material. Qualified tests are the marine algae test, luminous bacteria test and the acute toxicity test with amphipods.
The pT-value is the result of the most sensitive organism within a test series of bioassays on the same level. Bioassays are used besides other criteria in decision making of a disposal option. The classification into toxicity classes is carried out analogously to Table 3. Toxicity classes 0 – II are considered to be harmless. Higher results have to be considered in the impact prognosis; in these cases, the reasons for elevated toxicity shall be identified.

Besides HABAB or GÜBAK, special regulations and agreements with local authorities and ministries (depending on the place of relocation) are decisive for the assessment of the admissibility of the relocation of dredged material in German waterways and coastal areas.

NETHERLANDS_FRESHWATER AND MARINE/COASTAL, EX SITU

In line with EU regulations, excavated soil and dredged material are regarded as waste material while in situ sediments and soils fall under the water management legistlation. However the Dutch Soil Quality Decree that implements the EU Water Framework Directive and the EU Waste framework Directive regulates the beneficial use (on soils or in water systems) of excavated soils and sediments.

Two options exist:

1) When sediment needs to be dredged for navigational purposes: Only chemical analysis is used to consider the site of relocation (at sea, in freshwater, on land or in closed storage facilities). Assessment values used to be regulated by the ZBT – Zoute Bagger Toets (2007), which replaced the prior guideline, the CTT. Since 2008, the ZBT has become integrated into the Soil Quality Decree. While the previous CTT also contained bioassays, the Soil Quality Decree does not.

2) When other reasons do not apply, sediment in principle is not removed, because it is considered an essential element in river management and problems arise if too much is taken out.

Potential exceptions (removal for other than navigational purpose; →environmental dredging), for which there is a guidance, include:

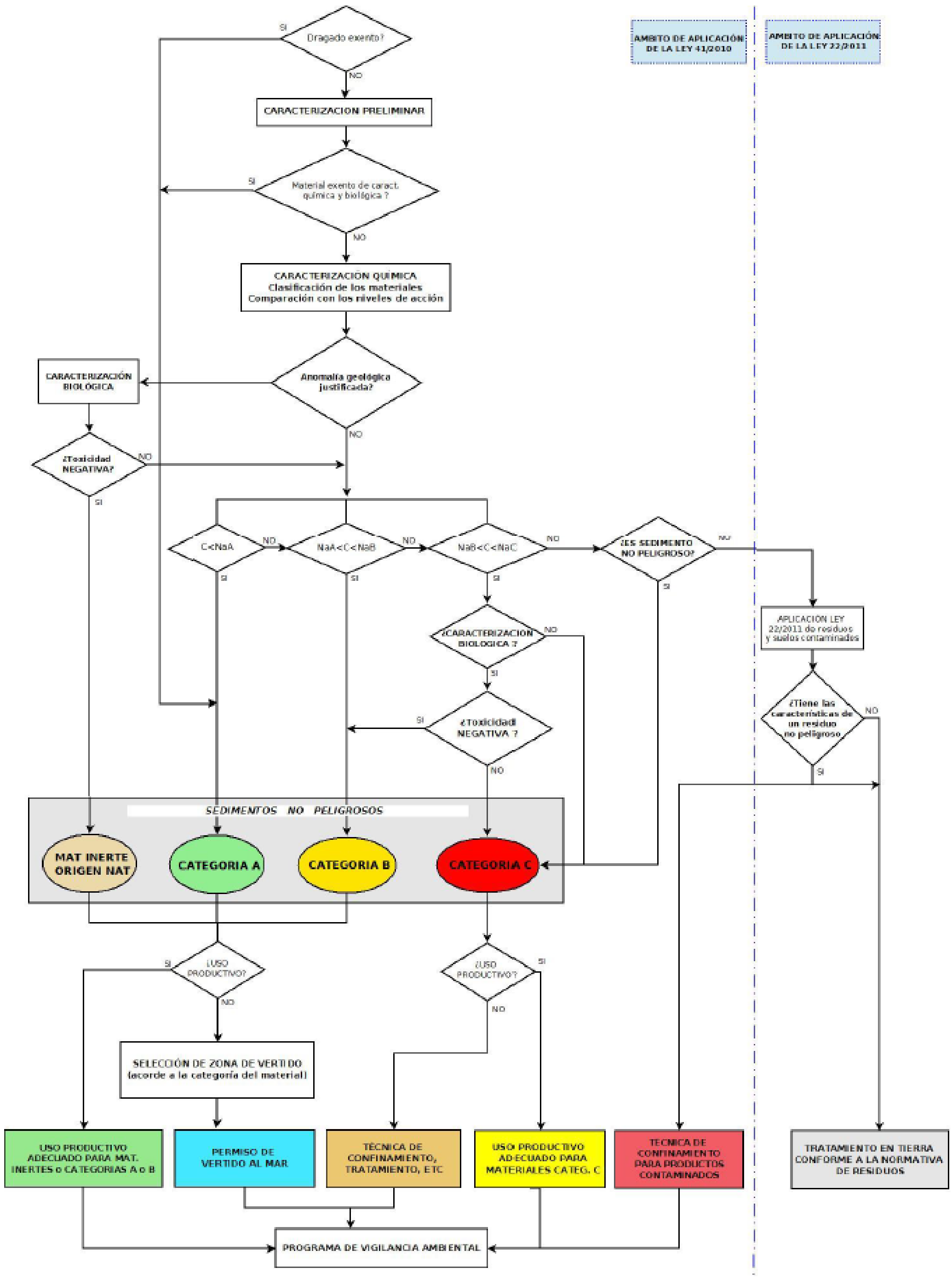
- Too high chemical concentrations, above threshold values (and above Intervention level) a permit (waterregulations) is needed for dredging to make sure that contaminants/contaminated sediment will not be dispersed (too much) in the water-body.
- Are goals (chemical and ecological WFD, human consumption, nature) not met? And it is likely that this is due to contaminated sediment.
- When by means of dredging, the Intervention Level in the new top layer will be exceeded, a check is needed (emission/immission test) if the new top layer will lead to “detoriation” of not. (in almost every case the conclusion is that the new top layer is not a threat for water quality)

For dredged material management options in the marine environment, the NL use only one set of action levels derived from background concentrations of which some provide guidance (guidance levels) while others are strict (threshold values). They direct towards pass or fail (total concentrations; not standardised on grain size or organic carbon).

Opposed to that, freshwater criteria allow classification of sediments into one of 4 classes, the chemical concentration being standardized for organic carbon and grain size.

SPAIN_DGMD (2017), ESTUARINE AND COASTAL WATERS, EX SITU

For dredged material management options in the marine environment, chemical quality criteria based on 3 action levels derived from background concentrations direct into one of 3 classes: A (free disposal) and B (restricted disposal) can be relocated at sea but C (if not excluded by ecotoxicological essays) should be isolated in closed storage facilities; inforcing land treatment above non-dangerous sediment legal limits (Figure 6)1.



There is another specific reference for sand beach nourishment[2].

[1] https://www.miteco.gob.es/images/es/anexo_directrices_tcm30-435295.pdf

[2] https://www.miteco.gob.es/es/costas/publicaciones/Instruccion%20Extracciones%20Arena%20rel2_tcm30-157025.pdf

UK_COASTAL/MARINE, EX SITU

UK is considering implementation of a tiered approach. Figure 6 shows the tiered approach (based on [13]) proposed in the High Level Review of Current UK Action Level Guidance, [14].

The current action levels used were derived in 1995 from UK datasets for naturally occurring elements on the basis of expert judgement applied to frequency distributions of the results from dredged material analyses obtained over several years. Nominally Action Level 1s (cAL1) are aiming to reflect background concentrations, and Action Level 2 (cAL2) are aiming to reflect concentrations that are harmful to the environment. With regard to exceedance of ALs, a weight of evidence approach is applied rather than a straight pass or fail.

Building from the current approach, a new tiered approach is being considered. Physical analysis (such as particle size analysis), followed by chemical analysis and comparison with 2 action levels (cAL1 and cAL2) would be completed. Concentrations below AL1 are considered to be of no concern, and disposal at sea is possible. Contaminant concentrations between AL1 and AL2 require further consideration, such as comparison with historic levels, knowledge of the disposal site receptors, and possibly evidence from ecotoxicological testing. Exceedance of AL2 results means that the concentrations measured are considered to be harmful to environment but provision of additional evidence such as results of ecotoxicological testing demonstrating that this material is nonharmful may enable such material to be disposed of at sea although additional mitigation measures are likely to be required to ensure the environment is protected.

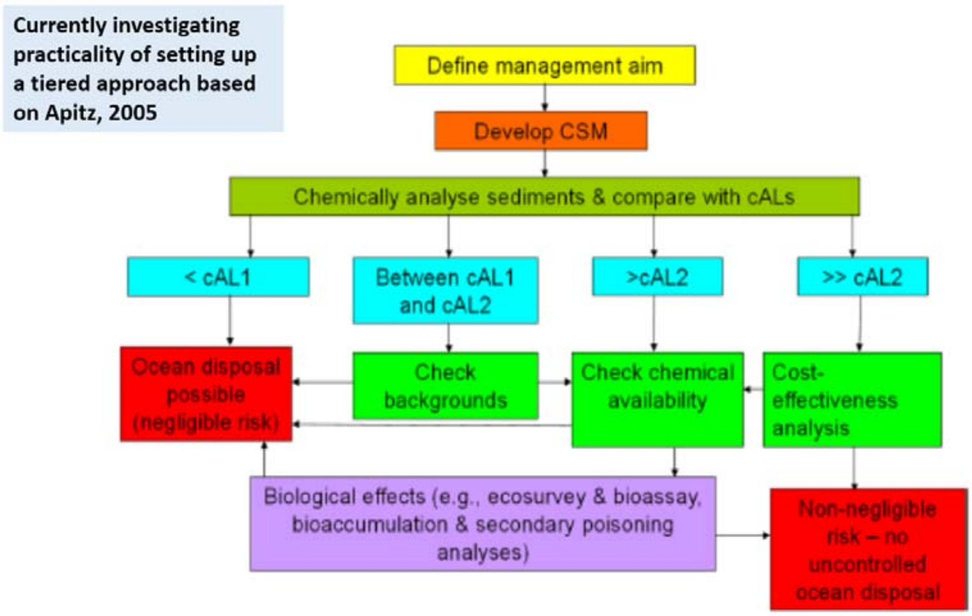


Figure 6: Decision framework on dredged material management in the UK (slide provided by Claire Mason)

SWITZERLAND_FRESHWATER, IN SITU (UNDER DEVELOPMENT)

A new assessment concept for in situ sediments is currently under development in Switzerland, intended to support a uniform and professional practice of the way in which sediment surveys are carried out by the regional environmental agencies (cantons) in charge of implementing environmental monitoring of surface water bodies.

The assessment concept relies on measured environmental concentrations in the fraction < 2 mm, although it provides recommendations for the selection of the matrix for chemical analyses according to study objectives and sediment properties (Table 4). A list of 20 substances is proposed for sediment monitoring, prioritized according to existing monitoring data, contamination sources, and/or substance properties.

Measured environmental concentrations are compared with numerical sediment quality guidelines (EQS_{sed}), derived using ecotoxicological data and background concentrations. The proposed quality criteria (EQS_{sed}) are not numerical requirements and are not legally binding (in accordance with Annex 2 of the Water Protection Ordinance), but allow classifying sediments in five quality classes. A tiered approach is at present under discussion to integrate bioavailability, mixture toxicity, and other ecotoxicological/biological tools.

Table 4: Principle of the method proposed in Switzerland for in situ sediment quality assessment.

<table>
<tr><th colspan="3">Objective</th><th>Monitoring of sediment quality</th><th>Diagnosis: identifying the causes of known biological impairment</th><th>Assessment & monitoring of potential biological impairment at known hot spots</th><th>Trend monitoring</th></tr>
<tr><td colspan="3">Problems to solve</td><td>a) Obtain an overview of biological impact of sediment quality on a cantonal or regional scale, both spatially and temporally
b) Find indication for biological impacts of sediment quality</td><td>a) Test for contribution of sediments to known ecological impairment (e.g. bad score in MSK modules)</td><td>a) Monitor the impact at identified hot spots (e.g. point-sources or known discharges)
b) Prioritize sites on the basis of sediment quality
c) Remediation planning and success control</td><td>a) Identify spatial and temporal trends of sediment contamination
b) Prioritize sites based on chemical contamination</td></tr>
<tr><td colspan="3">Type of assessment</td><td colspan="3">Ecotoxicological</td><td>Chemical</td></tr>
<tr><td rowspan="4">Matrix for analysis</td><td rowspan="4">% sediment <63 µm in 2 mm fraction</td><td>< 5%</td><td colspan="4">Assessment not recommended[1]</td></tr>
<tr><td>< 20%</td><td colspan="3" rowspan="3">< 2 mm</td><td>< 63 µm</td></tr>
<tr><td>20-80%</td><td>(< 63 µm or) 2 mm[2]</td></tr>
<tr><td>> 80%</td><td>2 mm[3]</td></tr>
<tr><td colspan="3">Evaluation</td><td colspan="3">Classification of sediments into 5 classes through comparison with EQS_{sed}</td><td>Classification by comparison with EQS_{sed} or other established threshold[4]</td></tr>
</table>

[1]Sampling sites with less than 5% fine fraction (<63 µm) are discouraged for sediment monitoring (EC 2010). [2]The fraction <2 mm can already identify point sources of pollution and spatial trends in sediment contamination when the sediment contains at least 20% fines (< 63 µm) but this may not hold true of all instances. [3]According to the results from field trials for sites that have high proportion of fines, the measurements are representative for the entire matrix, and hence results can be used for comparison to EQS_{sed}. [4]For non-ionic substances EQS_{sed} are normalized for organic carbon content, accounting for the matrix effect on bioavailability to some extent. Else, measured concentration values have to be compared with established thresholds from older measurements in the region.

OVERVIEW OVER GUIDELINES, ASSESSMENT PRINCIPLES AND DECISIONS MADE ON FICTITIOUS CASE SITES

Table 5: Overview over national guidelines, assessment principles and decision made on fictitious case sites

Country	Name of the Guideline	legal status of framework	Freshwater / Marin	Incentive		Assessment principle	Triad or tiered?	With the intention of …..	Decision made on sediments in case study			Is dredging for environmental reasons in general (unrelated to the case study) considered/carried out?
				environ-mental quality (in situ)	dredging (ex situ)				A	B	C	
Belgium	VLAREM	Sediment EQS, implemented in Flanders	Freshwater	*in situ*		Sediment EQS and biotests (Ostracod, Thamno) and community data: chemical concentrations are corrected for concentration of organic material and grain size. Enrichment factors compared to a clean reference sediment are calculated. Depending on the envrichment factors (logIndex), quality classes are calculated (separation of classes not science based). One out, all out: The worst class decides.	Triad	assessing sediment quality in situ (Monitoring), no decisions on remediation are made.	4	4	1	considered but currently only in two regions carried out.
Belgium	Threshold 1	not implemented	Freshwater	*in situ*					"-"	"-"	"+"	
Belgium	Threshold 2	in development	Freshwater	*in situ*					"-"	"-"	"+"	
Belgium	Ecodocks	not implemented (only inside the Port of Antwerp)	Brackish (port of Antwerp)			Excel tool that combines existing information to get insight in fluxes and risks (ecotox and spreading), related to dredging, shipping, different source, etc.. Bioassays are not intended to be included, existing information is used to support desicions related to dredging, shipping, sluices, …	integrated		not possible to compare, to specific			has been done once (for TBT)
Belgium	VLAREBO (reuse)	Implemented			*ex situ*				"-"	"-"	"-"	
France	Environmental code (Articles L and R214-1 et seq)	Implemented in France	Freshwater, marine		*ex situ*	The extent of the assessment depends on sediment quality (compared to SQC), mass of sediment concerned, distance between operation procedure and shellfish growing areas, proximity to environmentally protected areas. When it has been decided, that it should be dredged, the fate of the dredged material depends on the exceedance of SQC (N1, N2 for marine; 0.5*QSM and S1 for freshwater; McDonald et al. 2000). No exceedance: relocation in the river. Exceedance: Biotests. If these show hazardous properties: land disposal	Tiered	Deciding about dredging and fate of the DM	S1 and 0.5*QSM are exceeded. Before DM can be relocated, ecotox testing would be required.			yes, but guideline in development which aims at a global assessment of sediments with more LOEs to integrate
Italy	M.D. n. 173/2016	Implemented in Italy	Marine		*ex situ*	sediment classification: Comparison of measured concentrations with 2 reference values (L1, L2). Based on this variation, a Chemical Hazard quotient is calculated. Ecotoxicological assessment is based on biotest battery. Additional lines of evidence can be used as well (e.g. bioaccumulation). Integrated approach: A weight of evidence approach is used to decide on the fate of the material (5 sediment classes).	Triad	Deciding about the fate of the dredged material	D (confinced and sealed disposal)	D	C (confined disposal in port areas	
Italy	Law 84/1994 art. 5bis - DM7.11.2008 for sediment management in heavy contaminated marine coastal areas (National Relevance Sites)	national law for special sites (national remediation sites as opposed to the urban sites).	Marine		*ex situ*	integrated chemical-physical and ecotoxicological approach; definition of specific site chemical values based on ecotoxicological effect data (PEL) for the evaluation of sediment quality; positive ecotoxicological response limits some management option (i.e. no disposal at sea, no beach nourishment, etc.); ecotox response is the main driver in decison making on the sediments' fate not WOE approach		Deciding about dredging and fate of the DM	confined and sealed disposal (CDF)	confined and sealed disposal (CDF)	no disposal at sea	considered yes, but not done up to now as it is not for control of environemtal quality. Action to remove the sediment is not mandatory.

Table 5, continued

Country	**Name of the Guideline**	**legal status of framework**	**Freshwater / Marin**	**Incentive**		**Assessment principle**	**Triad or tiered?**	**With the intention of …..**	**Decision made on sediments in case study**			**Is dredging for environmental reasons in general (unrelated to the case study) considered/carried out?**
Germany	HABAB-WSV	Implemented for German federal waterways (revised 2017)	Freshwater		*ex situ*	sediment is not classified in absolute terms but relativ to the contamination downstream of the relocation site (DM should not exceed 3 times the concentration of the downstream area). Biotest data are also gathered in parallel to chemical analysis (pT value). If ecotox data lead to a stricter decision than chemical data (e.g. forbid relocation) more studies are required.	Ecotox and chemistry	Deciding about the fate of the dredged material	A not considered further, no impact on downstream sites assumend (sediment	Material must be treated and disposed on land	Relocation is possible under all circumstances, even in the marine environment.	principally possible, but in the scope of the Federal States (due to the objectives of the WFD)
Germany	GÜBAK	Implemented for Federal waterways and Federal coastal States	coastal, marine		*ex situ*	Unless the material consists of natural soil or is composed of more than 90 % sand or coarse material (>63 %), chemical and ecotoxicological analyses have to be done. Guiding values (as opposed to limit values) are based on background levels: RV1: background contamination/contamination close to the coast. RV2: 3 times RV1. Ecotoxicological data (acute and chronic) are supposed to be carried out. If RV2 is exceeded, ecotox	Ecotox, chemistry, potentially macrozoobenthos and fish.	Deciding about the fate of the dredged material				principally possible, but in the scope of the Federal States (due to the objectives of the WFD)
NL		national guideline	Freshwater		*ex situ*	chemical quality criteria direct into one of 4 classes (standardised on grain size and organic carbon)	no	Deciding about the fate of the dredged material	not allowed to relocate in freshwater	allowed to relocate under restrictions in	free to relocate in freshwater	principally possible, if convincingly stated on the grounds of the WFD/MSF
NL		national guideline	Marine		*ex situ*	chemical quality criteria direct into pass or fail (one out, all out) (total concentrations; not standardised on grain size or organic carbon)	no	Deciding about the fate of the dredged material	Not allowed to relocate at sea	Not allowed to relocate at sea	Allowed to relocate at sea	
NL		national guideline (not required by law)	Freshwater/ brackish/ marine	*in situ*		Building a reasoning (free to chose parameters) why remediation should help in reachting goals set at the location (for exampel WFD, fishery or shellfish culture, nature etc)	all is allowed; triad, tiered, chemical, ecological, ecotoxicological but also hydrological, dilution etc	Deciding on the benefit or remediations in comparison to other options to reach goals set	insufficient data	insufficient data	insufficient data	
Spain	Marine Strategie Tecnical Comission	national guideline	Estuarine & Coastal		*ex situ*	chemical quality criteria direct into one of 3 classes. Ecotox is used not to define but to exclude toxicity.	no	Deciding about the fate of the dredged material	Leave it	benefical use	Sea disposal	No
UK		not yet implemented, in development	marine		*ex situ*	Tiered approach with chemical concentrations, being compared with 2 action levels. If AL2 (or AL1??) are exceeded, impact on biota needs to be established (ecotox, ecosurvey)		Deciding about the fate of the dredged material	no disposal at sea, dredged with mitigation	no disposal due to high PCB	no disposal due to high PCB	
Switzerland	Strategy for sediment quality assessment	in development, will not be legally binding	freshwater	*in situ*		chemical quality criteria to allow classifying sites in 5 quality classes. Under development.	Tiered (under development)	assessing sediment quality in situ (Monitoring), no decisions on remediation are made.				

EXCHANGE OF EXPERIENCES

Participants were asked on the second day to exchange their experiences with regard to sediment classification and management decision, based on (1) what works well and (2) what does not; and (3) where are future challenges or potentials. The following gives a summary on topics that have been raised and do not necessarily reflect the opinions of everyone in the group.

WHAT WORKS WELL:

Some frameworks were explicitly mentioned as working well: VLAREM and the Dutch system for relocation of sediment at sea and freshwater. Also, some monitoring programs were considered as suitable. The procedure to chemically assess sediments and dredged material was considered clear and well-defined. The application of practical approaches was considered an advantage, and the integration of circular economy was seen as positive. One participant also stated that the enthusiastic sediment community was certainly “well working”.

WHAT DOES NOT WORK WELL?

There were a lot more points made and controversially disputed with regard to what currently does not work well: On a broader perspective, it was criticised that there are only few basin-wide sediment management strategies in Europe, which would also need to address quantity issues such as sediment “hunger” in river systems. To have different management frameworks and options (e.g. by national/federal institutions) in one catchment was not considered helpful.

Some remarks dealt with the sediment quality criteria and the way that risks are assessed. Several people stated that we do not have enough quality criteria, because environmental quality standards (EQS) for sediments are missing that would relate to the EQS of the WFD, and because emerging substances like microplastics, flame retardants, pharmaceuticals etc. are not covered. Some quality criteria (QC) that are in place may be unrealistic. In many frameworks, quality criteria are used as strict thresholds, following a “one out, all out” principle. All these aspects may lead to unnecessarily high costs for sediment management. With regard to the final management decision made, it should also make a difference whether QC are derived from e.g. background levels or from ecotoxicological data.

It was mentioned that the integration of chemical and ecotoxicological data could improve environmental safety in decision-making, but HPA stated that according to their experience, ecotoxicological data lacked reproducibility. Also, assessment schemes for ecotoxicological data are not harmonized and need improvement.

Another aspect, which had also become clear on day 1 was that there are no decision-making systems for when to clean up contaminated sites for the sake of the WFD or the protections of biodiversity.

CHALLENGES AND POTENTIALS

Several comments identified as one challenge a necessary stronger focus on effect-based decisions, in form of European sediment quality guidelines that could be effect-based and/or as in integrated (but pragmatic) decision framework that involves bioassays and biological community data as further lines of evidence. The fundamental understanding that chemical data do not have to explain biological test results needs to be better communicated.

Another identified challenge was decision making on *in situ* sediments: For environmental dredging, there are currently no standards and there is no funding in Europe. An assessment scheme would need to be able to prioritize contaminated sites in order to allow allocation of scarce funds to the most relevant hot spots.

Potentials were seen in tiered approaches, an EU-Framework for sediments, and a platform to share knowledge and learn from case studies.

SUMMARY OF THE WORKSHOP

The discussions in the workshop showed that the issue of sediment management guidelines continues to be a relevant topic, also driven by the WFD, MSR and potential impacts from contaminated sediments.

Experiences with sediment management guidelines have a differently long history: While some countries have guidelines that go back decades and have been revised a couple of times (e.g. Netherlands, Germany), other countries' legal binding frameworks are very recent (e.g. Spain).

Most guidelines tackle ex situ management and are enforced because of the need to dredge for navigational purposes. Legally binding regulations for classification of sediments in situ which may lead to decisions on environmental dredging do not exist. Some concepts are available (Belgium, NL) or under development (e.g. France), but environmental dredging – to the knowledge of the participants – is not anywhere carried out as a requirement.

Tiered as well as triad approaches were presented. In tiered approaches, chemical analysis was usually the first tier, followed by ecotoxicological analyses in the second. Few frameworks were truly integrated weight of evidence approaches with chemical, biological and ecotoxicological data as lines of evidence with the same weight (e.g. Italy). There is no apparent trend that biological effect-based decisions would be assigned a higher priority within frameworks. While Italy and the new framework in France by Babut assign the same or even a stronger weight to biological effect-based data as to chemical data, other approaches that used to base decisions on ecotox test data have removed them from their classification (e.g. Netherlands).

With regard to the assessment of the 3 fictitious cases most of the applied regulations forbid relocation of the material from the two higher contaminated sediments to the aquatic system. More variability resulted from the less contaminated sediment C. Here decisions ranged from "free to relocate" in Belgium, the Netherlands and Spain, to "confined or no disposal" in Italy and UK. In Germany, relocation in coastal seas and marine waterways according to GÜBAK (2009) was principally possible, if the comprehensive impact assessment to be carried out would have shown that no significant or persistent impairment was to be expected and a monitoring programme would be carried out". However, the database is not sufficient for a final evaluation.

Even though this was a relatively short exercise and restricted mostly to chemical data, differences in the evaluation of data become clear when sediments are of low to moderate quality. Variability in decision-making will be even more pronounced when ecotoxicity data are considered within the decision making framework. Further work in this respect appears to be timely and necessary.

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