

Workshop Report

River Sediments and Related Dredged Material in Europe

*Scientific Background from
the Viewpoints of Chemistry,
Ecotoxicology and Regulations*

GKSS Research Centre, Geesthacht, Germany

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The Workshop was organised by the GKSS Research Centre and the Technical University Hamburg-Harburg as part of the Rhine Research Project II (POR II) for the Rotterdam Municipal Port Management on the current and future contamination of dredged material and related emissions and immissions in the Rhine catchment area.

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Executive Summary

Dredged material is an important issue from the volumes dredged and its contamination which restricts disposal/relocation options. As part of the Rhine Research Project II (POR II) on current and future contamination of dredged material and related emissions and immissions in the Rhine catchment area for the Rotterdam Municipal Port Management, the GKSS Research Centre and the Technical University Hamburg-Harburg organised this workshop, attended by invited experts from European countries, from USA and Canada.

The workshop focused on scientific aspects of evaluating and implementing bioassays into decision-making frameworks for dredged material management. Conclusions and recommendations were derived aiming at stakeholders as dredged material managers, e.g. port authorities, river basin managers as well as other national and international authorities and organisations involved in the sediments / dredged material issue. The results of this workshop were presented at a follow-up workshop dealing with policy and regulatory aspects in Rotterdam (17-19 April 2000).

Regulations and guidelines for the hazard assessment of contaminated sediments as well as decision-making frameworks e.g. for the relocation of dredged sediments into the marine environment are not harmonised, neither on an international nor the European level, for some countries not even on the national level.

At present in European countries, the United States and Canada, science-based quality criteria are in use for the assessment of the quality of contaminated sediments. Action levels are derived for management decisions, e.g. permits for relocation into the marine environment, taking into account political considerations (environmental yield / costs ratios). Moreover expert judgement is integrated to a more or less extent into the decision-making processes in different countries.

Current lists of action levels generally consist of chemical criteria for some metals as well as organic contaminants as polycyclic aromatic hydrocarbons and polychlorinated biphenyls. In several countries the use of bioassays as additional criteria for the hazard assessment of contaminated sediments or dredged material is under discussion or already under evaluation. At present a set of a few standardised bioassays for acute toxicity is available.

During the workshop there was consensus that a responsible dredged material management is needed. The main aim should be to reduce emissions from point sources as well as from diffuse sources in the catchment area which would ensure or enable in the long-term

- the reduction of inputs of contaminants via rivers into the marine environment,
- the relocation of dredged material in rivers as well as into the marine environment,
- beneficial uses of dredged material (e.g. in agriculture, habitat creation) and
- cost-effective relocation/use of dredged material

without imposing unacceptable risks to the environment.

At present the management of dredged materials mainly comprises hazard assessment of contaminants at the dredging site. Despite the inherent difficulties of conducting risk assessments at the disposal site (the receiving environment), it should be integrated in future approaches for decision-making frameworks (research demand).

For the sake of being cost-effective hazard assessment should be carried out in a multi-level approach:

- Level I: limited chemical criteria, limited test battery with bioassays
- Level II: application of an extended battery of bioassays as well as case studies in order to identify the culprit chemicals

Level II should only be applied for toxic or highly toxic materials where the toxicity can not be explained by the presence of the investigated chemicals. TIE-like (Toxicity Identification Evaluation) approaches are a promising tool to establish links between effect potentials and causative chemicals as well as to distinguish between toxic potentials from man-made and natural compounds (e.g. phytoestrogens).

Recommendations on the evaluation and implementation of bioassays as criteria for dredged material management are:

- At present the application of 3-4 standardised bioassays for acute toxicity including at least one whole sediment test is recommended.
- Before the implementation of these bioassays they should be evaluated in a 'research mode' parallel to the currently implemented chemical criteria.
- Effort should be taken to tackle the interpretation of bioassay results with the long-term goal to integrate the results from different bioassays and possibly even the chemical criteria into one 'yardstick' for the classification of contaminated sediments / dredged material.
- The development and standardisation of chronic tests and receptor-based assays / biomarkers should be carried out in order to cover other modes of actions and sublethal effects. The latter might in future replace chemical analyses undertaken at high costs (e.g. CALUX assay for chemicals with dioxin-like mode of action).

As a spin-off from the workshop an initiative for a European Sediment Research Network (SedNet) was launched. It is planned to be driven by stake holder (port authorities, river quality managers) demands and focuses on the dissemination of knowledge, reviewing research needs (problem catalogue) as well as on applied research solving actual problems. It is intended to establish thematic working groups, e.g.:

- "Source Identification Methods" including TIE-like approaches,
- "From hazard assessment towards risk assessment".

The latter thematic working group will give a broader platform for the idea – born during the workshop – for a project BIOSAFE (**B**iolegically Based **S**ediment Quality **A**ssessment by **F**ull Scale Field **E**valuation).

1 Introduction

The GKSS Research Centre carries out, on behalf of the Rotterdam Municipal Port Management, and in collaboration with the Institute for Environmental Studies (IVM, Amsterdam), the Institute of Freshwater and Fisheries Ecology (IGB, Berlin) and the Technical University of Hamburg-Harburg (TU-HH, Hamburg) an integrated science-policy study (Rhine Research Project II, POR II) on the management of dredged material. Primary aims are to investigate and predict future quality of sediments originating from the Rhine catchment area and current and future policies on regulations with regard to dredged material.

As part of the project this science-oriented workshop had been organised by GKSS and TU-HH, followed by a second workshop held in Rotterdam (17-19 April 2000) organised by GKSS and CSERGE (UK), the latter focussing on policy and regulatory aspects in the scope of river sediments and dredged material as part of the system catchment-coastal sea.

The science-oriented workshop, reported on in this document, was attended by invited experts from European countries, from USA and Canada, presenting lectures and posters during the first public day. During the following two non-public days in two parallel working groups and in the plenum major issues as described in the background paper (Appendix I) were discussed. The workshop agenda is outlined in Appendix II.

The discussion during the workshop focused on scientific aspects of evaluating and implementing bioassays into decision-making frameworks for dredged material management. Conclusions and recommendations should be derived aiming at stakeholders as dredged material managers, e.g. port authorities, river basin managers as well as other national and international authorities and organisations involved in the sediments / dredged material issue. The results of this workshop were presented at the follow-up workshop dealing with policy and regulatory aspects in Rotterdam.

4 Report of Working Group I (science-oriented)

Chair: Bram Brouwer, Rapporteur: Susanne Heise

Jos M. Brils, Marc Eisma, Lee Grapentine, Carolin Peters, Cor Schipper, Maria J. Belzunce Segarra, Marnix Vangheluwe

The discussion in the working group focussed on 3 subjects:

1) the strategy of biotests, 2) the applicability of the Toxicity Identification Evaluation-Method (TIE) and 3) the use of biotests in an Ecological Risk Assessment (ERA).

The participants agreed that the ultimate goal of biotest application should be the assessment of possible risks for the receiving environment. Momentarily, however, it's use is limited to the identification of hazards of dredged materials and therewith to the description of the present status rather than a prediction of possible effects.

1) Strategy of biotesting

Criteria for biotests should be ecologically relevant and thus consider different exposure routes and feeding regimes. Therefore whole sediment tests with sediment-dwelling organisms of different feeding habits should be preferred: These organisms cover pore-water exposures as well as direct exposure due to different kinds of ingestion or bodywall contact.

However, if a stringent correlation between pore water and whole sediment test results is evident, pore water testing as a supplementary test system can be used for practical reasons.

Regarding their general applicability for routine measurements, those tests should be preferred, that are easily repeatable, reproducible and to a minimal extent be biased by confounding factors. They should be standardised and validated, so that procedures are well worked out and documented, and differences between laboratories can be kept low.

Concerning the interpretation of biotest results: those tests should be chosen that have a higher resolution, e.g. by showing a wide range of dose-effect responses rather than binary (yes or no) results, and therewith enable a gradual quantification of toxicity.

Toxicity results in the first tier should give information about general toxicity of the sediment and thus demand that no toxic effects are missed. Biotests that are applied during this first stage should thus be sensitive to a broad spectrum of chemicals and include different effect-modes.

Although a lot of those substances can be detected by acute toxicity tests, especially mutagenic, developmental and endocrine effects will only show up in chronic test systems which are currently not well developed and established for marine sediments. An urgent need for research in this direction has been identified during this workshop.

To prevent the need for extensive use of chronic, long-term, testing for sediment toxicity evaluation, the development and introduction of chemical-class specific biotests such as CALUX as a quick discriminator of endocrine and developmental potency is strongly recommended.

As no single test will be able to fulfil all of the criteria stated, the application of a biotest battery is suggested which might also include different trophic levels. It should be composed in such a way, that it covers most chemicals, the most important effect-modi and the most significant exposure routes in order to minimise the number of false negative results, pretending wrongly, that no toxicity exists.

To exclude tests, giving redundant information, from a battery is preferred because of economical and effectivity reasons, but it is acknowledged, that a weight-of-evidence-approach can be useful where confidence in single tests is limited or when authorities have to be persuaded of extensive implications.

2) Toxicity Identification Evaluation (TIE)

The TIE approach is regarded as very promising to identify true causes of toxicity and should be used as a second tier to characterise the chemicals of concern in e.g. a sediment catchment area.

Attributing ecotoxicity in biotests to chemical compounds in a cause-effect-way is important for a refined risk assessment and for establishing emission reduction measures. A toxic signal in one of the TIE-steps could trigger and direct the performance of ecological risk assessments before a sediment can be disposed of. Additionally, by this method, new chemical compounds of concern may be identified whereby others might become regarded as being of minor ecological importance.

Mesocosm studies in connection with TIE could be used as an important scientific tool to investigate processes and pathways that connect biotest information and ecologically significant effects, hence giving information about bioavailabilities and exposures.

For relevance, these studies should be done on whole sediments instead of pore water, which has mostly been used in the past.

Research in the field of TIE development and application, however, is fragmented and largely uncoordinated. For effectivity reasons the formation of a thematic network for TIE research and development on the European level is strongly recommended.

3) Ecological Risk Assessment (ERA)

ERA has two elements: the probability of something happening and the consequences when it does. So it consists of the assessment of the status quo, which might involve the identification of a hazard, and the estimation of exposure scenarios and, following consequently, possible effects on organisms.

As exposure and effects can't be depicted from chemical analyses, biotests have to form a substantial element of ERA. By characterising substances of concern, modes of exposure and the sensitivity of organisms, e.g. with the help of mesocosm studies or on the basis of field bioassays, prediction of field impacts might become possible.

However the natural variability of toxicity in the receiving environment complicates the identification of add-on toxic effects by dredged material and, thus, must initially be quantified in order to differentiate baseline "natural" effects from add-on chemical-based effects in biotest results. Furthermore, different biotest responses can be due to variations between organisms, different samples of the sampling site and the confounding factors. Consideration of among-site variations therewith is of high importance.

However, the information of bioassays is not yet evaluated in terms of going from hazard to risk assessment.

Therefore it is strongly recommended to perform a full-scale field evaluation study (biotests, chemical analyses, ecological impacts) to confirm bioassay-based predictions of adverse effects of sediment disposal. This would represent an important first step in the implementation of biotests in Ecological Risk Analysis.

A proposal for such a study (BIOSAFE, (**B**io**l**ogically **B**ased **S**ediment **Q**uality **A**ssessment by **F**ull **S**cale **F**ield **E**valuation)) was discussed and presented in the podium discussion of the workshop.



5 Report of Working Group II (application-oriented)

Chair: Remi Laane, Rapporteur: Juergen Gandrass

Ulrich Foerstner, Charlotte Hagner, Falk Krebs, Guilherme Lotufo, Peter Mollema, Axel Netzband, Birgit Schubert, Joost Stronkhorst, John Thain

Introduction – general statements

The discussion was driven by **scientific arguments** but it was tried to keep in mind that the 'end users', e.g. harbour authorities and regulatory authorities, have the stringent need **for reliable criteria that are easy to handle** (suitability for the decision-making processes involved in the management of dredged material).

However we intended to integrate **future perspectives** for the development of tools and strategies. From a practical point of view these would have to be run in a first stage including standardisation and harmonisation in a 'research mode' to prove their applicability and then in the second stage could be implemented into guidelines / regulations.

In the working group there was consensus that the discussion on bioassays as additional criteria for the assessment of the quality of dredged material has to take into account the feasibility of implementation into a **decision-making framework for the management of dredged material**.

This framework has not only to cover hazard assessment at the dredging site and if possible risk assessment with regard to the relocation of dredged material but has also to take different management options with all their pros and cons, their feasibility etc. into account.

It has been recognised that, to a large extent, contamination of dredged material is due to the prevailing concentrations of contaminants in suspended particulate matter that settles in areas of low energy and has to be dredged and relocated in order to maintain navigation.

In that regard the following general demands were recognised:

With regard to policies and regulations **a responsible dredged material management** is needed but at the same time the **main aim should be to reduce emissions from point sources as well from diffuse sources in the catchment area**.

The latter would ensure in the long-term

- (1) the **reduction of inputs from rivers directly into the marine environment** via suspended particulate matter (SPM) carrying contaminants,
- (2) to **enable the relocation of dredged material** in the rivers itself as well as in the marine environment,
- (3) to **enable different sorts of beneficial uses** (nourishment, mudflats, habitat-creation),
- (4) to stop the need for expensive land-based treatment and/or safe disposal of contaminated dredged material,

without imposing unacceptable threats to the aquatic ecosystem.

In the following a summary of conclusions and recommendations is given on questions like the availability of suitable bioassays, approaches towards decision making processes, methods to

assess sediment toxicity data and how to translate data from laboratory experiments to field situations.

Question 1: Are presently suitable bioassays or batteries of tests available?

With regard to decisions on the disposal of dredged material in the marine environment available bioassays are listed (Table 1) that are already standardised, i.e. agreed methods are available with standard operating procedures (SOPs) and quality assurance / control measures (QA/C). As well the endpoints, the used matrices (whole sediment, aqueous phase, extract) and their current use (dredged material, notification¹, monitoring, research) are stated.

Conclusions

- A set of a few **standardised bioassays** for testing whole sediments as well as aqueous phases (pore-waters, elutriates, extracts) **are available** for testing dredged materials as well as for other purposes.
- The endpoints of these bioassays can mainly be summarised as looking at the **acute toxic** potential.
- Some of them, e.g. Microtox[®], *Corophium volutator*, have already been harmonised on a European level by intercalibration (e.g. Round-Robin Tests).
- Harmonisation could depend on the regional availability of the species.
- A shift from tests for acute toxicity towards chronic toxicity is expected.
- There is a **developing field of chronic tests and receptor-based tests / biomarkers** which are mostly not yet standardised. As example the DER CALUX assay for chemicals with dioxin-like modes of action is included in Table 1.

Recommendations

- A **battery of tests with 3-4 bioassays** listed in Table 1 including **at least one whole sediment test** should be carried out.
- The **development of chronic tests and receptor-based assays / biomarkers** should be carried out. Standardisation and harmonisation is necessary. Arguments are: (1) chronic tests could be more sensitive and cover as well other modes of action of chemicals than tests for acute toxicity. (2) receptor-based assays / biomarkers may cover persistent bioaccumulating compounds otherwise overlooked and might in future replace chemical analysis undertaken at high costs, e.g. CALUX assay for chemicals with dioxin-like mode of action.

¹ Requirements of testing for the registration of 'new chemicals'

Table 1: Available standardised bioassays for the assessment of dredged material and for other purposes

bioassay	endpoint	agreed method SOP	agreed method QA/C	matrix	in use for dredged material	in use for notification	in use for monitoring	in use for research
Amphipods (e.g. <i>Corophium volutator</i>)	mortality	X	X	whole sediment	X	X	X	X
	chronic	X	X	whole sediment	-	-	X	X
Algae	growth inhib.	X	X	aqueous phase	-	X	-	X
Polychaete (e.g. <i>A. marina</i>)	mortality, growth, casting	X	X	whole sediment	X	-	X	X
Sea urchins (e.g. <i>E. cordatum</i>)	mortality, reburrowing	X	X	whole sediment	X	-	X	-
	development	X	X	aqueous phase	-	-	X	X
Bacteria (e.g. Microtox®)	bio-luminescence	X	X	aqueous phase, suspended sediment	X	?	X	X
Mollusc larvae (e.g. oyster larvae)	development	X	X	aqueous phase	X	-	X	X
Copepod (e.g. <i>Tisbe, A. tonsa</i>)	survival, reproduction	X	X	aqueous phase	X	X	X	X
Cell-lines (e.g. DRE CALUX)	dioxin like mode of action	X	-	extract	X	-	X	X

- The bioassays should not only be **applied** to dredged materials but **also to upstream river sediments**, discharges of point sources included if possible. This seems reasonable for tracing back toxic potentials in dredged materials to its sources in the catchment basin as well as for the sake of comparability for the assessment of sediment quality. Some assays with marine species can be carried out with freshwater sediments but there might be the need to implement tests with fresh water species as well.
- With regard to the interpretation of the results there is also the need for (1) guidelines of **sampling strategies** (number and distribution of representative samples)², (2) **standardisation and harmonisation of sampling**, e.g. for pore-waters and elutriates.

Question 2: *What are the current status and future approaches towards a decision-making framework for the disposal of dredged material?*

Current approaches for decision-making frameworks for the disposal of dredged material are schematically summarised in Figure 1. Focussing on the disposal in an aquatic system, e.g. coastal marine areas, it comprises the assessment of the dredged material (hazard assessment) as well as the risk assessment at the disposal site / receiving environment.

1. Hazard assessment includes:

- Defining hazard-levels for dredged material (potential risk)
- Deriving science-based quality criteria (SQC) on the basis of e.g. NOEC values

Currently different approaches to derive SQC for dredged material exist:

- equilibrium partitioning concept, i.e. wqg (water quality guideline value) x K_d, good criteria for water phase and translation to SPM and sediments
- spiked sediment toxicity tests
- co-occurrence analysis (matching the bulk sediment chemistry with effects observed in the field or in bioassays with in the field collected sediments)

2. Risk assessment includes:

- **Executing an overall impact study** (chemistry, toxicity, and benthic community) **at the disposal site / receiving environment**

Conclusions

- The **decision making process** will be in the short-term as well as in the long-term **influenced by political decisions, resulting in action levels**. Generally decisions on the management of dredged material are driven by a combination of ecological and economic arguments (environmental yield / costs ratios).
- Already defined **SQC** for individual chemicals **differ more than one order of magnitude**.

² Some ASTM guidelines already exist

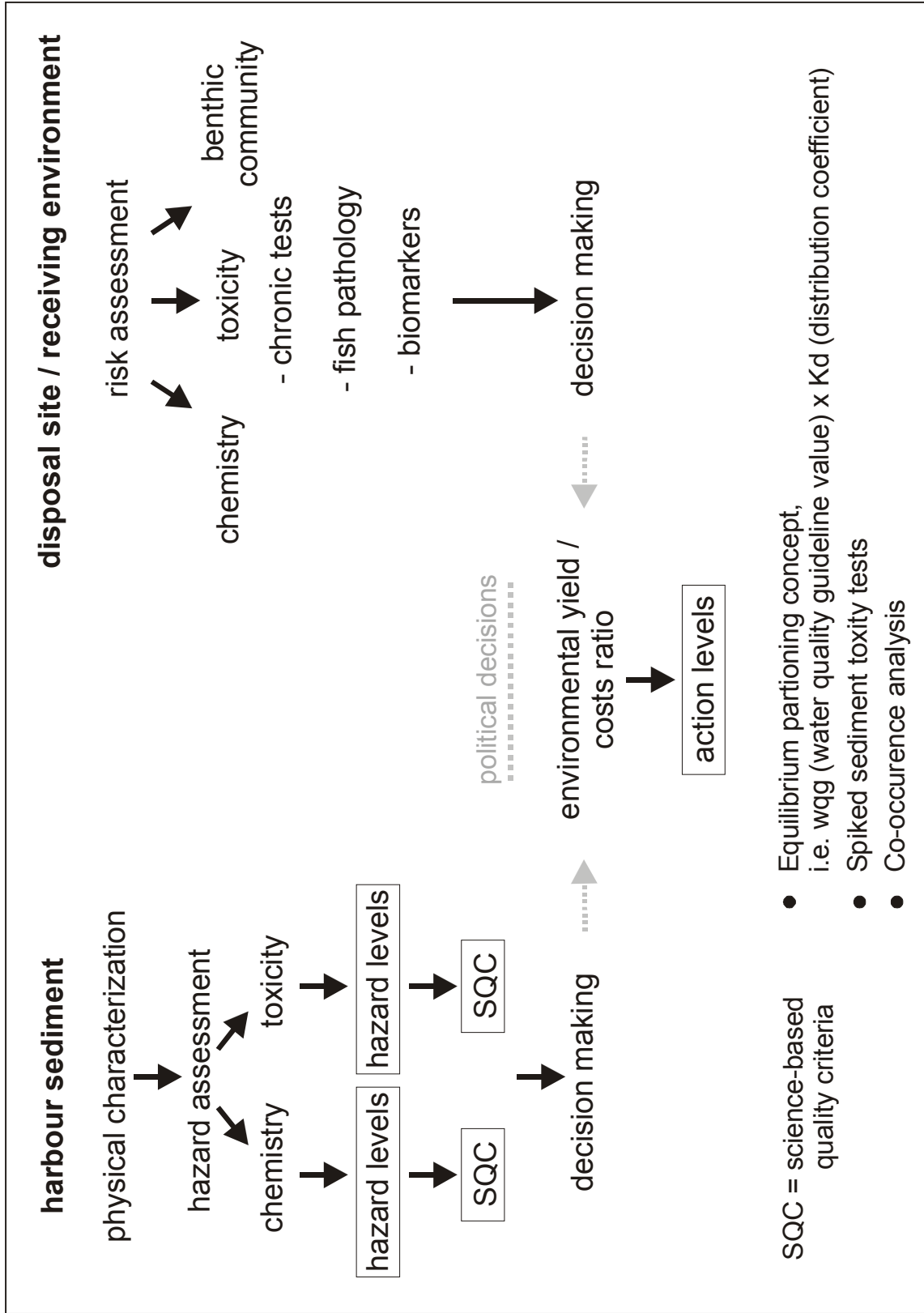


Figure 1: Decision-making framework for the disposal of dredged material

Recommendations

- The **hazard assessment of dredged material** should be implemented in a **TIER-like approach**:
 - TIER I: limited chemical criteria, limited test battery with bioassays
 - TIER II: for toxic to highly toxic material for which the toxicity can not be explained by the investigated chemicals an **extended battery of bioassays** can be applied as well case studies undertaken to identify the culprit chemicals (e.g. **TIE approaches**).
- **Standardisation and harmonisation** of deriving science-based quality criteria (**SQC**).
- For a **risk assessment at the disposal site** in the marine environment **baseline studies** have to be undertaken including the disposal site itself as well as the effected area (dispersion of disposed/re-suspended material).
- More effort has to be undertaken to make **the step from hazard assessment of dredged material to the risk assessment at the disposal site** / receiving environment (see also question 5: Translation of results from laboratory to field situations and vice versa).
- **Monitoring the benthic community at the deposition site** can function as a '**safety net**' and might also have an impact on the modification of perhaps too stringent science-based quality criteria not taking into account other parameters like e.g. the coastal zone of the Southern Bight of the North Sea being a high dispersive environment. However benthic communities are often affected by physical impacts at the disposal site and it might be difficult to distinguish from impacts due to contamination.

Question 3: Which methods could be used to assess sediment toxicity data?

The decision-making process demands **reliable criteria which are easy to handle**. Currently there is no census for best methods to be applied. In the following list some methods are still under development or are visions for development (e.g. toxic units concept).

- Comparison with reference sediments
In order to ensure statistical significance, dependent on the number of samples and allowed uncertainty, there should be at least 10 to 20% difference between dredged material and reference sediments, depending on the bioassay.
- Absolute classes
 - Power analysis (statistical derived min. limit value for classification in combination with eco(toxico)logically derived value, e.g. 25% mortality for amphipods acceptable with regard to the development of population)
 - Dilution factors for aqueous-phase tests (pore waters, elutriates, extracts)
 - Relative classes (e.g. TU, 'toxic units') which summarise results of different types of toxicity tests maybe even the chemical criteria into one yardstick ('toxic units concept'),
- Expert systems (research mode)
- Fuzzy logic based systems for classification

General recommendation

- **Harmonisation** of methods should be approached in future (research mode, statistically sound and comparable databases as a prerequisite).

Conclusions for reference sediments

- The use of reference sediments is already current practice, e.g. In the United States. Generally the statistical difference between dredged material and reference sediments is evaluated.
- **Criteria for ideal reference sediments** are: (1) same grain size distribution and organic carbon content, (2) relatively uncontaminated in the sense of no response in applied toxicity tests, (3) as close as possible to the disposal site.
- The **choice of sites for reference sediments is crucial** because it forms an integrated part of the decision-making framework (examples exist where decisions for the disposal of dredged material mainly depend on the choice of the reference sites).

Recommendations for reference sediments

- Evaluation of the **original state at the disposal site** before disposal of sediments (often impossible as sites already have been used for a long time).
- The **statistical evaluation between dredged material and reference sediments** is of high importance. In order to ensure statistical significance, dependent on the number of samples and allowed uncertainty, there should be at least 20% difference between dredged material and reference sediments).

Question 4: *What evidence can be obtained from results derived from experiments under laboratory conditions and in field situations? Can the results be translated?*

Figure 2 depicts tools for hazard/risk assessment which can be applied under laboratory conditions as well as under field conditions in a simplified manner.

Results from chemical analysis give amounts of single substances – the use of standardised and harmonised methods assumed – at a comparably high reproducibility in analysed samples. However their relevance to field situations in terms of negative effects to the aquatic ecosystem, not taking into account e.g. their bioavailability, persistence, bioaccumulation etc., is low.

Field studies e.g. on benthic organisms have a high relevance with regard to possible impacts on the ecosystem but have a comparable low reproducibility. In between these two categories fall biomarkers, bioassays and mesocosm experiments.

The general problem is the translation of results between these categories of tools in either direction. This translation is essential in linking effects to toxic potentials to individual chemical substances and vice versa. In the case of biomarkers / receptor-based assays as the before-mentioned CALUX assay the results can be linked to the acting chemicals relatively straight forward. For most of the used bioassays this task is more complex. Promising tools for linking

toxic potentials derived from bioassays to their causative chemicals – translating the results – are TIE-like approaches.

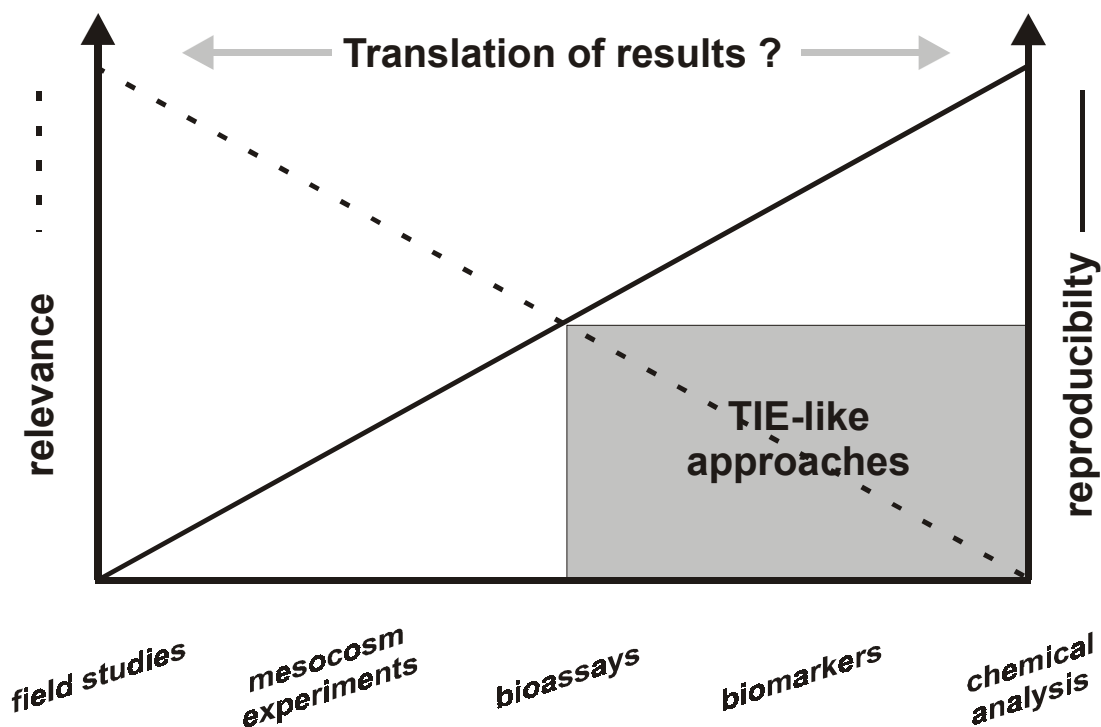


Figure 2: Translation from results derived under laboratory conditions and in field studies

Conclusion

- Without translation of results from chemical analysis, biomarkers, bioassays, (mesocosm experiments), and field studies the **link between effects and causative chemicals** as well as other influencing parameters can not be achieved.

Recommendations

- Efforts should be made to develop strategies for progressing **from hazard assessment of dredged material to the risk assessment at the disposal site**. This includes the necessity to improve translation of results as depicted in Figure 2.
- Advantages and disadvantages of **mesocosm studies** should be considered carefully before undertaking these studies at high costs.
- The application of **TIE-like approaches** is a reasonable tool under certain circumstances (see question 5).

Question 5: Of what use are TIE-like approaches?

The term **TIE** (Toxicity Identification Evaluation) refers to TIE protocols established by US-EPA. Similar approaches are described in literature where as well the term **bioassay-directed chemical analysis** was coined. They have in common that they combine chemical non-target analysis with toxicity tests with **the aim to identify the culprit chemicals**, i.e. identifying the chemicals which mainly contribute to toxic potentials.

Conclusions

- The identification of the **relevant chemicals** using TIE-like procedures is a prerequisite for **linking them to their emission sources** (first step for reduction measures).
- The **translation to field situations is not covered by TIE** approaches.
- The **obstacle** for TIE are **low or moderately contaminated** materials where the toxic potentials are dependant on a **broad spectrum of compounds** at low concentrations (mixed toxicity). Although the contaminants can be identified they might not be linked any more to their toxic potentials.

Recommendations

- TIE studies have relatively high costs and **should be applied in TIER II**, for dredged material/sediments (toxic to highly toxic) **where the toxic potential can not be explained by the identified chemicals** (chemical criteria in Tier I).
- TIE should be applied to **distinguish between toxic potentials from man-made and natural compounds** (e.g. phytoestrogens). This is comparable to the background approach for heavy metals.