Framework for the Environmental Impact Factor for Drilling Discharges (EIF_{DD})

Mathijs.G.D. Smit
Formerly TNO-IMARES,
Presently IRIS / Statoil

Outline

- Introduction
- Development of a framework
  - Identification of stressors
  - EU-TGD requirements for PNEC derivation
  - PNECs for non-toxic stressors
  - Combining risks
- Risk communication: The EIF
- Conclusions

Introduction - scope

- EIF produced water developed and successfully implemented
- Risk managements tool for drilling discharges?
  - Years of experience with monitoring activities
- Drilling discharges
  - More complex (toxicants and non-toxic stressors)
  - Two compartments (water column + sediment)
  - Different time scales

Introduction – risk based

- Internationally agreed principles for environmental hazard and risk assessment are available. (EU-TGD, 2003)
- Combining the essential elements of hazard and exposure should provide a good basis for risk assessment of drilling discharges.
- The approach attempts, as much as possible, to be consistent with EU guidance for chemical risk assessment.
- Incorporation of these principles enhances acceptance for regulatory purposes
- Monitoring data for validation of the modelling
- However EU-TGD focuses on RCR for single stressors
- No guidance for evaluation of complex mixtures
- No guidance for non-toxic stressors

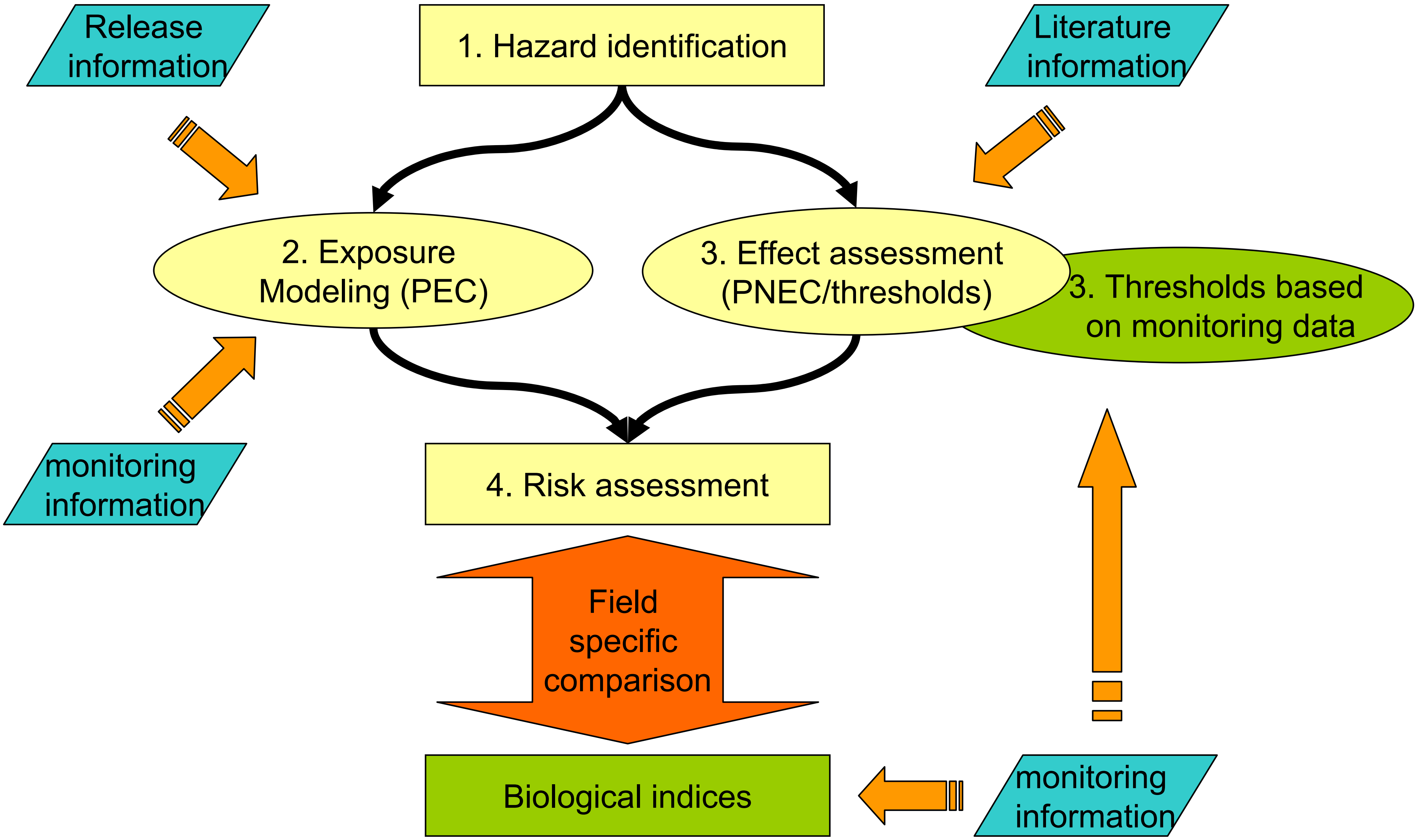
Introduction - challenges

- Application of principles for environmental hazard and risk assessment originally developed for evaluation of single toxic components to mixture of toxic and non-toxic stressors
- Including requirements on precautionary from EU-TGD
- Including two compartments
- Including short and long term exposure
- Estimating the overall risk of toxic and non-toxic stressors in one estimator (EIF)

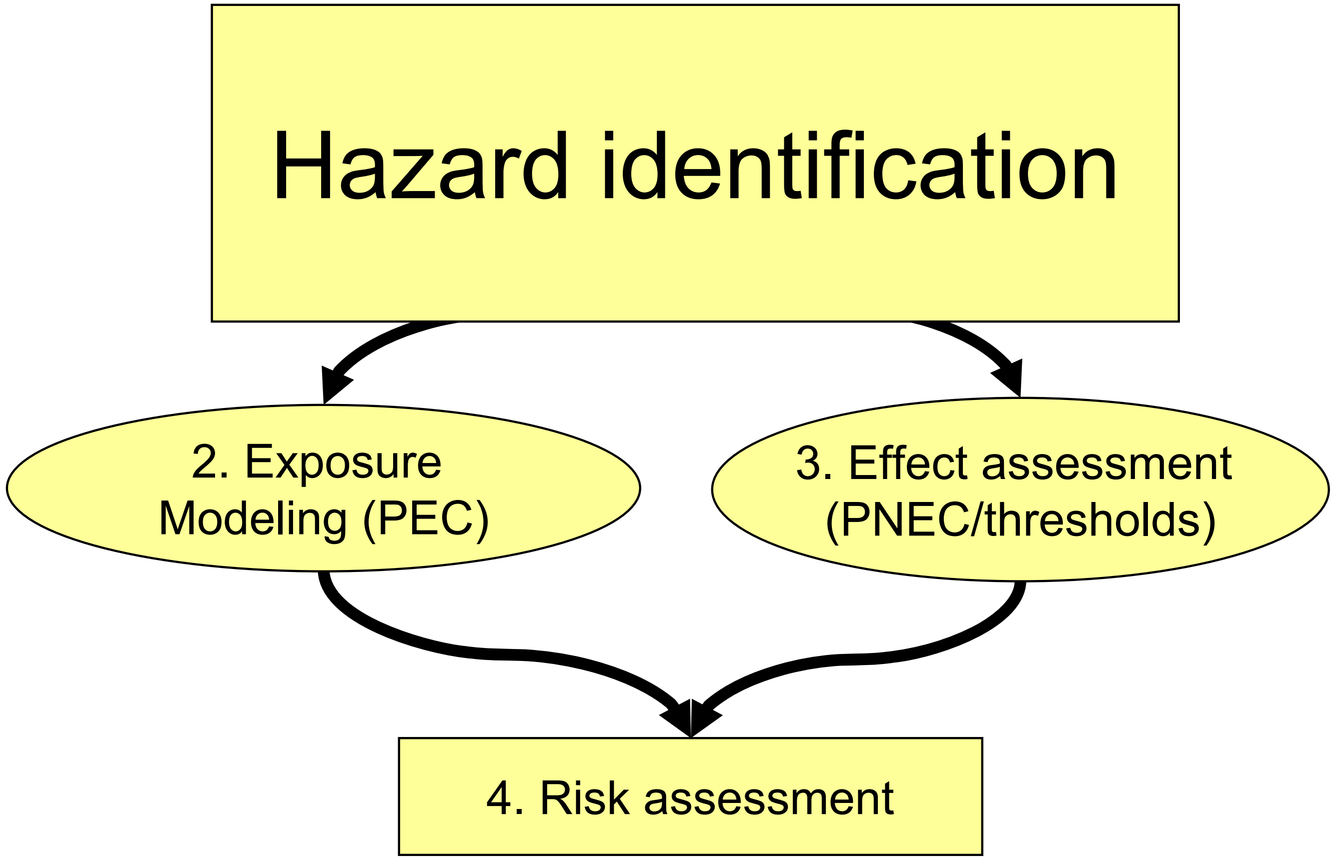
Development of a framework

Internationally agreed principles basis for the EIF_DD:

- Hazard identification
- Exposure assessment
- Effect assessment
- Risk assessment
- Validation


Release information
1. Hazard identification
Literature information
2. Exposure Modeling (PEC)
3. Effect assessment (PNEC/thresholds)
3. Thresholds based on monitoring data
monitoring information
4. Risk assessment
Field specific comparison
Biological indices
monitoring information

Concept development – risk assessment



Hazard identification

- Based on detailed knowledge within companies and scientific literature (e.g. Patin, 1999; Neff, 1987)
- **Stressors in the water column**
  - Toxicity (chemicals)
  - Suspended matter (barite, bentonite, etc.)
- **Stressors in the sediment**
  - Toxicity (chemicals)
  - Oxygen depletion (caused by degradation)
  - Change in grain size (cuttings and mud)
  - Burial (cuttings and mud)

Chemicals in the EIF_DD

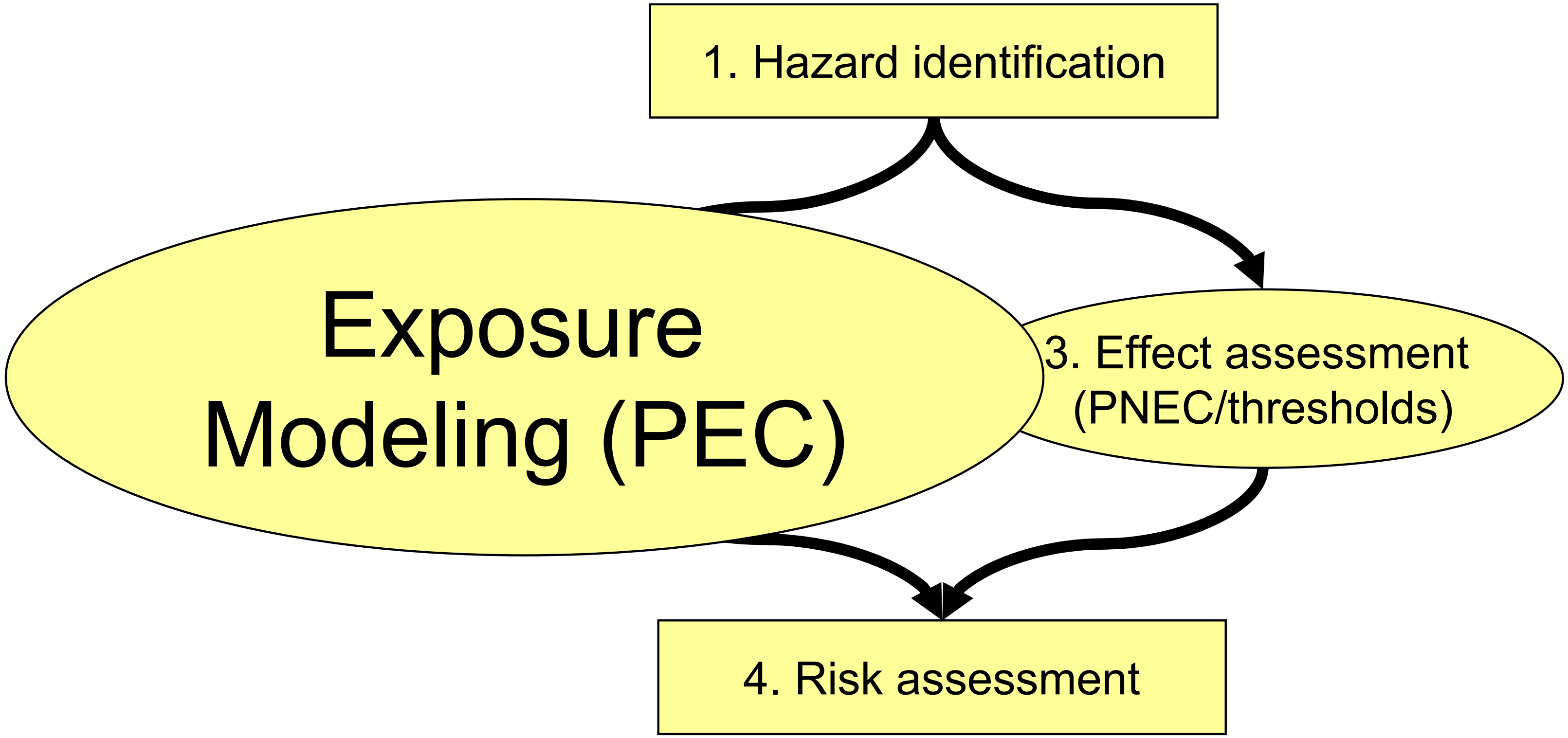
- **Three categories of chemicals:**
  - Metals (as ingredients of added chemicals and weighting agents)
  - Natural organic compounds (PAHs, aliphatic hydrocarbons etc.)
  - Added chemicals (drilling fluid chemicals e.g. non-PLONOR, PLONOR chemicals etc.) (OSPAR agreement 2004-10)

- **Selection criteria:**
  - The total amount used/discharged (PLONOR)
  - Bioavailability and toxicity potential
  - Potential for non-toxic disturbances (O_2 depletion, burial etc.)

”added chemicals” in EIF_DD

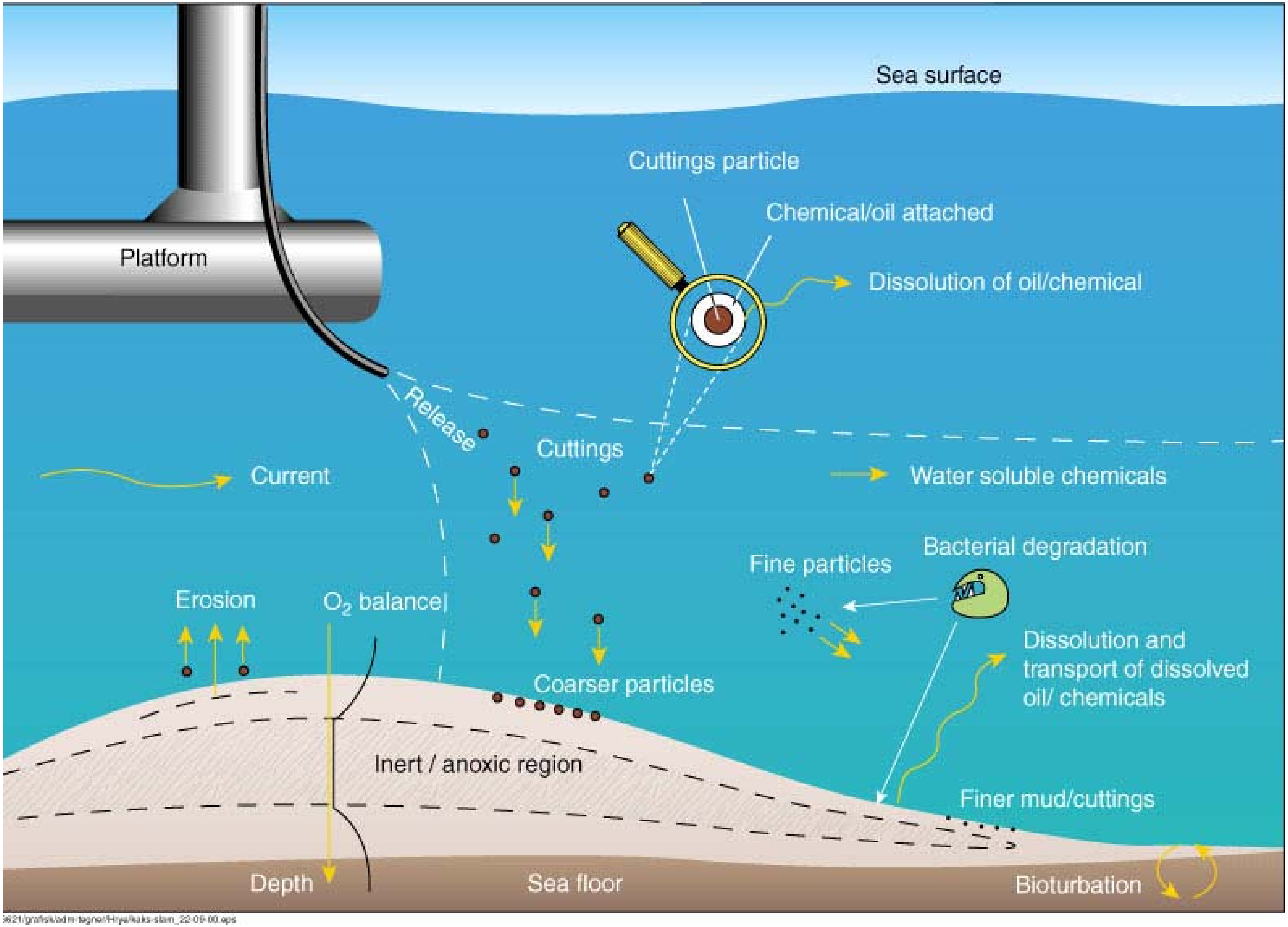
- **All non-PLONOR chemicals**
- **Selected PLONOR chemicals or green chemicals**
  - 6 out of 17 most discharged PLONOR chem. (NCS: Hydro, Total and Statoil in 2003)
- **EIF_{DD} water column:**
  - Suspended particulate matter (weighting agents: barite, ilmenite etc.)
  - Chemical substances with log Kow/Koc < 3 (non-PLONOR)
  - Chemical substances with Kow/Koc ≥ 3 attached to suspended particulate matter
- **EIF_{DD} sediments:**
  - Chemical substances with log Kow/Koc ≥ 3 (non-PLONOR)
  - Weighting agents: barite, ilmenite etc.
  - Bentonite clay and quarts etc.

Concept

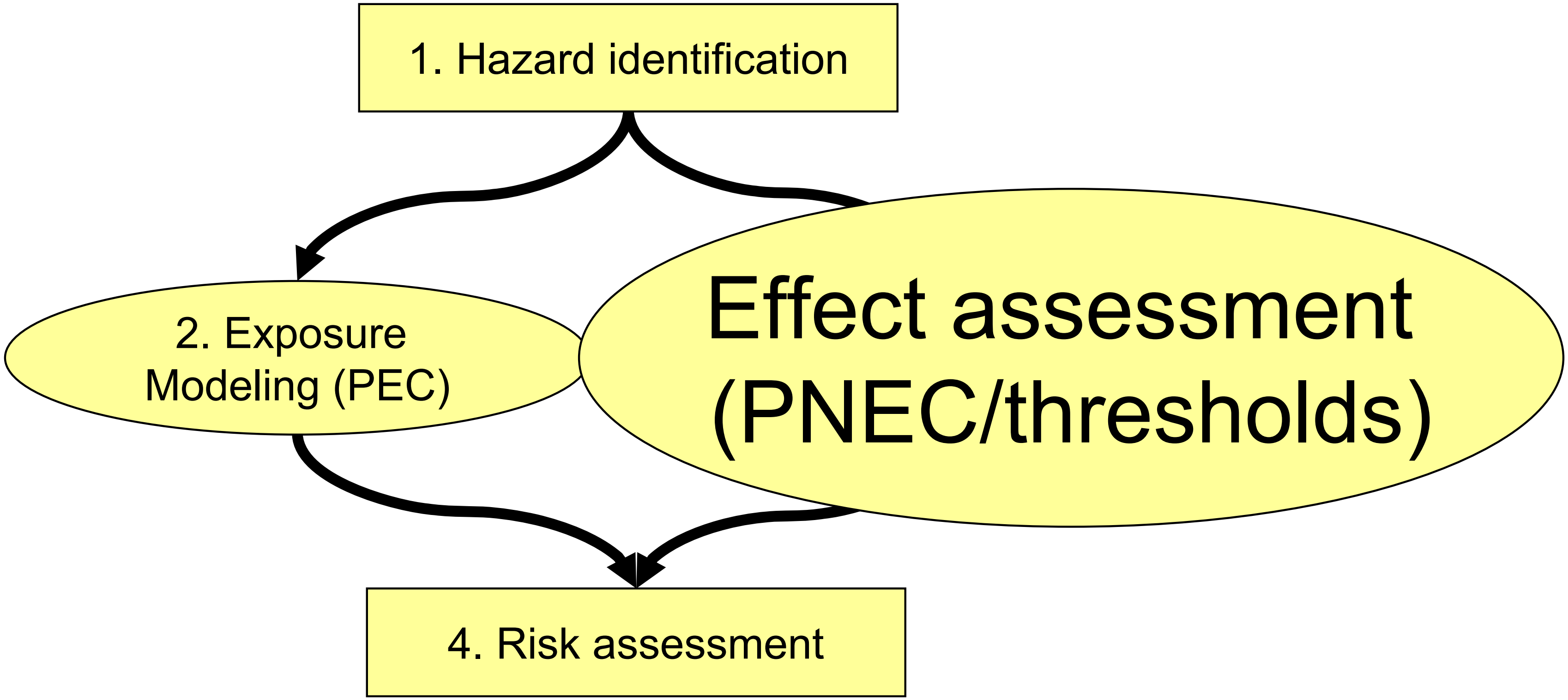

1. Hazard identification
Exposure Modeling (PEC)
3. Effect assessment (PNEC/thresholds)
4. Risk assessment

Exposure modelling

- DREAM model upgraded to cover the sediment compartment
- Varying concentrations in time and space in the water column and sediment
(Rye et al., accepted IEAM)


Sea surface
Cuttings particle
Chemical/oil attached
Dissolution of oil/chemical
Platform
Release
Cuttings
Current
Water soluble chemicals
Bacterial degradation
Fine particles
Erosion
O_2 balance
Dissolution and transport of dissolved oil/ chemicals
Coarser particles
Inert / anoxic region
Finer mud/cuttings
Depth
Sea floor
Bioturbation

Concept


1. Hazard identification
2. Exposure Modeling (PEC)
Effect assessment (PNEC/thresholds)
4. Risk assessment

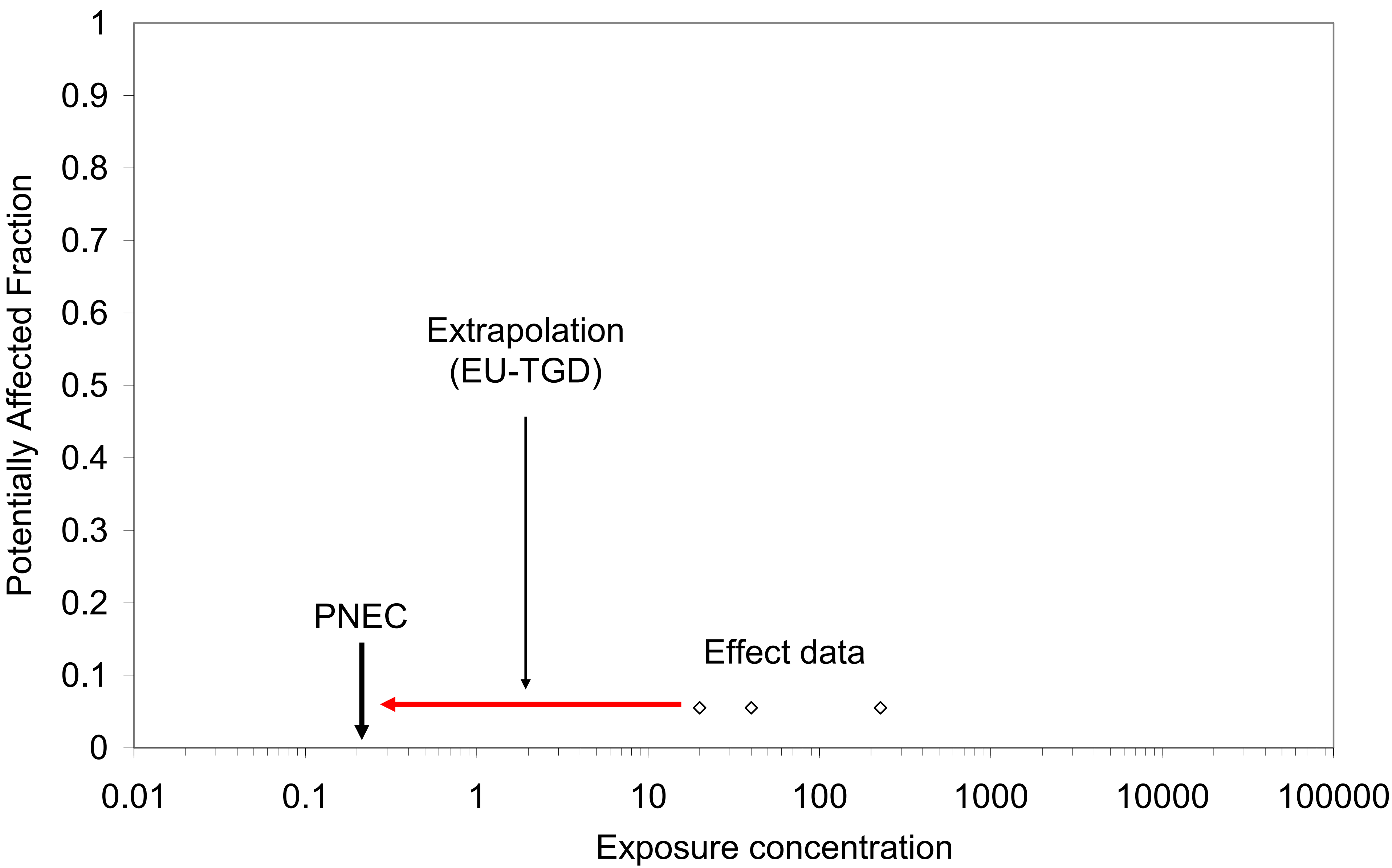
EU-TGD requirements for PNEC derivation

- Approach using assessment factors (safety factors)
- Approach using species sensitivity distributions (SSDs)

EU-TGD requirements for PNEC derivation

- Approach using assessment factors (safety factors)
- Collect toxicity data
- Select lowest NOEC or EC50 value
- Apply assessment factor to this value
- Assessment factor depends on availability, quality and nature of the collected data (e.g. number of taxonomic groups, acute or chronic)

Few acute (EC50s) or chronic effect data (NOECs) available

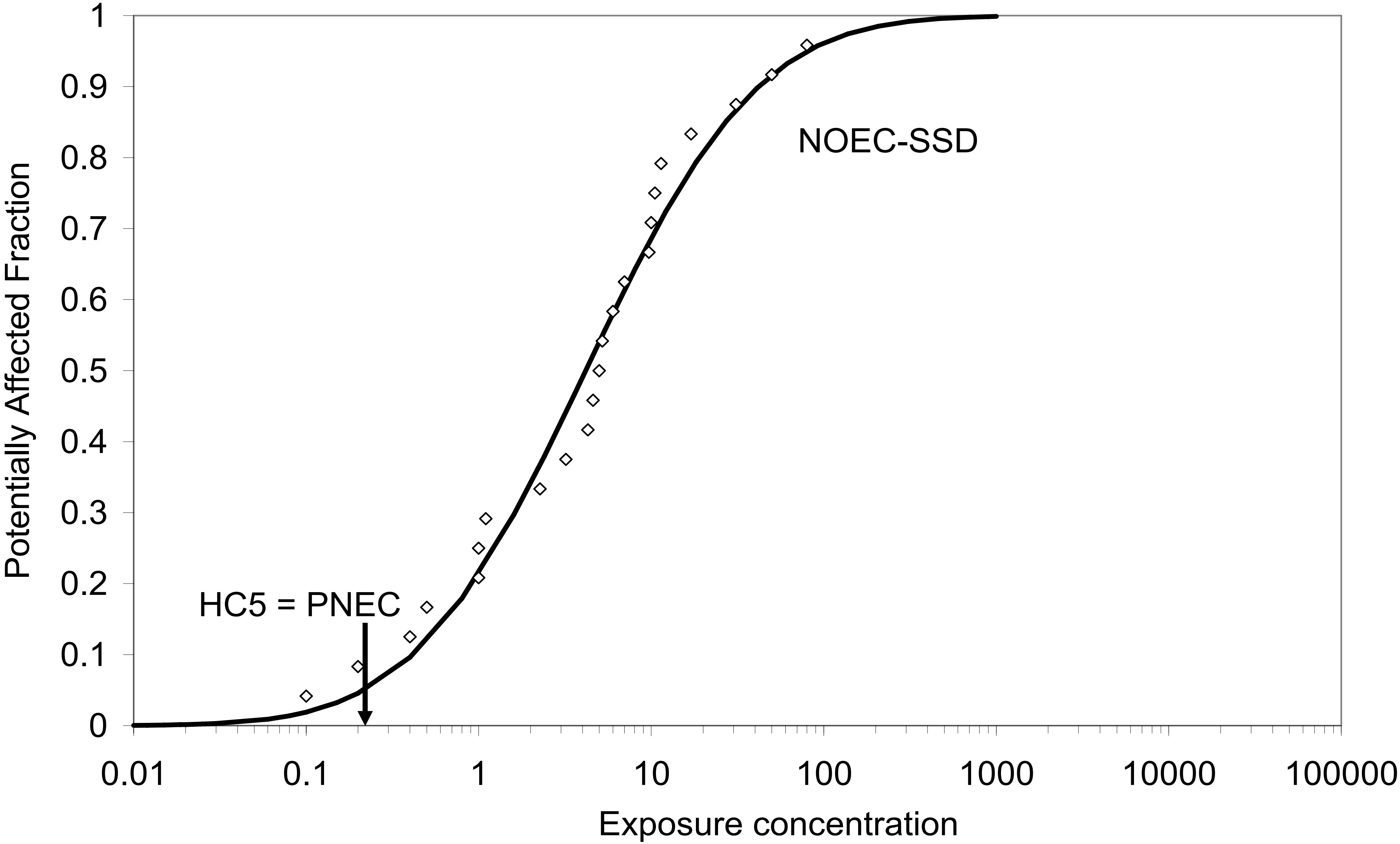


Data set	AF
Lowest short-term L(E)C50 from FW or SW representatives of three taxonomic groups of three trophic levels	**10000**
Lowest short-term L(E)C50 from FW or SW representatives of three taxonomic groups of three trophic levels + two additional marine taxonomic groups	**1000**
One long-term NOEC (FW or SW crustacean reproduction or fish growth studies)	**1000**
Two long-term NOECs from FW or SW species representing two trophic levels	**500**
Lowest long-term NOECs from three freshwater or saltwater species representing three trophic levels	**100**
Two long-term NOECs from FW or SW species representing two trophic levels + one long-term NOEC from an additional marine taxonomic group	**50**
Lowest long-term NOECs from three FW or SW species representing three trophic levels + two long-term NOECs from additional marine taxonomic groups	**10**

EU-TGD requirements for PNEC derivation

- Species Sensitivity Distributions
  - Chronic NOECs for 15 species, 8 taxonomic groups
  - Sensitivity of tested species represents species in the field
- Collect toxicity data
- Calculate mean and standard deviation
- Draw distribution and derive 5th percentile (HC_5)
- Apply assessment factor between 1-5 (if necessary)

Many chronic no effect data (NOECs) available
(> 15 species, > 8 taxonomic groups (EU-TGD)



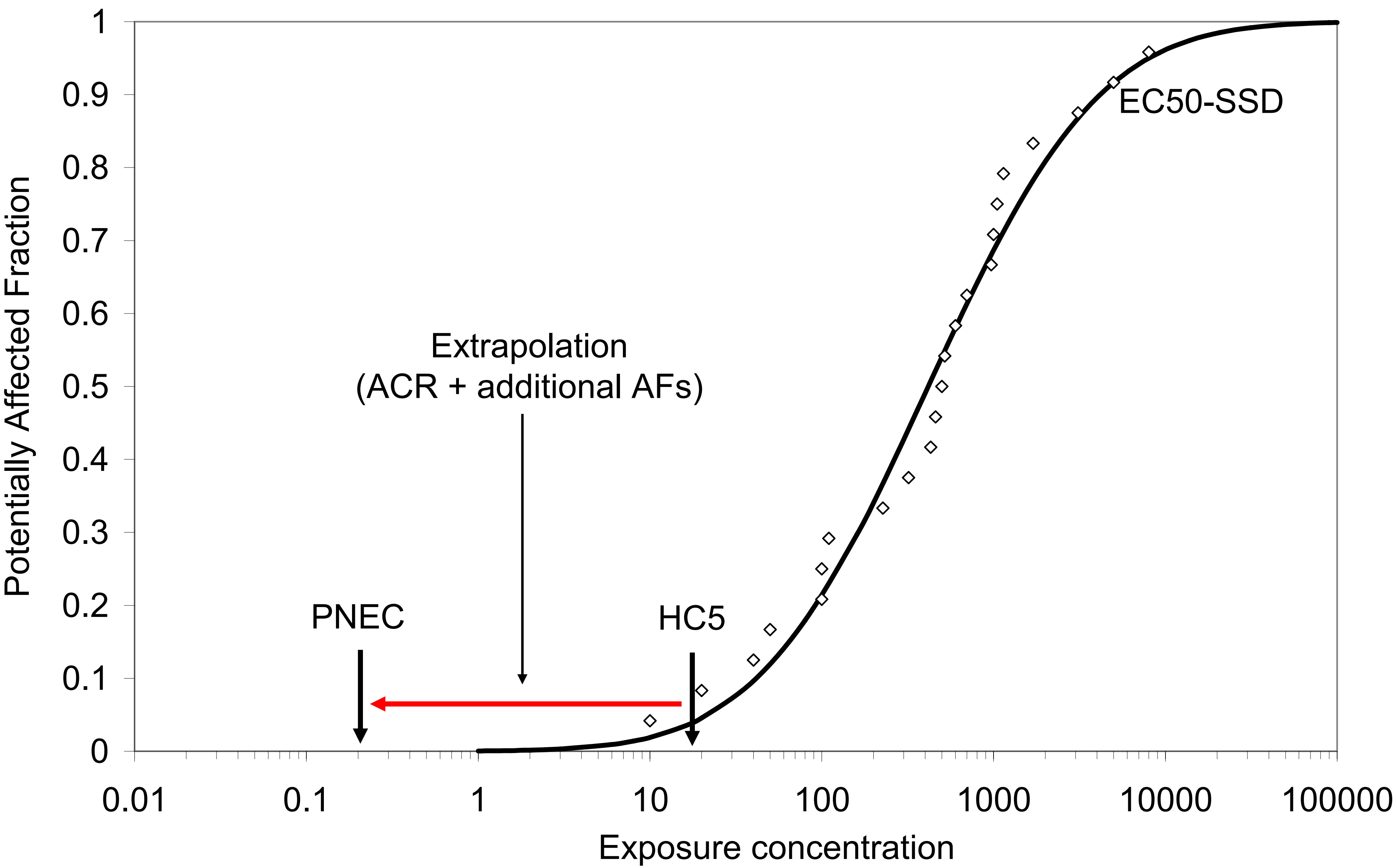
PNEC derivation for non toxic stressors

- No guidance available for non-toxic stressors
- No standard laboratory test protocols available
- Stick to well described principles for risk assessment
- Data availability is low for non toxic stressors
- Assessment factor approach can result in PNECs below natural background levels (e.g. metals)
- SSD approach based on EC50s for non-toxic stressors (Aldenberg et al., 2002; De Zwart, 2002)

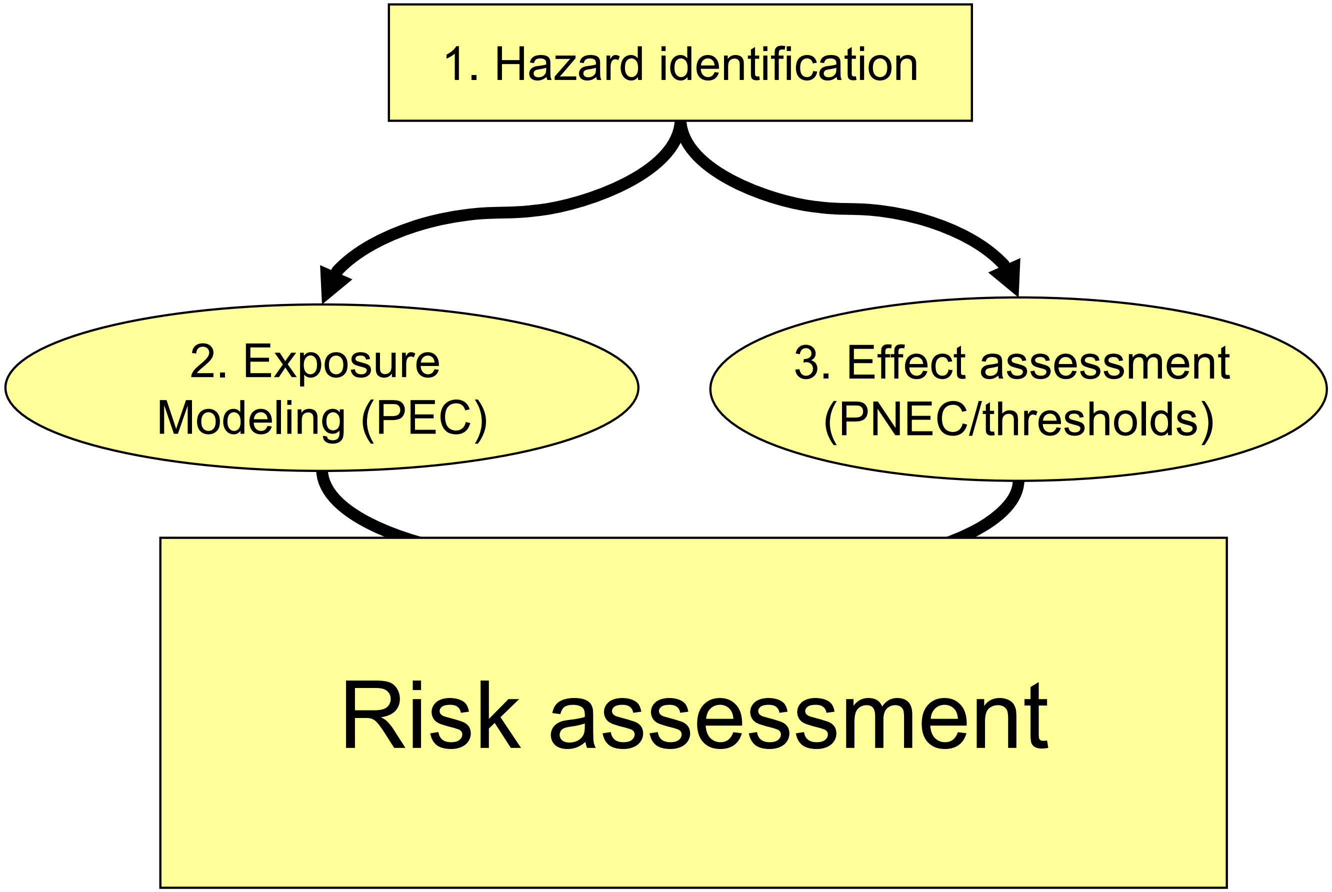
PNEC derivation for non toxic stressors

- Collect toxicity data (EC50s or other effect data)
- Calculate mean and standard deviation
- Draw distribution and derive 5th percentile (HC_5)
- Apply Acute to Chronic Ratio (ACR) plus an additional assessment factor (if necessary)

Many acute effect data (EC50s) available



Concept


1. Hazard identification
2. Exposure
Modeling (PEC)
3. Effect assessment
(PNEC/thresholds)
Risk assessment

Risk assessment principles

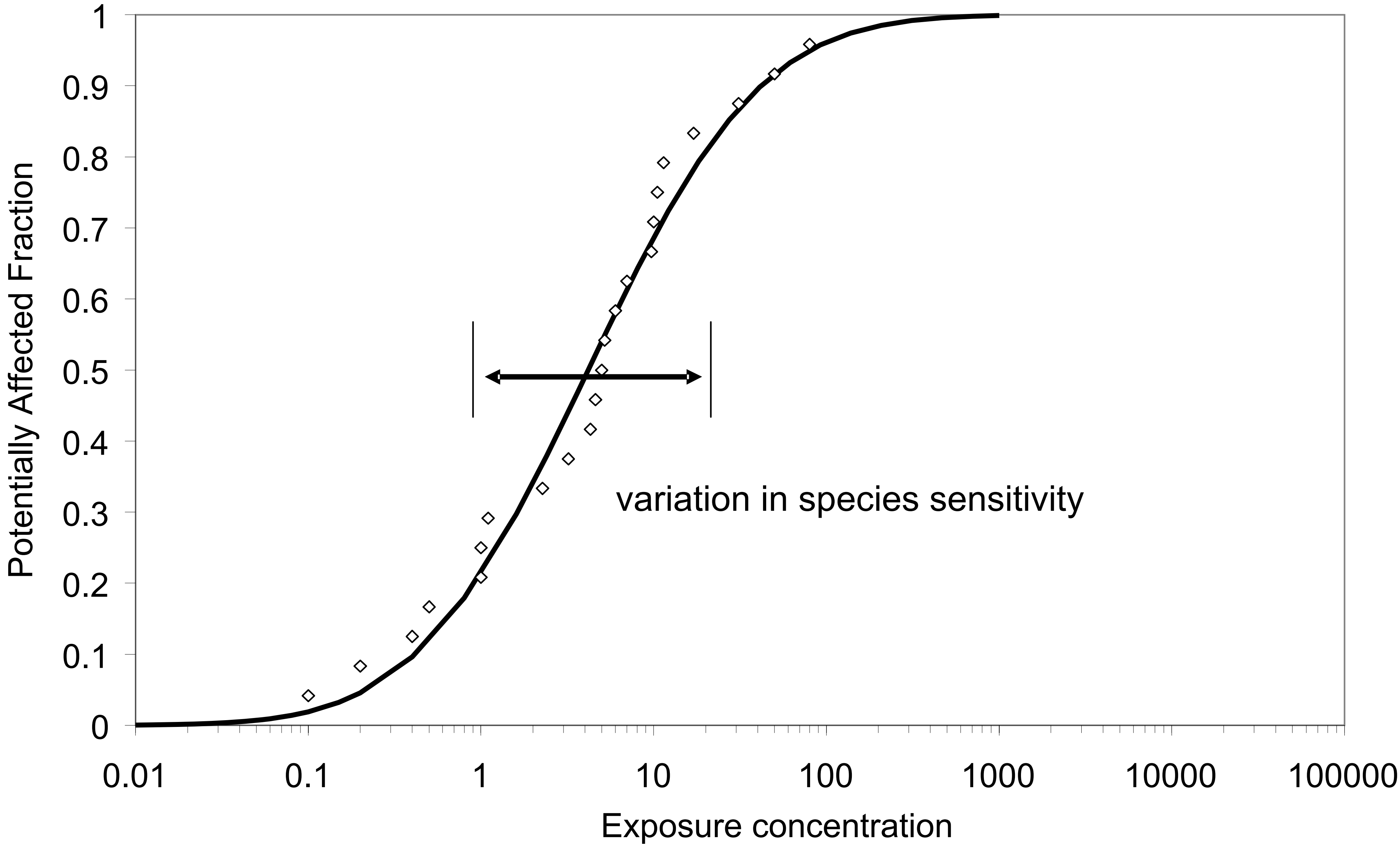
- Time variable exposure concentrations calculated with DREAM (PEC)

- Threshold values (PNECs) following EU-TGD or SSDs
  - Toxicants few data: assessment factors (TGD)
  - Toxicants many data: SSDs based on chronic NOECs (TGD)
  - Non-toxic stressors: SSDs based on EC50s (De Zwart,2002)

- Evaluation of single stressors:
  - Comparison of PEC and PNEC → *PEC: PNEC ratio*

Combining risks

- PEC:PNEC ratios for different stressors should not be added (Solomon and Takacs, 2002; Jager et al., 2006)
- PEC:PNEC ratios can be calculated into risk probabilities (Potentially Affected Fraction: PAF) (Karman and Reerink, 1997)
- Risk probabilities for single stressors can be combined into one joint risk probability (De Zwart and Posthuma, 2005)
- In order to do this an indication of the variation in species sensitivity in needed (next to the PNEC)


Potentially Affected Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.01
0.1
1
10
100
1000
10000
100000
Exposure concentration
variation in species sensitivity

Combining risks

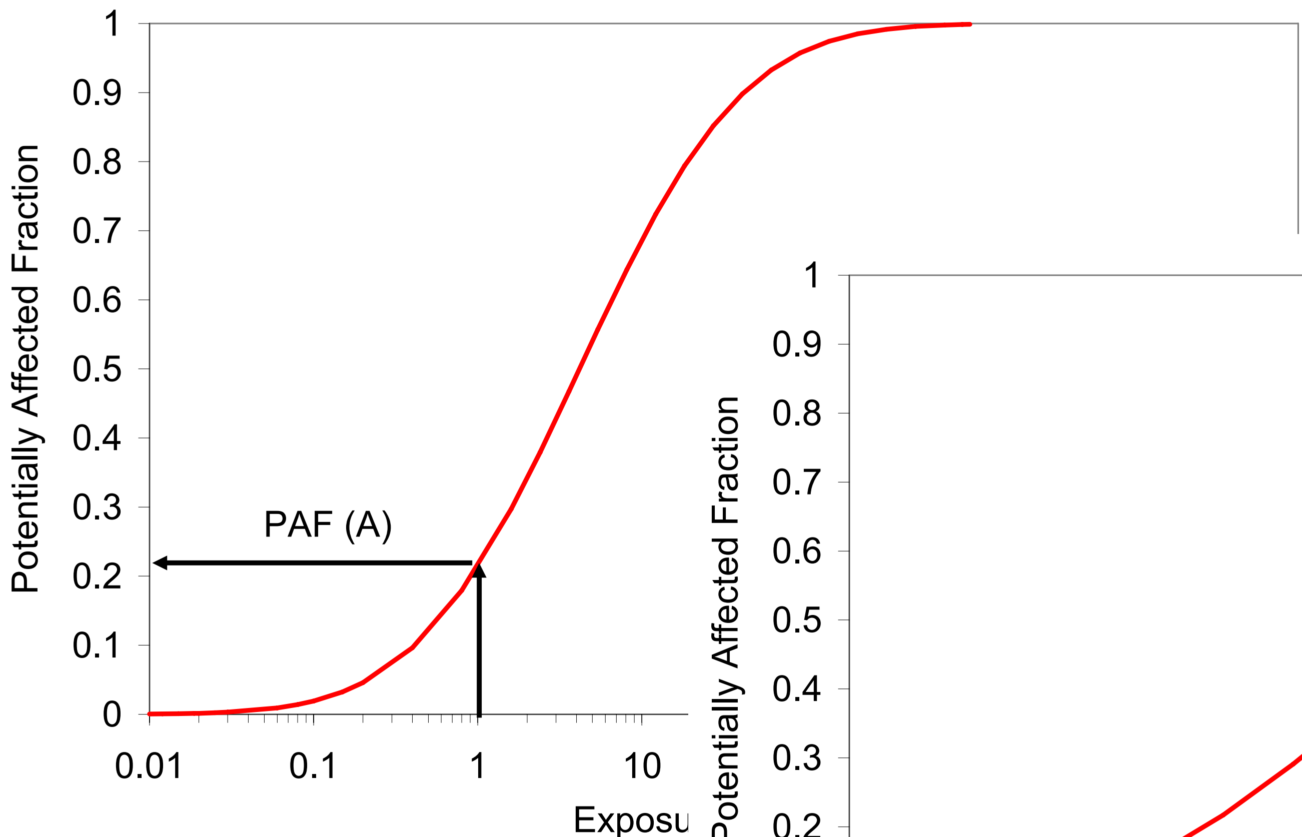
- Joint risk probability(A,B) =
  risk(A) + risk(B) – risk(A) * risk(B)
  (De Zwart and Posthuma, 2005)

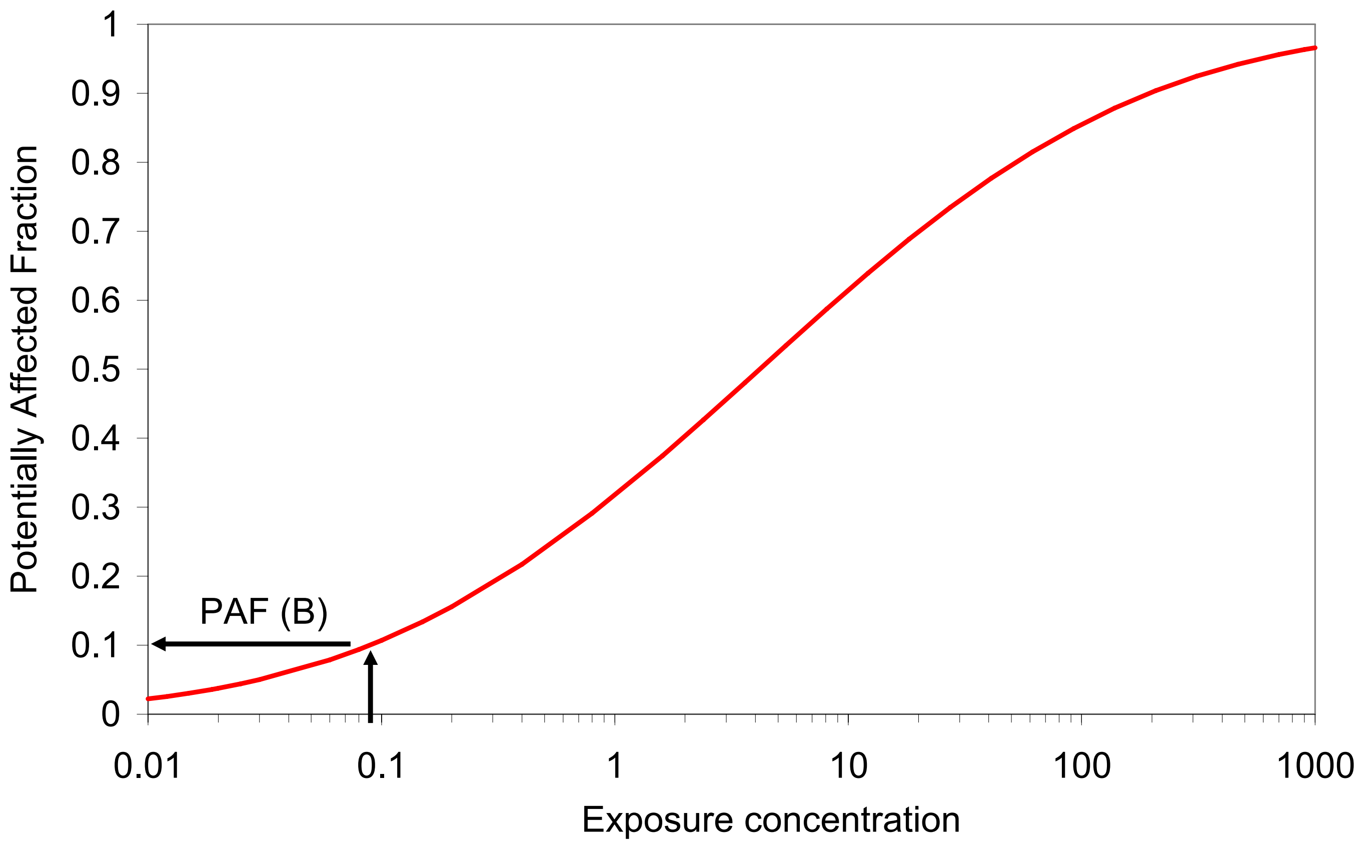
- For complex mixtures joint risk probability < 5% as criterion

- If joint risk probability < 5%, all PEC:PNEC ratios for all single stressors in the mixture are below 1

- Stricter than the EU-TGD!

Combining risks



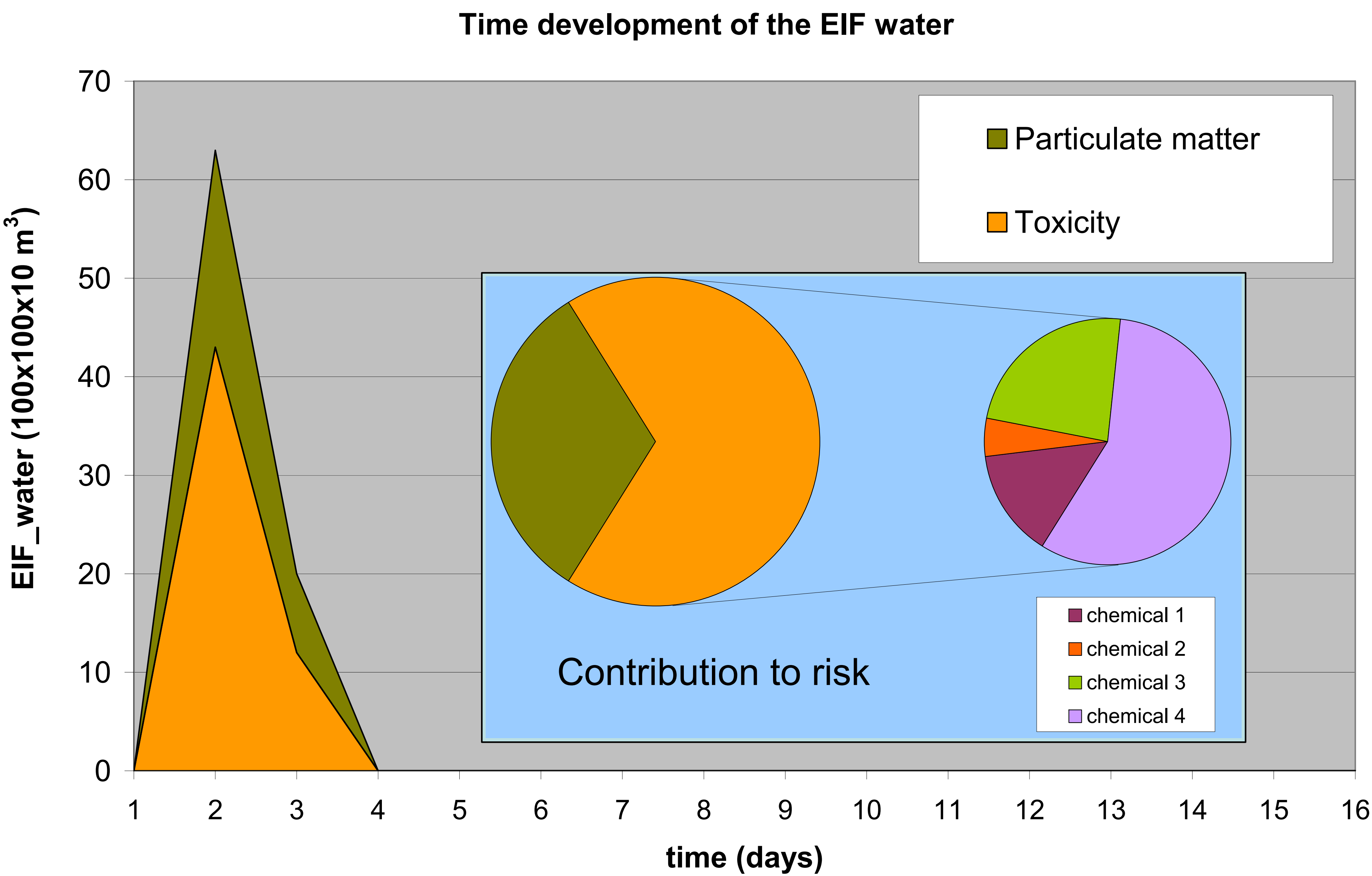


Risk communication: The EIF_DD

- Joint risk probability resulting from all stressors is calculated for sediment and water column grid cells
- Joint risk probabilities change over time due to changing concentrations
- Two EIF factors are developed
  - EIF_DD_water column
  - EIF_DD_sediment

Risk communication: The EIF_DD water

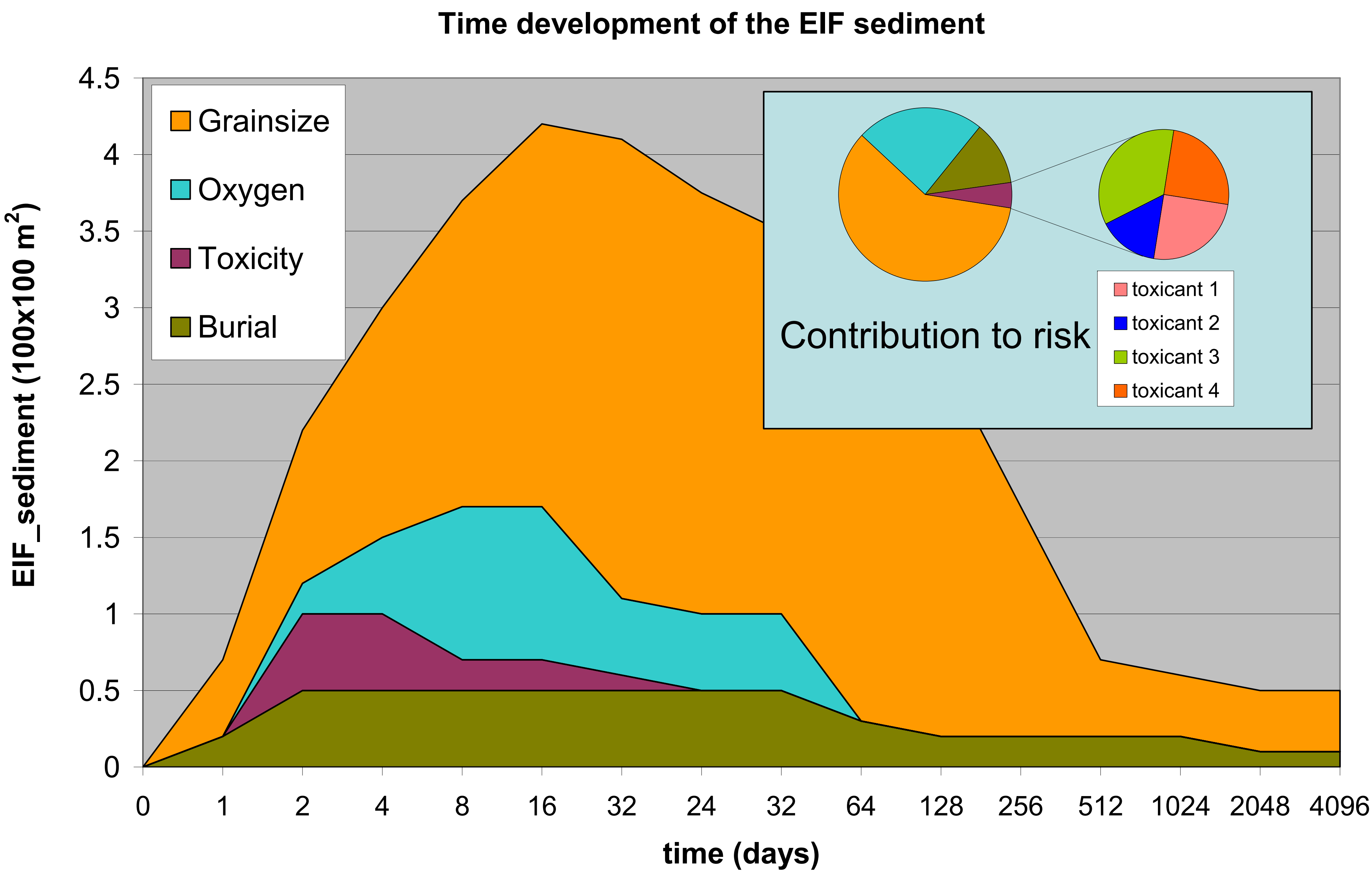
- The same approach as the EIF produced water (Johnson et al., 2000)
- Maximum number of grid cells with joint risk probability >5% during a simulation (This equals to the maximum volume of water where an environmental risk is present)
- EIF_DD_water = 1 →
  100 x 100 x 10 m^3 water column at risk


Time development of the EIF water
EIF_water (100x100x10 m3)
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
time (days)
Particulate matter
Toxicity
Contribution to risk
chemical 1
chemical 2
chemical 3
chemical 4

Risk communication: The EIF_DD sediment

- Comparable to EIF_DD_water
- Number of grid cells with joint risk probability >5% during a simulation are recorded. (This equals to a sediment area where an environmental risk is present)
- This number can be produced as a time profile
- EIF_DD_sed = 1 ⟶

  100 x 100 m^2 sediment area at risk


Time development of the EIF sediment
EIF_sediment (100x100 m^2)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Grainsize
Oxygen
Toxicity
Burial
Contribution to risk
toxicant 1
toxicant 2
toxicant 3
toxicant 4
0 1 2 4 8 16 32 24 32 64 128 256 512 1024 2048 4096
time (days)

Conclusions

- By using the accepted guidelines for risk assessment from the EU-TGD (EC, 2003) together with the well documented principles for probabilistic risk assessment (Aldenberg et al., 2002), the described concept provides a sound basis for the evaluation of drilling discharges, which should enhance acceptance of the overall approach.

- The approach provides an important step toward addressing complex multi-stressor risks in a scientifically sound way

Conclusions

- Precautionary from the EU-TGD is considered by including the assessment factor approach
- PNECs based on the assessment factor approach and PNECs based on the SSD approach are equally treated even though it is considered that the first are scientifically less robust (Okkerman et al., 1991).
- The assessment factor approach is scientifically not the most preferred methodology (Garay et al., 2000, Tannenbaum, 2005, Jager et al., 2006) and other, scientifically more valid methods, are available (Pennington, 2003), nonetheless the assessment factor approach is applied for chemicals in order to comply with the EU-TGD.

Conclusions

- The approach incorporates one of the strong elements of the SSD approach, which is the combination into a joint risk probability (De Zwart and Posthuma, 2005).
- The approach facilitates the incorporation of natural background concentrations. This is relevant for natural occurring substances (e.g. metals) and some non-toxic stressors (e.g. suspended clays) as the assessment factor approach might predict PNEC levels below the natural background (Struijs, 1997; Crommentuijn, 2000).

Conlusions

- For the combination of the risks from toxic and non-toxic stressors in one joint risk probability response-additivity is assumed.

- In the future the use of weight factors could be considered in order to discriminate between the severities of impacts from the different stressors

- Evaluation and validation of the assessment results will be required as both the assessment factor approach and SSD approach focus on the preservation of ecosystem structure. These risk assessment endpoints still leave subjects open for interpretation if one considers the lack of ecosystem dynamics, such as food web relationships

Conclusions

- The overall objective of environmental management for offshore practices is to reduce the environmental risk.
- Discharging close to the sediment floor could reduce the risks to the water column, but could also result in a higher risk to the sediment compartment.
- This dilemma indicates that both risks should be compared in a quantitative way and that local environmental characteristics should be taken into account.
- Further improvement of the tool should be placed in the light of relevance of the environmental risks from drilling discharges compared to other risks related to other discharges from offshore oil and gas installations.

Evaluation of environmental risks from toxic and non-toxic stressors; a proposed concept for a risk-based management tool for offshore drilling discharges

Authors:

Mathijs G.D. Smit*

Robbert.G. Jak

Henrik Rye

Tone K. Frost

Ivar Singsaas and

Chris C. Karman

SETAC – IEAM: Integrated Environmental Assessment and Management

Acknowledgement

The oil companies financing the ERMS program are acknowledged for financial support as well as scientific input during the program.

Contractors in the program have been: Akvaplan-niva, Battelle, MUST, RF-Akvamiljø, SINTEF, TNO and University of Oslo, with SINTEF as the co-ordinator of the program.