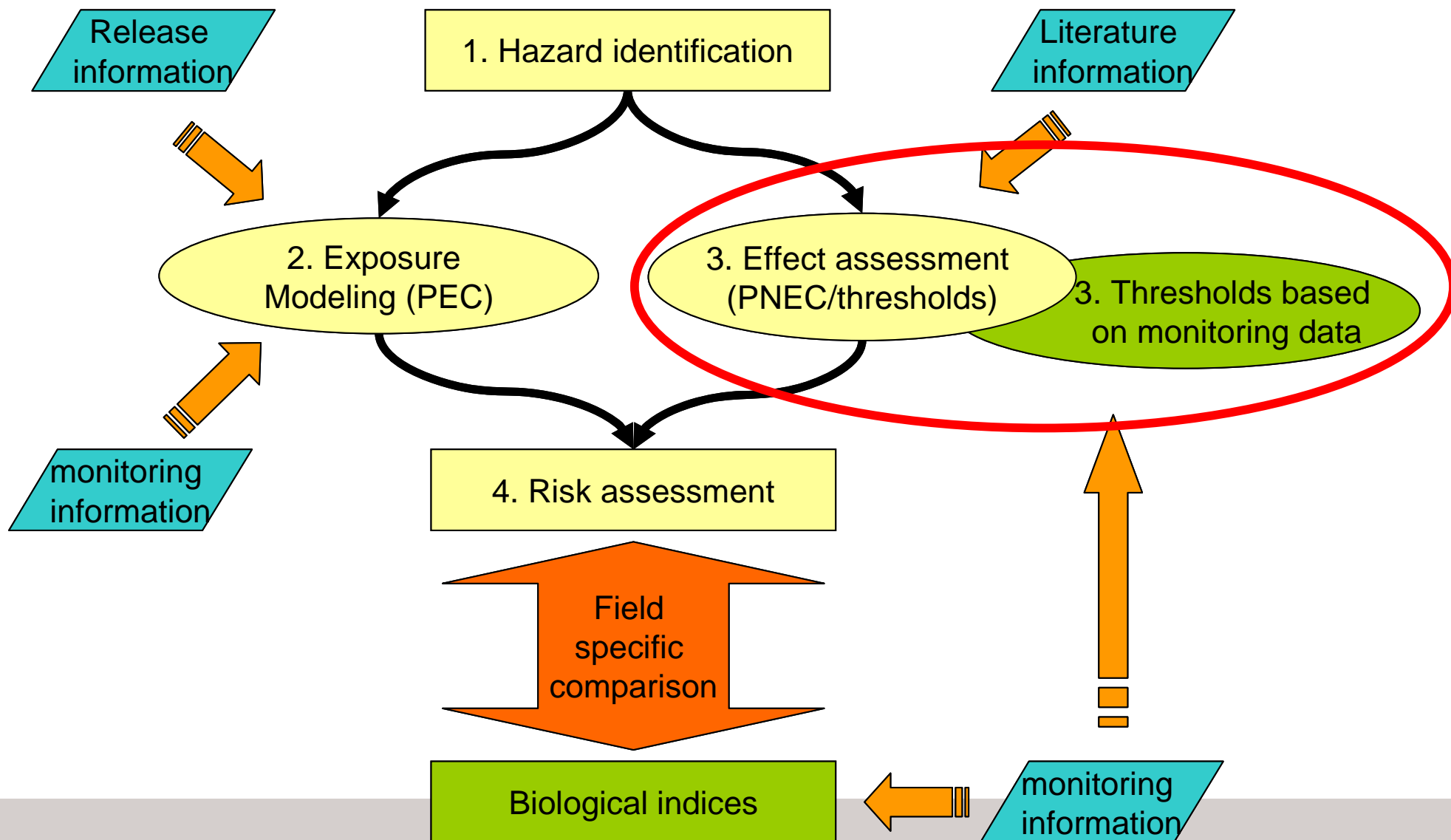


Toxic and non-toxic disturbances PNEC estimation and validation

Tone Frost, Statoil

EIF_{DD} framework



Outline

- Stressors in EIF drilling discharges (EIF_{DD})
- EU-TGD requirements for PNEC derivation
- Selected PNEC approaches for the water column
- Sediment toxicity literature review
- Selected PNEC approaches for the sediments
- Validation of toxicity threshold values derived from literature versus field monitoring data

Stressors in EIF drilling discharges - EIF_{DD}

- **Toxic and non-toxic stressors**

- **Stressors in water column:**
 - **Toxicity of chemical substances:**
 - Heavy metals (weighting agents)
 - Non-PLONOR and some PLONOR chemical substances

 - **Physical effects of suspended particles:**
 - Fine particles (weighting agents, bentonite clays)

Stressors in ELF drilling discharges (ELF_{DD})

- **Stressors in sediment**
 - **Toxicity of chemical substances:**
 - Heavy metals (added as weighting agents)
 - Added chemical substances*
 - Oil hydrocarbons (PAHs, aliphatic hydrocarbons)
 - **Burial of organisms**
 - **Oxygen depletion**
- } - Cuttings and fine particles**
- Oil hydrocarbons
- Added chemical substances
- **Change in sediment structure (grain size)**
 - Cuttings
 - Fine mud particles**

* Added non-PLONOR and some PLONOR

** Fine particles: weighting agents, bentonite clays

EU-TGD requirements for PNEC derivation

■ Toxicity as a stressor

- Standardised test protocols and guidance (EU-TGD) are available
- Assessment factor approach – water column & sediment
 - Derived from the most sensitive endpoint (NOEC or LC/EC50) on single substances
 - PNEC derived from use of assessment factors (10 to 10 000)

EU-TGD requirements for PNEC derivation

- **Species Sensitivity Distribution (SSD) approach – water column**
 - Recommended if large data sets are available
 - Applied to all reliable NOECs (longterm) including minimum 10 -15 NOEC data for different species covering at least 8 taxonomic groups
 - Draw distribution and derive 5th percentile ($HC_5\%$)
 - An additional assessment factor may be applied (1 to 5)

EU-TGD requirements for PNEC derivation

- **Equilibrium partitioning method – the sediment compartment**
 - Method based on use of aquatic toxicity data
 - Recommended used as an additional approach to AF approach when only acute sediment toxicity data are available
 - The lowest PNEC value from using both methods is recommended used for risk calculations

Selected PNEC approaches - water column

■ Toxicity - heavy metals:

- SSD approach applied
- SSD analysis:
 - freshwater data
 - saltwater data
- Additional AF from 2.6 to 3.6

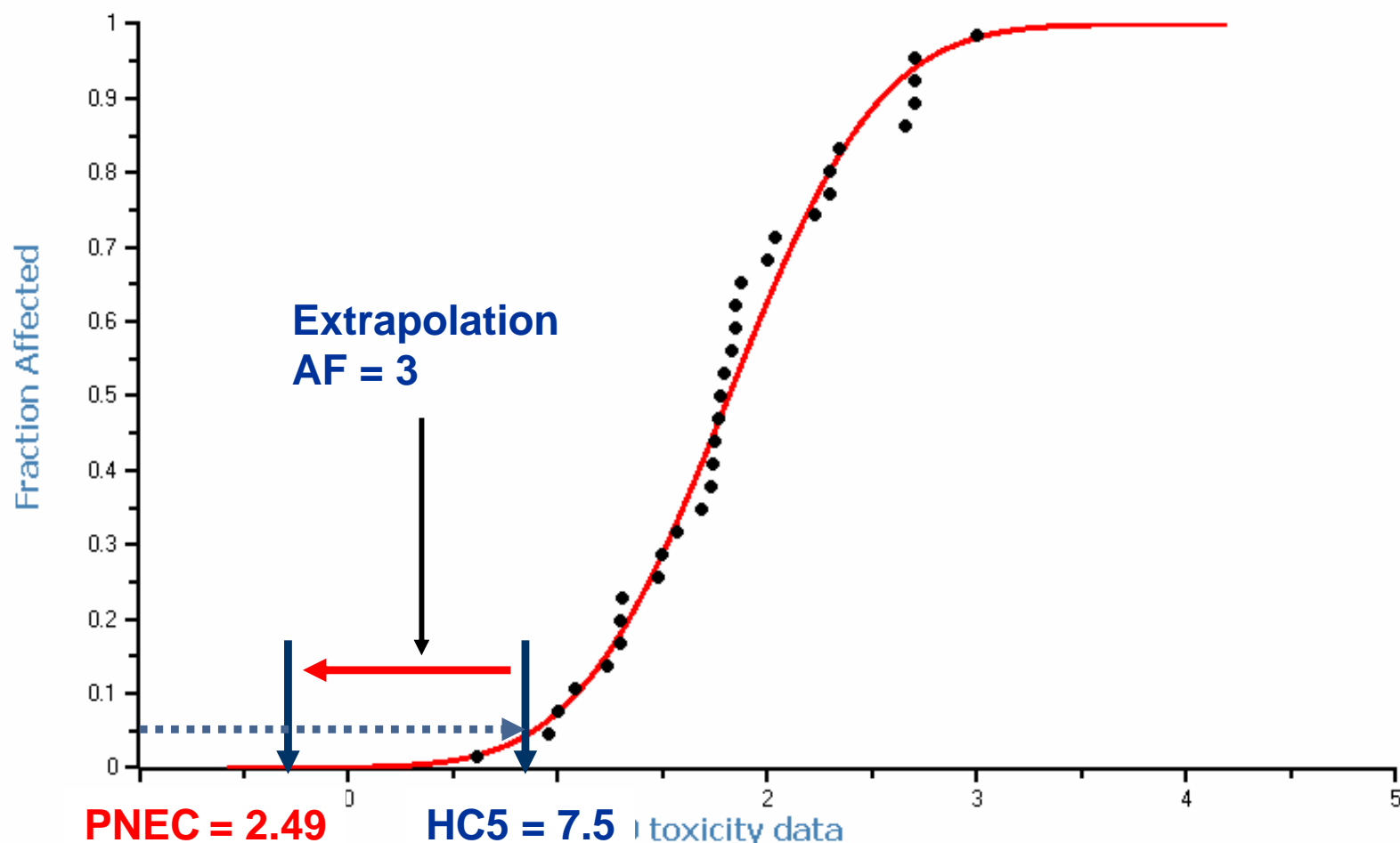
Component	NCS background concentrations (µg/l)	Approach for PNEC derivation	
		AF approach ^b (µg/l)	SSD ^d (µg/l)
Zinc	0,3 -1,4 ^a	0,46 ^c	3,07
Copper	0,02 -0,5 ^a	0,02 ^c	0,64
Nickel	-	1,22 ^c	1,53
Cadmium	0,004 - 0,023 ^a	0,028 ^c	0,18
Lead	0,02 - 0,081 ^a	0,182 ^c	2,49
Inorganic mercury	0,001 - 0,003 ^a	0,008 ^c	0,04

a) Data from OLF, 1998. b) Assessment factors TDG, 1996. c) Data from Frost, 2002.

d) Data from Källquist, 2007 (TGD, 2003)

Species sensitivity distribution (SSD) for lead

SSD Graph



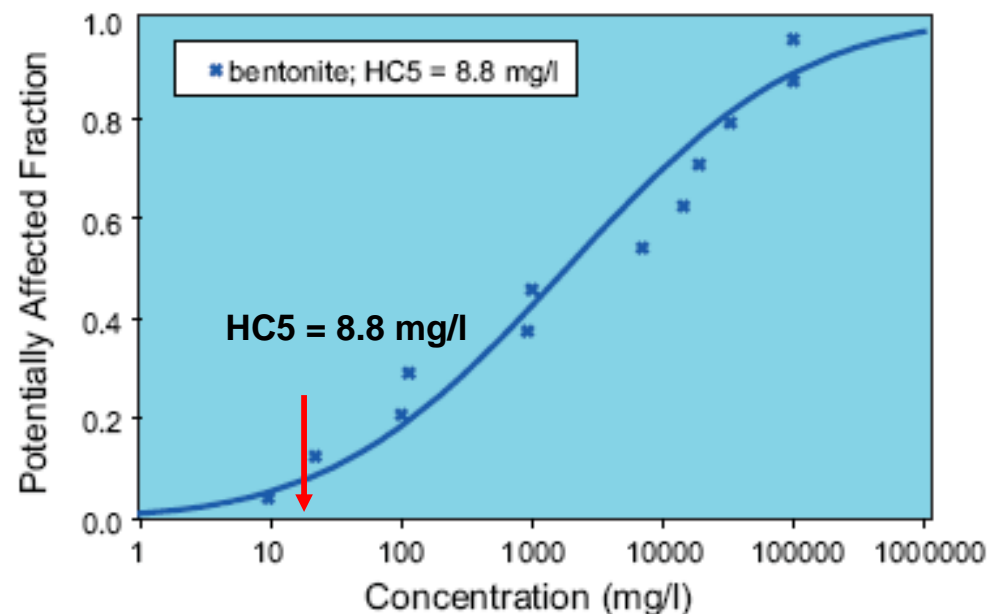
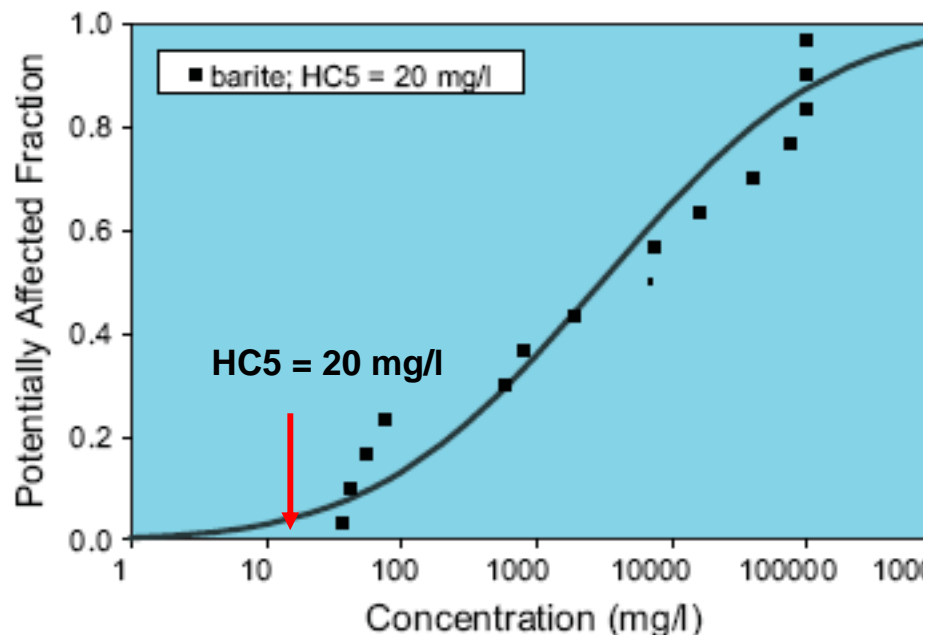
Selected PNEC approaches - water column

- **Toxicity - added chemical substances:**
 - Assessment factor approach applied
 - data availability is low – the SSD approach can not be used
 - only acute toxicity data available
 - Exploration drilling – discharge of limited duration (“batch discharge”) - “intermittent” release (TGD)
 - Assessment factor PNEC added drilling chemicals water column
→ to be reduced by a factor 10

Selected PNEC approaches - water column

- **Physical effects of suspended particles:**
 - Lack of guidance for derivation of threshold values for "non-toxic disturbances"
 - No standardised laboratory test protocols available
 - Collection on effect data (NOEC or LC/EC50)
 - Barite
 - Bentonite
 - Clays
 - Attapulgate

SSDs and threshold values for SMP



	Barite	Bentonite
Number of species in the SSD	15	12
HC5 (exact value)	20.0 mg/l	8.8 mg/l
Assessment factor - Acute to chronic ratio	10	10
Assessment factor - Data quality unknown	10	10
PNEC	0.20 mg/l	0.09 mg/l

Sediment toxicity literature review

- **Collection of toxicity data for derivation of $PNEC_{\text{sediment}}$**
 - Metals (Cd, Cu, Zn, Pb, Hg and Cr)
 - PAHs (acenaphthene, fluoranthene, phenanthrene and pyrene)
 - 6 PLONOR chemicals


- **Species and life-stages living in close contact with the sediment**

- **Controlled spiked sediment exposures with single substances**

- **Quality assurance of the data**

Sediment toxicity literature review

Conclusions

- Dominated by endpoints with focus on acute toxicity with lack of toxicity endpoint data from long-term studies
- Data available for a limited number of species/taxonomic groups
- Revealed too few data to fulfil the quality and diversity requirements to derive reliable SSD plots
- Assessment factors from 1000 to 10 000 
PNECs far below the background concentrations
- **Sediment toxicity data for metals and PAHs considered unreliable for derivation of $\text{PNEC}_{\text{sediment}}$**

Selected PNEC approaches - sediments

- **Toxicity - added chemical substances and oil hydrocarbons**

- Equilibrium Partitioning Approach (EqP)
 - Following the US-EPA (2003)/ EU-TGD, 2003
 - $PNEC_{water}$ – as used in "EIF produced water"

$$PNEC_{sediment} = Kp_{sediment} * PNEC_{water}$$

Based on AF approach

PNEC_{sediments} for oil hydrocarbons

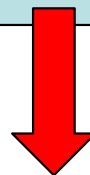
Component	NCS BC sediments	Approaches for calculation of PNEC _{sediment} (mg/kg)	
		AF ^c	EqP
Acenaphthene	-	0,0433	2,3 ^c
Fluoranthene	< 0,048 ^a	0,0023	3,0 ^c
Phenanthrene	< 0,046 ^a	0,01	2,4 ^c
Pyrene	< 0,054 ^a	0,147	-
C ₀ -C ₃ naphthalenes	-	-	2,05 ^d
2-3 ring PAHs	-	-	0,11 ^d
4+ ring PAHs	-	-	0,40 ^d
Σ PAH	0,072 ^b	-	-
Aliphatic hydrocarbons	-	-	319,5 ^d

Selected PNEC approaches - sediments

■ Toxicity – heavy metals

- Equilibrium Partitioning Approach (EqP)
 - Based on the EU-TGD 2003
 - $PNEC_{water}$ – EU-TGD (2003)^a
 - Background concentrations (C_b) in sediments taken into account

$$PNEC_{sediment} = (Kp_{sediment} * PNEC_{water}^a) + C_b^b$$



Based on SSD approach

PNEC_{sediments} for heavy metals

Metal	Background concentrations NCS ^a	Approaches for calculation of PNEC _{sediment} (mg/kg)	
		AF ^b	EqP ^c
Ba	4.6 – 554 (131)	-	-
Cd	0,003 – 0,130 (0,037)	0,0013	0,04
Cr	2,58 – 39,2 (14,6)	0,147	29,37
Cu	0,3 – 17,2 (4,10)	0,0068	4,13
Inorg. Hg	0,003 – 0,100 (0,021)	0,0015	2,49
Pb	1,92 – 46,5 (10,7)	0,029	10,90
Zn	0,42 – 83,7 (20,7)	0,0319	21,16

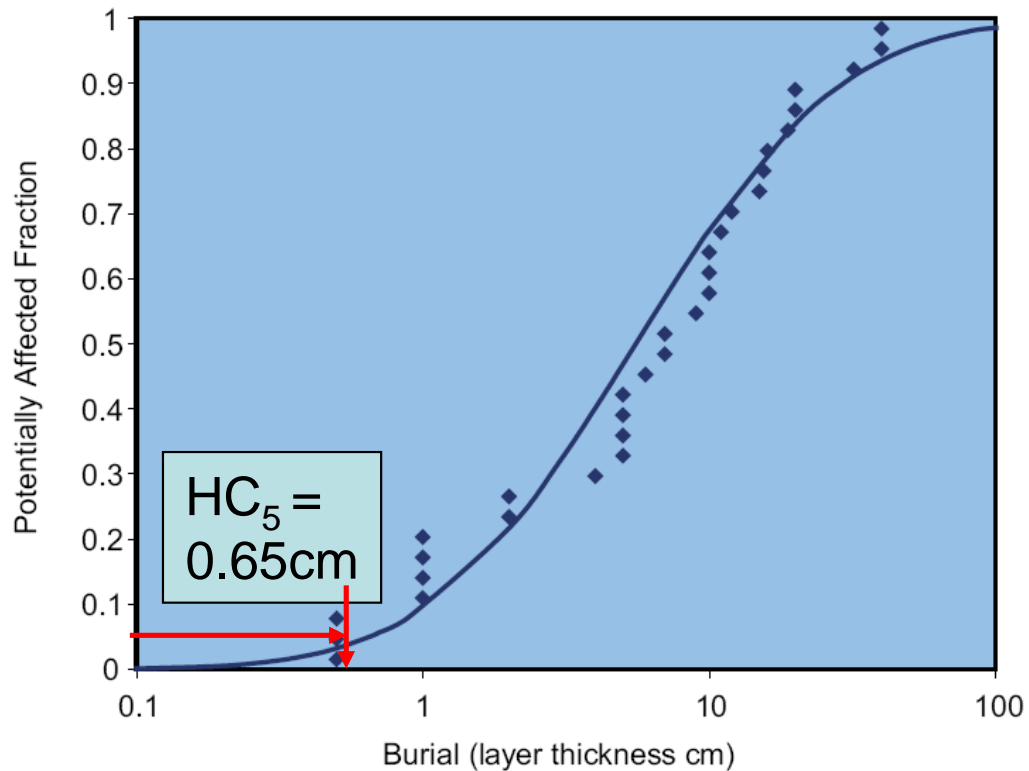
Selected PNEC approaches – sediments

- **Non-toxic stressors - burial and change in grain size**
- Lack of guidance for derivation of threshold values for "non-toxic disturbances"
- No standardised laboratory test protocols available
- Stick to well described principles for risk assessment

Selected threshold values - non-toxic stressors in sediments

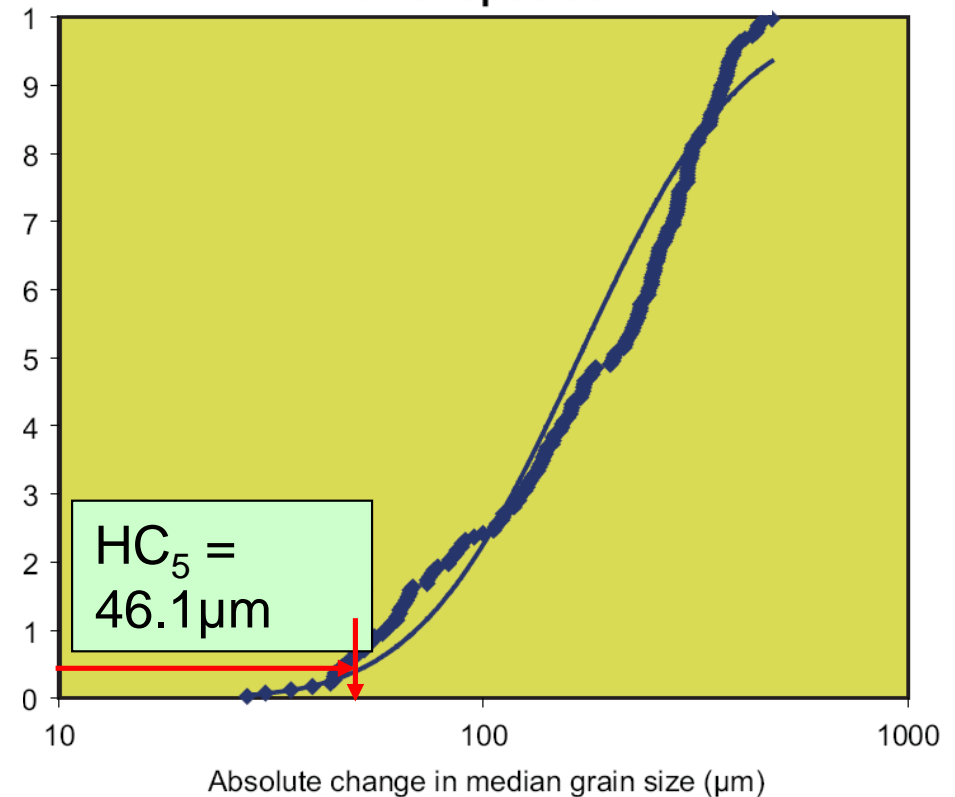
Burial

Species sensitivity to burial by exotic sediment
number of species = 32



Change in grain size

Species sensitivity to changes in grainsize
number of species = 300



SSDs for O₂-depletion

- For oxygen depletion no SSD is derived
- Threshold value is set to 20% reduction of O₂ in the oxygenated sediment layer

Threshold effect values non-toxic stressors

	O ₂ -depletion	Burial	Grain size
Number of species in the SSD	NA	32	300
HC5 (exact value)	NA	0.65 cm	46.1 µm
Assessment factor Acute to chronic ratio	-	-	-
Assessment factor Data quality unknown	-	-	-
Effect threshold value	20% reduction	0.65 cm	46.1 µm

Validation - toxicity threshold values versus field monitoring data

Metal	Approaches for calculation of PNEC _{sediment} (mg/kg)		
	EqP ^a	f-PNEC ^b	FTV ^c
Ba	-	2286	848
Cd	0,04	0,062	0,030
Cr	29,37	10,08	10,47
Cu	4,13	6,46	3,23
Inorg. Hg	2,49	0,104^c	0,020 ^c
Pb	10,90	14,65	9,93
Zn	21,16	30,97	19,15

a) TGD (2003) Equilibrium Partitioning approach b) SSD-based field-derived threshold values (Bjørnesæter, 2006)

c) MWM-approach field-derived threshold values (Brakstad et al., 2006)

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Assessment factors marine sediment (TGD, 2003)

PNECs from acute sediment toxicity data:

Available test results	Assessment factor	PNEC _{marine sediment}
One acute freshwater or marine test	10000	Lowest of LC50 /10000 and equilibrium partitioning method
Two acute tests including a minimum of one marine test with an organism of a sensitive taxa	1000	Lowest of LC50 /1000 and equilibrium partitioning method

PNECs from long-term sediment toxicity data:

Available test results	Assessment factor
One long term freshwater sediment test	1000
Two long term freshwater sediment tests with species representing different living and feeding conditions	500
One long term freshwater and one saltwater sediment test representing different living and feeding conditions	100
Three long term sediment tests with species representing different living and feeding conditions	50
Three long term tests with species representing different living and feeding conditions including a minimum of two tests with marine species	10



Assessment factors marine water (TGD, 2003)

Data set	Assessment factor
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