How can we improve the sediment risk assessment in the Port of Hamburg Maintenance Dredging Program? - A new concept is needed

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OUTLINE

I. Implementation of toxicity tests in international dredged material management guidelines

II. Ecotoxicological risk assessment according to national dredged material management guidelines

III. Results of the ecotoxicological assessment of dredged material from the Elbe fairway of Hamburg

IV. Reliability of the test results

V. Harmonisation of test procedures

VI. Future Outlook: A new concept is needed

I. Implementation of toxicity tests in international dredged material management guidelines

International conventions for the protection of the marine environment

Dredged Material Management Guidelines

HELSINKI (2007)

HELCOM GUIDELINES FOR THE DISPOSAL OF DREDGED MATERIAL AT SEA
Adopted in June 2007

OSPAR (1998)

OSPAR Guidelines for the Management of Dredged Material
(Reference Number: 1998-20)

IMO

LONDON (2000)

SPECIFIC GUIDELINES FOR ASSESSMENT OF
DREDGED MATERIAL

I. Implementation of toxicity tests in international conventions

IMO

London Convention (2000)

Biological characterization

4.7 If the potential impacts of the dredged material to be dumped cannot be assessed on the basis of the chemical and physical characterization and available biological information, biological testing should be conducted.

[…]

Biological characterization of dredged material

Method	OSPARCOM	HELCOM	LC
Biological tests: • acute toxicity • chronic toxicity • potential for bioaccumulation • potential for tainting	X	X	X
Biomarker	X	X	
Microcosm	X	X	
Mesocosm	X	X	
Benthic Community	X	X	X

II. Ecotoxicological risk assessment according to national dredged material management guidelines

Directives for the Handling of Dredged Material on Federal Waterways

➢ Inland waters (HABAB 2000)

• **Freshwater test-set**

Bioluminescence test
DIN EN ISO 11348-2 (1998)

Freshwater algae test
DIN 38412-L33 (1981)

lbacon.de

Acute toxicity Daphnia
DIN 38 412 - L30 (1989)

aquasense.nl

➢ Coastal waters (HABAK 1999)

• **Saltwater test-set**

Bioluminescence test
DIN EN ISO 11348-2 (1998) (mod.)

Marine algae test
DIN EN ISO 10253 (2006)

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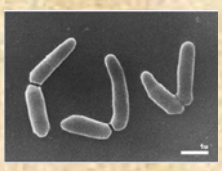

Bacteria solid contact test
DIN 38412-48 (2002)

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microbewiki.kenyon.edu

Acute toxicity amphipods
DIN EN ISO 16712 (2007)

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II. Ecotoxicological risk assessment according to national dredged material management guidelines

Evalution of the test results

HABAB – Inland waters

Highest dilution step without effect	Dilution factor	pT-value	Toxicity class		Management categories (HABAB 2000)
Original sample (80%)	2^{0}	0	0	toxicity not detectable	**Case 1:** unrestricted disposal 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	**Case 2:** Case-by-case decision of disposal
1:16	2^{-4}	4	IV	increased toxicity	
1:32	2^{-5}	5	V	high toxicity	**Case 3:** should not be disposed
1:64 and higher	$\leq 2^{-6}$	6	VI	very high toxicity	
pT-value for each test			based on the most sensitive test of the test-set		based on ecotoxicological assessment

II. Ecotoxicological risk assessment according to national dredged material management guidelines

Evalution of the test results HABAK – Coastal waters

pT-value	Toxicity class		Management categories (HABAK 1999)
0	0	toxicity not detectable	**Case 1:**
1	I	very low toxicity	Disposal at sea possible.
2	II	low toxicity	Monitoring after 3 years.
3	III	moderate toxicity	**Case 2:** Disposal at sea depends on weighing against land disposal and
4	IV	increased toxicity	impact hypothesis. Impact reduction procedures. Monitoring after 3 years.
5	V	high toxicity	**Case 3:** Disposal at sea depends on weighing against land disposal and impact
6	VI	very high toxicity	hypothesis. Intensive impact reduction procedures. Monitoring after 1-3 years.
	based on the most sensitive test of the test-set		based on ecotoxicity, chemical analysis of pollutants and nutrients

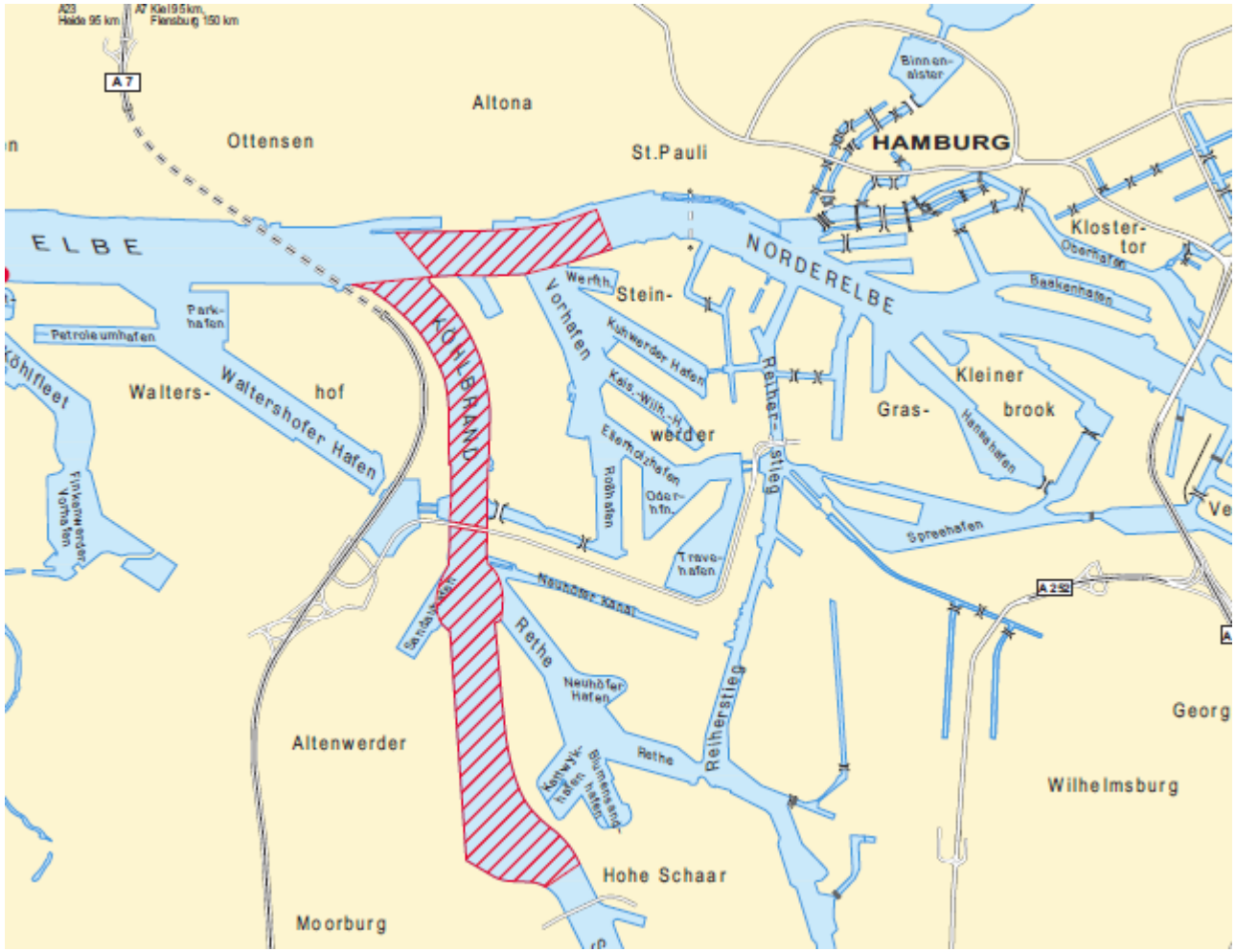
II. Ecotoxicological risk assessment according to national dredged material management guidelines

HABAK – Coastal waters

pT-value	Toxicity class		Management categories (HABAK 1999)
0	0	toxicity not detectable	**Case 1:**
1	I	very low toxicity	Disposal at sea possible.
2	II	low toxicity	Monitoring after 3 years.
3	III	moderate toxicity	**Case 2:** Disposal at sea de… …disposal and
4	IV	increased toxicity	impact hypothesis. Impac… …r 3 years.
5	V	high toxicity	**Case 3:** Disposal at sea… …osal and impact
6	VI	very high toxicity	hypothesis. Intensive im… …fter 1-3 years.
	based on the most sensitive test of the test-set		based on ecotoxicity, chemica… of pollutants and nutrients

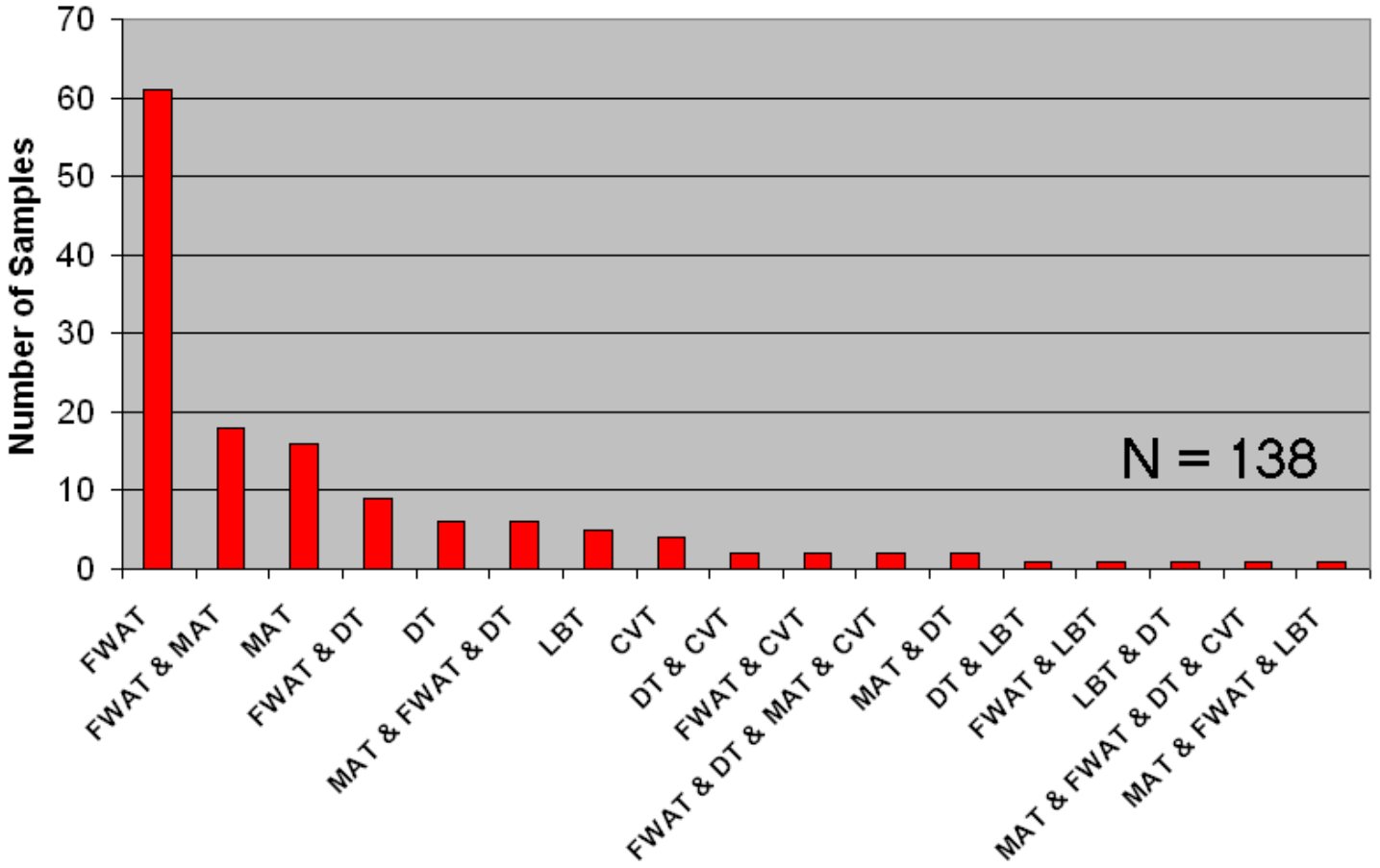
+ additional agreements with federal states

III. Results of the ecotoxicological sediment assessment from the Elbe fairway of Hamburg



III. Results of the ecotoxicological sediment assessment from the Elbe fairway of Hamburg

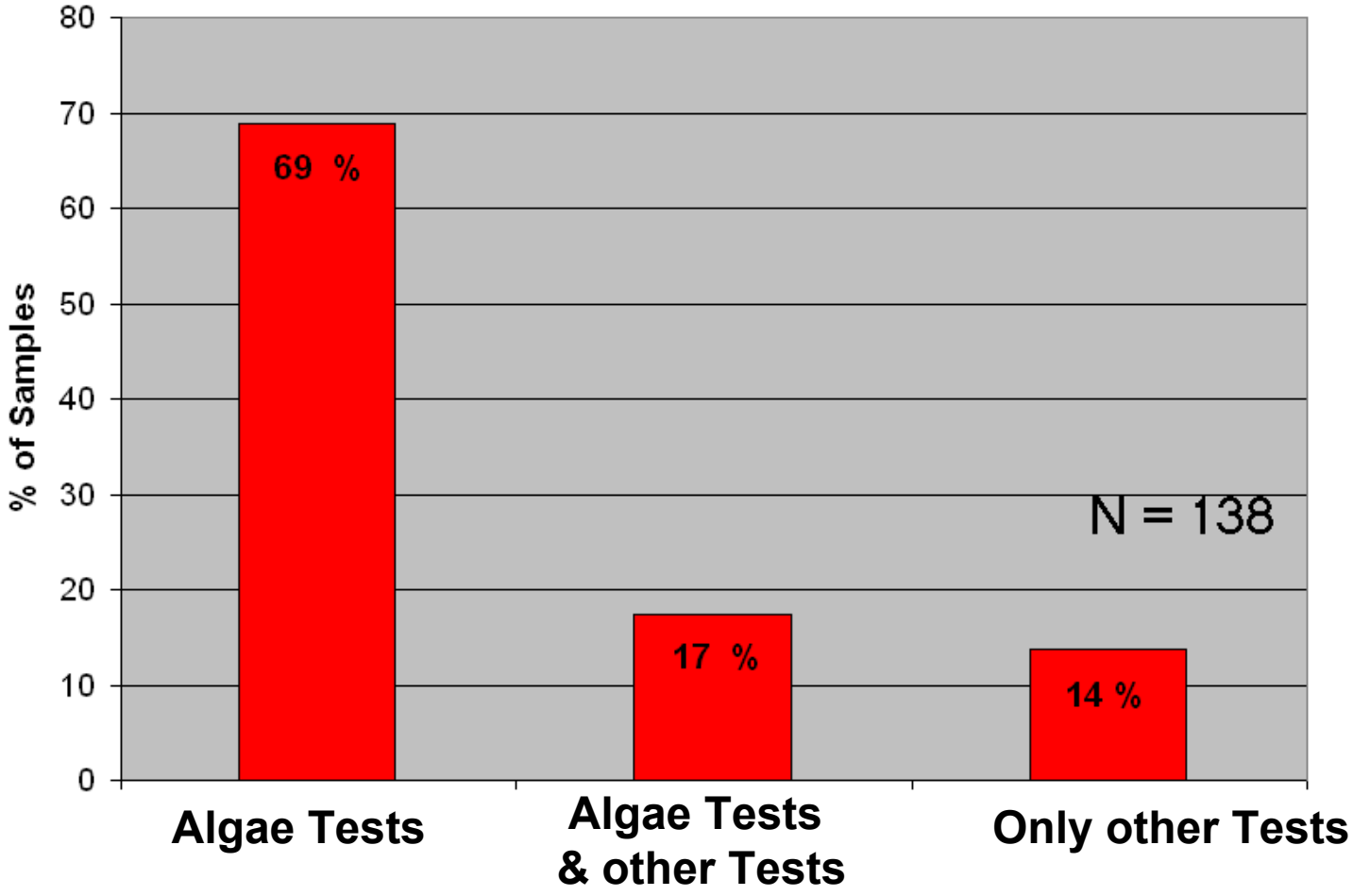
The most sensitive test(s) of the test set



Samples from 2005-2009 Elbe, fairway of Hamburg

III. Results of the ecotoxicological sediment assessment from the Elbe fairways of Hamburg

The most sensitive test(s) of the test set



Samples from 2005-2009 Elbe, fairway of Hamburg

IV. Reliability of the test results

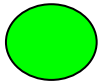
1. Analysis of unknown double samples/ measurements within the laboratories - intra-laboratory comparison

- Elbe & harbour samples (2006-2009/08)
  - Freshwater test-set
  - Marine test-set
  - Intra-comparison of 2 laboratories

- North Sea samples (2006-2009/04)
  - Marine test-set
  - Intra-comparison of 1 laboratory

IV. Reliability of the test results

Criteria for the evaluation of the intra-laboratory comparison



- **delta pT-values**

• % of sample-pairs, for which equal pT-values were determined	≥ 70 %
• maximum pT-difference	≤ 2
• pT-difference leads to HABAB/HABAK Case 3 category	≤ 5%

Intra-laboratory comparison – Elbe Bioluminescence Assay (LBT) – Lab 1

pT - Value Matrix of Double Measurements [N] (N=38) (PW+EL)

pT Value	0	1	2	3	4	5	6
0	33						
1	2	0					
2	1	0	0				
3	0	0	0	0			
4	0	0	0	1	0		
5	0	0	0	0	1	0	
6	0	0	0	0	0	0	0

Font Size	Difference [pT-Values]	% of Cases
	0	87
	1	11
	2	3
	3	0
	4	0
	5	0
	6	0

pT - Value Matrix of Double Measurements [%]

pT Value	0	1	2	3	4	5	6
0	87						
1	5	0					
2	3	0	0				
3	0	0	0	0			
4	0	0	0	3	0		
5	0	0	0	0	3	0	
6	0	0	0	0	0	0	0

HABAB / HABAK Categories	% of Cases with differences
Category 1	8
Category 2	3
Category 3	3
% of equal results	87

Intra-laboratory comparison – Elbe
Daphnia test (DT) – Lab 1

pT - Value Matrix of Double Measurements [N] (N=36) (PW+EL)

pT Value	0	1	2	3	4	5	6
0	5						
1	8	5					
2	0	6	9				
3	0	1	0	1			
4	0	0	0	1	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

Difference [pT-Values]	% of Cases
0	56
1	42
2	3
3	0
4	0
5	0
6	0

pT - Value Matrix of Double Measurements [%]

pT Value	0	1	2	3	4	5	6
0	14						
1	22	14					
2	0	17	25				
3	0	3	0	3			
4	0	0	0	3	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

HABAB / HABAK Categories	% of Cases with differences
Category 1	39
Category 2	6
Category 3	0
% of equal results	56

Intra-laboratory comparison – Elbe Freshwater Algae Test (FWAT) – Lab 1

pT - Value Matrix of Double Measurements [N] (N=52) (PW+EL)

pT Value	0	1	2	3	4	5	6
0	2						
1	1	3					
2	1	4	5				
3	2	0	8	6			
4	0	1	2	4	2		
5	0	0	3	2	2	1	
6	0	0	1	2	0	0	0

Difference [pT-Values]	% of Cases
0	37
1	37
2	10
3	15
4	2
5	0
6	0

pT - Value Matrix of Double Measurements [%]

pT Value	0	1	2	3	4	5	6
0	4						
1	2	6					
2	2	8	10				
3	4	0	15	12			
4	0	2	4	8	4		
5	0	0	6	4	4	2	
6	0	0	2	4	0	0	0

HABAB / HABAK Categories	% of Cases with differences
Category 1	12
Category 2	33
Category 3	19
% of equal results	37

Intra-laboratory comparison – Elbe Freshwater Algae Test (FWAT) – Lab 2

pT - Value Matrix of Double Measurements [N] **(N=10)** (PW+EL)

pT Value	0	1	2	3	4	5	6
0	2						
1	1	2					
2	0	1	2				
3	0	0	1	1			
4	0	0	0	0	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

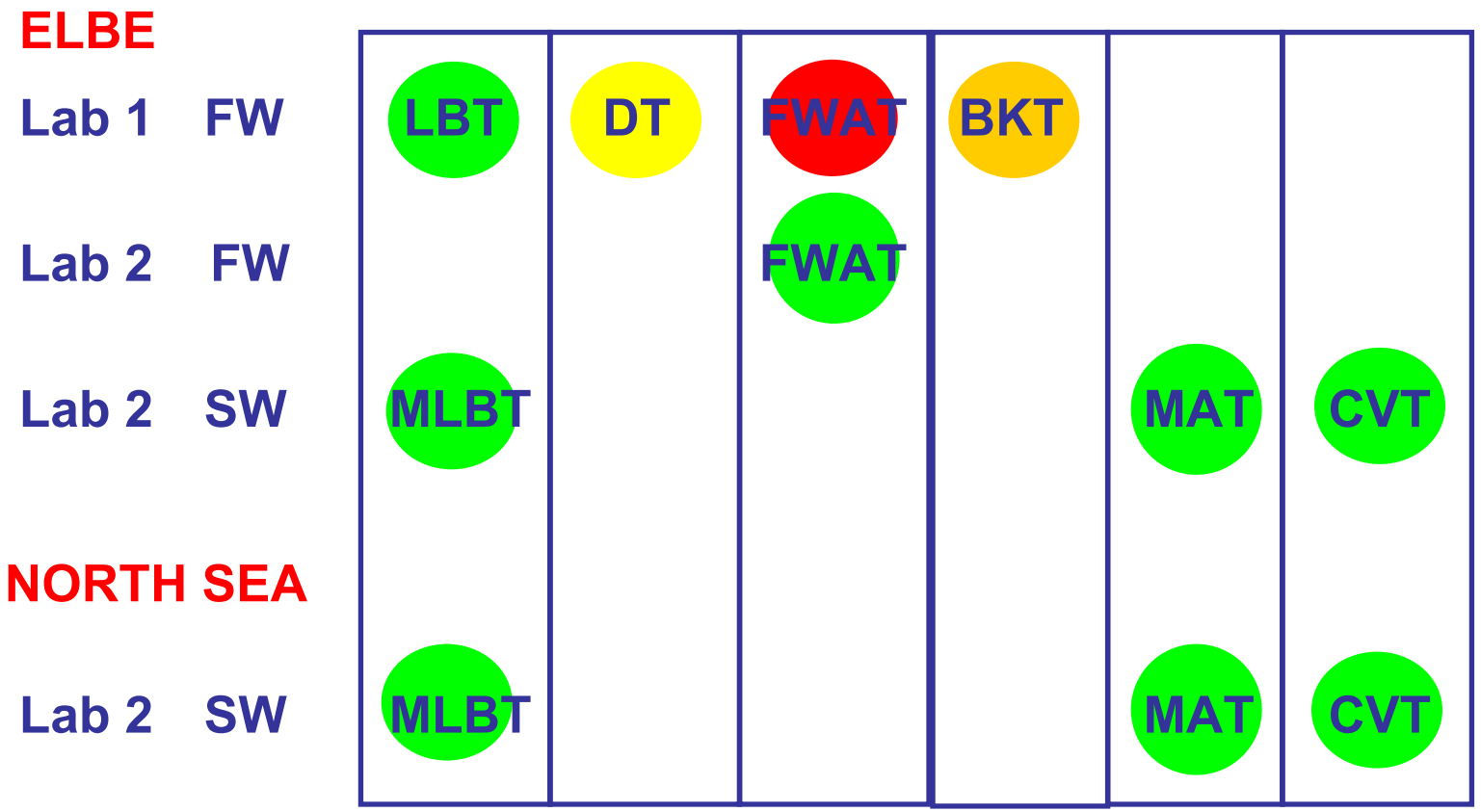
Difference [pT-Values]	% of Cases
0	70
1	30
2	0
3	0
4	0
5	0
6	0

pT - Value Matrix of Double Measurements [%]

pT Value	0	1	2	3	4	5	6
0	20						
1	10	20					
2	0	10	20				
3	0	0	10	10			
4	0	0	0	0	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

HABAB / HABAK Categories	% of Cases with differences
Category 1	20
Category 2	10
Category 3	0
% of equal results	70

Summary
Reliability of the test results
– intra-laboratory comparison



Summary
Reliability of the test results
– intra-laboratory comparison

- The freshwater algae test (FWAT) dominated the ecotoxicological classification of the dredged material from the fairway of Hamburg (2005-2009) as most sensitive test.

- The FWAT intra-laboratory comparison of unknown double samples/ measurements showed for Elbe & harbour samples
  - weak reliability in Lab1 (2006-2009, N=52),
  - good reliability in Lab2 (2009, N=10).

- The Daphnia test (DT) and the bacteria contact assay (BKT)
  - needs further improvement in accuracy & precision in Lab1

- The marine bioassays (Elbe & North Sea samples)
  - good reliability in Lab2.

IV. Reliability of the test results

2. Analysis of unknown double sample/ measurements with the freshwater algae test - inter-laboratory comparison

- Elbe & Harbour Samples (2009)
  - Comparison of
    - Lab 1 & Lab 2
    - Lab 1 & Lab 3

Inter-laboratory comparison– Elbe
Freshwater Algae Test Lab 1 – Lab 2

pT - Value Matrix of Double Measurements [N] **(N=36)** (PW+EL)

Lab 1 \ Lab 2	0	1	2	3	4	5	6
0		1					
1	1	1	2				
2	1	3		6	2		
3	2	3	1	3	2		
4	2	2		1			
5			2				
6				1			

Difference [pT-Values]	% of Cases
0	11
1	47
2	17
3	19
4	6
5	0
6	0

pT - Value Matrix of Double Measurements [%]

Lab 1 \ Lab 2	0	1	2	3	4	5	6
0		3					
1	3	3	6				
2	3	8		17	6		
3	6	8	3	8	6		
4	6	6		3			
5			6				
6				3			

HABAB / HABAK Categories	% of Cases with differences
Category 1	22
Category 2	58
Category 3	8
% of equal results	11

Inter-laboratory comparison– Elbe Freshwater Algae Test Lab 1 – Lab 3

pT - Value Matrix of Double Measurements [N] **(N=22)** (PW+EL)

Lab 1 \ Lab 3	pT Value	0	1	2	3	4	5	6
	0	4						
	1	2						
	2	1	2					
	3	3	1					
	4	4	3	2				
	5							
	6							

Difference [pT-Values]	% of Cases
0	18
1	18
2	18
3	27
4	18
5	0
6	0

pT - Value Matrix of Double Measurements [%]

Lab 1 \ Labor 3	pT Value	0	1	2	3	4	5	6
	0	18						
	1	9						
	2	5	9					
	3	14	5					
	4	18	14	9				
	5							
	6							

HABAB / HABAK Categories	% of Cases with differences
Category 1	23
Category 2	59
Category 3	0
% of equal results	18

IV. Reliability of the test results
Conclusion

Strong need for

- **improvement**
- **harmonisation**

of the test procedures

- **especially for the freshwater algae test**

V. Harmonisation of test procedures

- **Steps, which have been undertaken since 2008:**

1. **New, state-of-the-art guidance documents for sample preparation and each test procedure were developed.**

2. **Extensive and standardised database was established for each lab/ test/ sample.**

3. **First identification of key variables:**
   - **storage (duration/ temperature) of samples (Sed/EL/ PW)**
   - **Consideration of background fluorescence (AT, LBT)**
   - **Calibration of cell-density/ fluorescence (AT)**
   - **“fitness” of the controls (CVT, AT)**
   - **confounding factors e.g. ammonia toxicity, hydrogen sulphide**

VI. Future Outlook: A new concept is needed

Step 1 : Improving and harmonisation of ecotoxicological test procedures

Maximising intra-laboratory precision & accuracy

Step 2: Validation of the test procedures with a round robin test (inter-laboratory comparison)

Step 3: Development of a new concept

Development of a new concept

The current situation		The Future
1) The ecotoxicological sediment classification is based on the result of the most sensitive test, irrespective of the results of the other tests.	→	Integrate all test results into the ecotoxicological assessment (e.g. Fuzzy Logic & Hasse Diagram Methods (Heise & Ahlf 2009))
	→	Calculation of the test results considering the complete dilution series (EC50-values)
2) The test-set results are highly variable, but the logistic organization of the disposal needs a decision half a year in advance.	→	Identify typical categories of test results based on - temporal & spatial pattern - statistical modelling

Thank you for your attention !

Thanks to the Hamburg Port Authority for the good cooperation and funding this project.

Intra-laboratory comparison – Elbe Bacteria Contact Assay (BKT) – Lab 1

Class Matrix of Double Measurements (N=78) (1g, 2g, 3g)

Class	1	2	3
1	47		
2	14	12	
3	2	2	1

Difference [Class #]	% of Cases
0	77
1	21
2	3

Class Matrix of Double Measurements [%]

Class	1	2	3
1	60		
2	18	15	
3	2.6	2.6	1

HABAB / HABAK Categories	% of Cases with differences
Category 1	0
Category 2	18
Category 3	5
% of equal results	77

% Inhibition	Class
0-49	1
50-74	2
75-100	3

Intra-laboratory comparison – Elbe Marine Algae Test (MAT) – Lab 2

pT - Value Matrix of Double Measurements [N] **(N=36)** (PW+EL)

pT Value	0	1	2	3	4	5	6
0	5						
1	0	8					
2	0	4	8				
3	0	1	5	1			
4	0	0	1	1	1		
5	0	0	0	0	0	1	
6	0	0	0	0	0	0	0

Difference [pT-Values]	% of Cases
0	67
1	28
2	6
3	0
4	0
5	0
6	0

pT - Value Matrix of Double Measurements [%]

pT Value	0	1	2	3	4	5	6
0	14						
1	0	22					
2	0	11	22				
3	0	3	14	3			
4	0	0	3	3	3		
5	0	0	0	0	0	3	
6	0	0	0	0	0	0	0

HABAB / HABAK Categories	% of Cases with differences
Category 1	11
Category 2	22
Category 3	0
% of equal results	67

Intra-laboratory comparison – Elbe Marine Bioluminescence Assay (MLBT) – Lab2

pT - Value Matrix of Double Measurements [N] **(N=21)** (PW+EL)

pT Value	0	1	2	3	4	5	6
0	19						
1	0	0					
2	2	0	0				
3	0	0	0	0			
4	0	0	0	0	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

Difference [pT-Values]	% of Cases
0	90
1	0
2	10
3	0
4	0
5	0
6	0

pT - Value Matrix of Double Measurements [%]

pT Value	0	1	2	3	4	5	6
0	90						
1	0	0					
2	10	0	0				
3	0	0	0	0			
4	0	0	0	0	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

HABAB / HABAK Categories	% of Cases with differences
Category 1	10
Category 2	0
Category 3	0
% of equal results	90

Intra-laboratory comparison – Elbe
Marine Amphipod test (CVT) – Lab2

Class Matrix of Double Measurements [N] **(N=18)**

Class	1	2	3
1	13		
2	2	1	
3			2

Difference [Class #]	% of Cases
0	89
1	11
2	0

Class Matrix of Double Measurements [%]

Class	1	2	3
1	72		
2	11	6	
3			11

HABAB / HABAK Categories	% of Cases
Category 1	89
Category 2	11
Category 3	0
% of equal results	89

Intra-laboratory comparison – North Sea Marine Bioluminescence test (MLBT) – Lab 2

pT - Value Matrix of Double Measurements [N] **(N=28)** (PW+EL)

pT Value	0	1	2	3	4	5	6
0	28						
1	0	0					
2	0	0	0				
3	0	0	0	0			
4	0	0	0	0	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

Difference [pT-Values]	% of Cases
0	100
1	0
2	0
3	0
4	0
5	0
6	0

pT - Value Matrix of Double Measurements [%]

pT Value	0	1	2	3	4	5	6
0	100						
1	0	0					
2	0	0	0				
3	0	0	0	0			
4	0	0	0	0	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

HABAB / HABAK Categories	% of Cases with differences
Category 1	0
Category 2	0
Category 3	0
% of equal results	100

Intra-laboratory comparison – North Sea Marine Algae Test (MAT) – Lab 2

pT - Value Matrix of Double Measurements [N] **(N=28)** (PW+EL)

pT Value	0	1	2	3	4	5	6
0	26						
1	2	0					
2	0	0	0				
3	0	0	0	0			
4	0	0	0	0	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

Difference [pT-Values]	% of Cases
0	93
1	7
2	0
3	0
4	0
5	0
6	0

pT - Value Matrix of Double Measurements [%]

pT Value	0	1	2	3	4	5	6
0	93						
1	7	0					
2	0	0	0				
3	0	0	0	0			
4	0	0	0	0	0		
5	0	0	0	0	0	0	
6	0	0	0	0	0	0	0

HABAB / HABAK Categories	% of Cases with differences
Category 1	7
Category 2	0
Category 3	0
% of equal results	93

Intra-laboratory comparison – North Sea Marine Amphipod Test (CVT) – Lab 2

Class Matrix of Double Measurements [N] **(N=14)**

Class	1	2	3
1	12		
2	2	0	
3	0	0	0

Difference [Class #]	% of Cases
0	86
1	14
2	0

Class Matrix of Double Measurements [%]

Class	1	2	3
1	86		
2	14	0	
3	0	0	0

HABAB / HABAK Categories	% of Cases
Category 1	86
Category 2	14
Category 3	0
% of equal results	86