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The combination of chemical contamination, toxicity and in situ sediment structure is responsible for the low biodiversity of Lake Rummelsburg (Berlin)

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Lake Rummelsburg

a partly separated expansion of the river Spree
in the urban area of Berlin

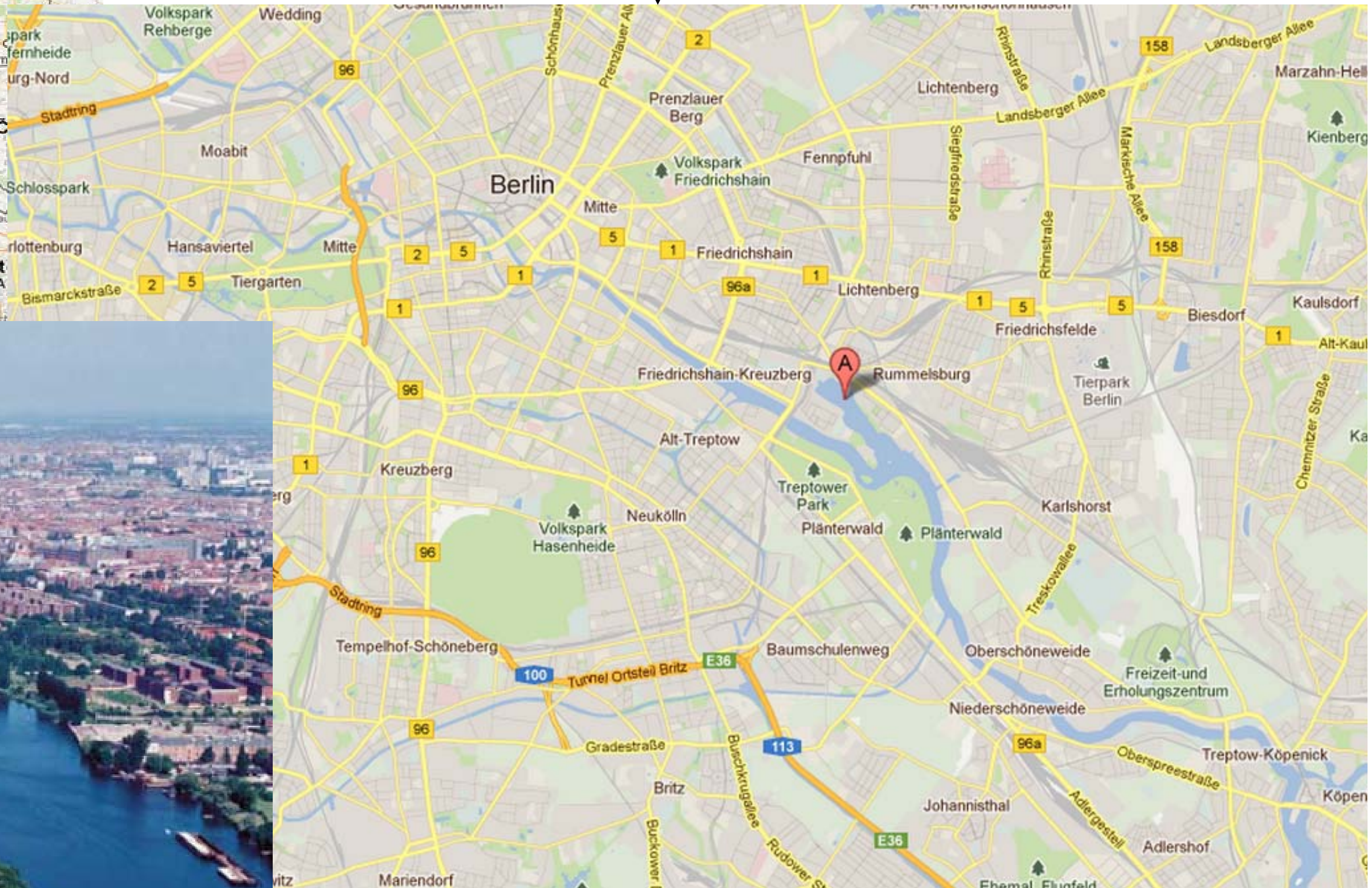

Foto source: Leaflet "Hilfe für den Rummelsburger See"
Senate Department for Urban Development and the Environment, Berlin

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Changed claims of utilization

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Since the 19th century mainly industrial use of the area around the lake

- asphalt-production, glass factory, galvanisation plant, old ships graveyard, effluents from waste water treatment plant, rain water drainage channel

City-centre brownfield land since the 1990s

Recently reclassification as **attractive services and residential area with water connection**

- Changed claims: residential area, „floating lofts“, watersports, recreation area

The lake has a problem

Sediments of the lake have been contaminated with heavy metals, mineral oil hydrocarbons and other organic contaminants due to the discharge of mainly industrial waste water in the course of about one century

Nutrients and easily biodegradable substances were carried into the lake

↓

Algal blooms, oxygen deficiency, odour constraints, accelerated formation of digested sludge, substancial ecological instability

↓

First measures 1999 – 2001
(Sediment conditioning)

First Measures

1) Installation of a bulkhead with drive-through access
2) Detection and clearing munitions
   phosphor bombs, grenades, weapons

Fotos: Leaflet "Hilfe für den Rummelsburger See"
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First Measures

1) Installation of a bulkhead with drive-
 through access
2) Detection and clearing munitions
 phosphor bombs, grenades, weapons
3) Partial sludge removal
 expensive environmental disposal procedures

Source: Leaflet "Hilfe für den Rummelsburger See"
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First Measures

1) Installation of a bulkhead with drive-through access
2) Detection and clearing munitions
   phosphor bombs, grenades, weapons
3) Partial sludge removal
   expensive environmental disposal procedures
4) Sediment conditioning with FeO(OH) and $CaNO_3$
5) Pneumatic destratification plant

Perforierte Rohre vor dem Verschweißen

Kompressoren

Fotos: Leaflet "Hilfe für den Rummelsburger See"
Senate Department for Urban Development and the Environment, Berlin

Current issues

Starting point: “no MZB in the lake” (investigation from 2006)

- What are the reasons for the biological deficiencies of the lake?

- What measures can be taken in order to improve the situation significantly?

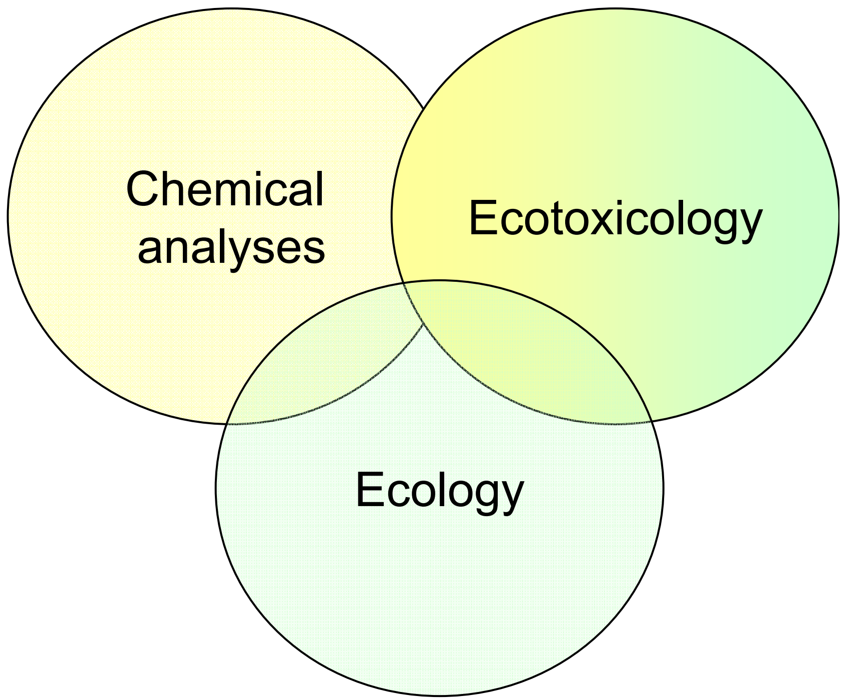
↓

Attempt to answer the questions by a **sediment triad approach**:

- chemical analyses
- toxicological tests
- ecological analyses (macro zoobenthos)

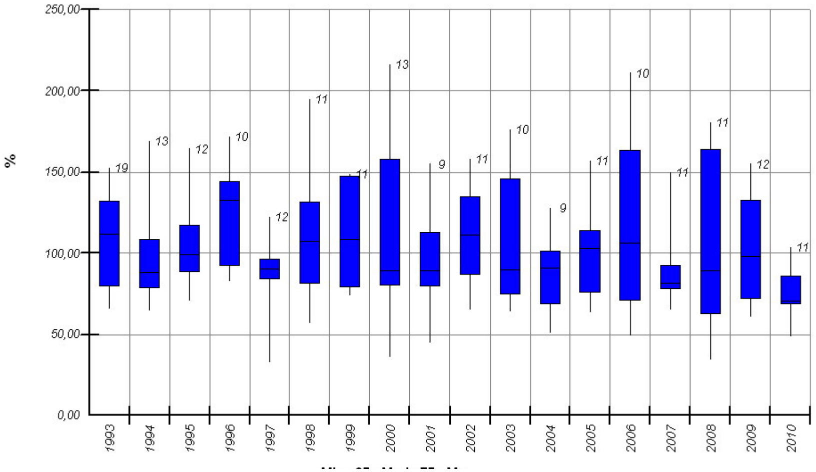
plus

- sediment guideline approach

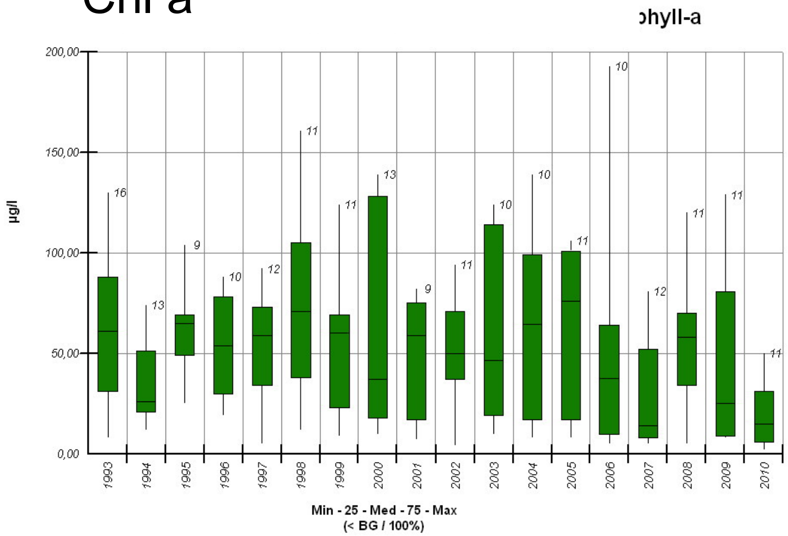


Some water quality parameters

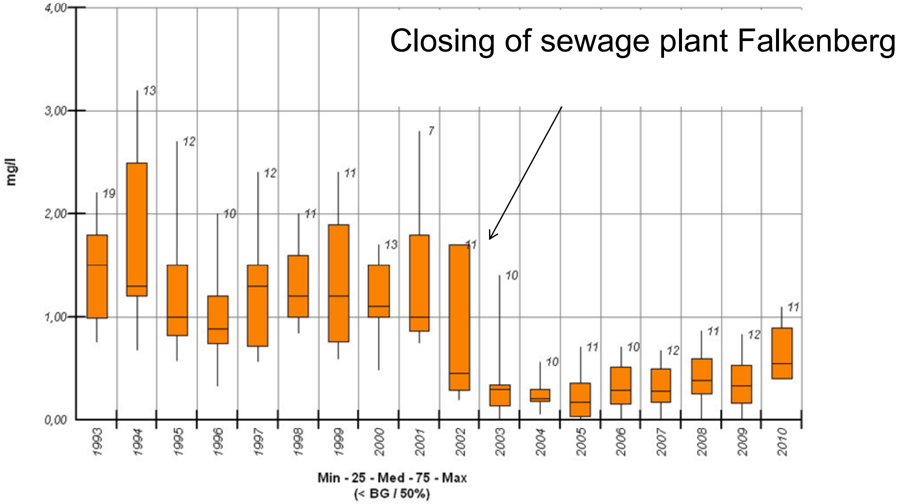
Oxygen saturation Index



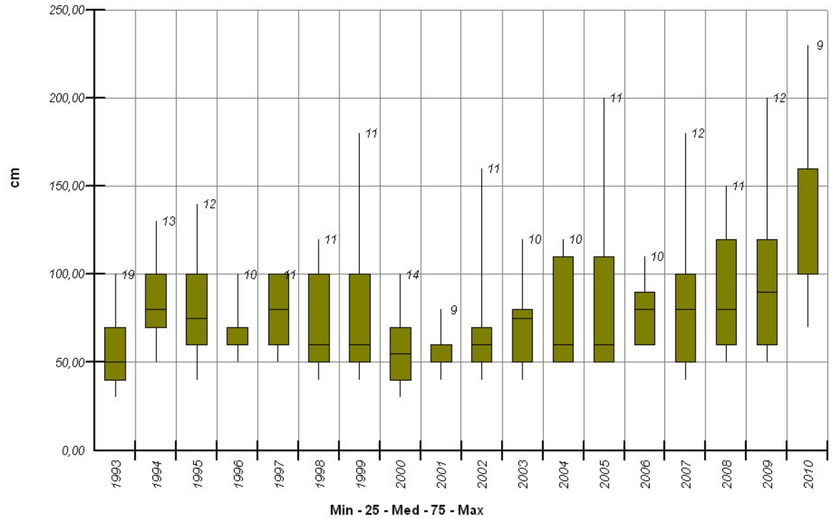
Chl a



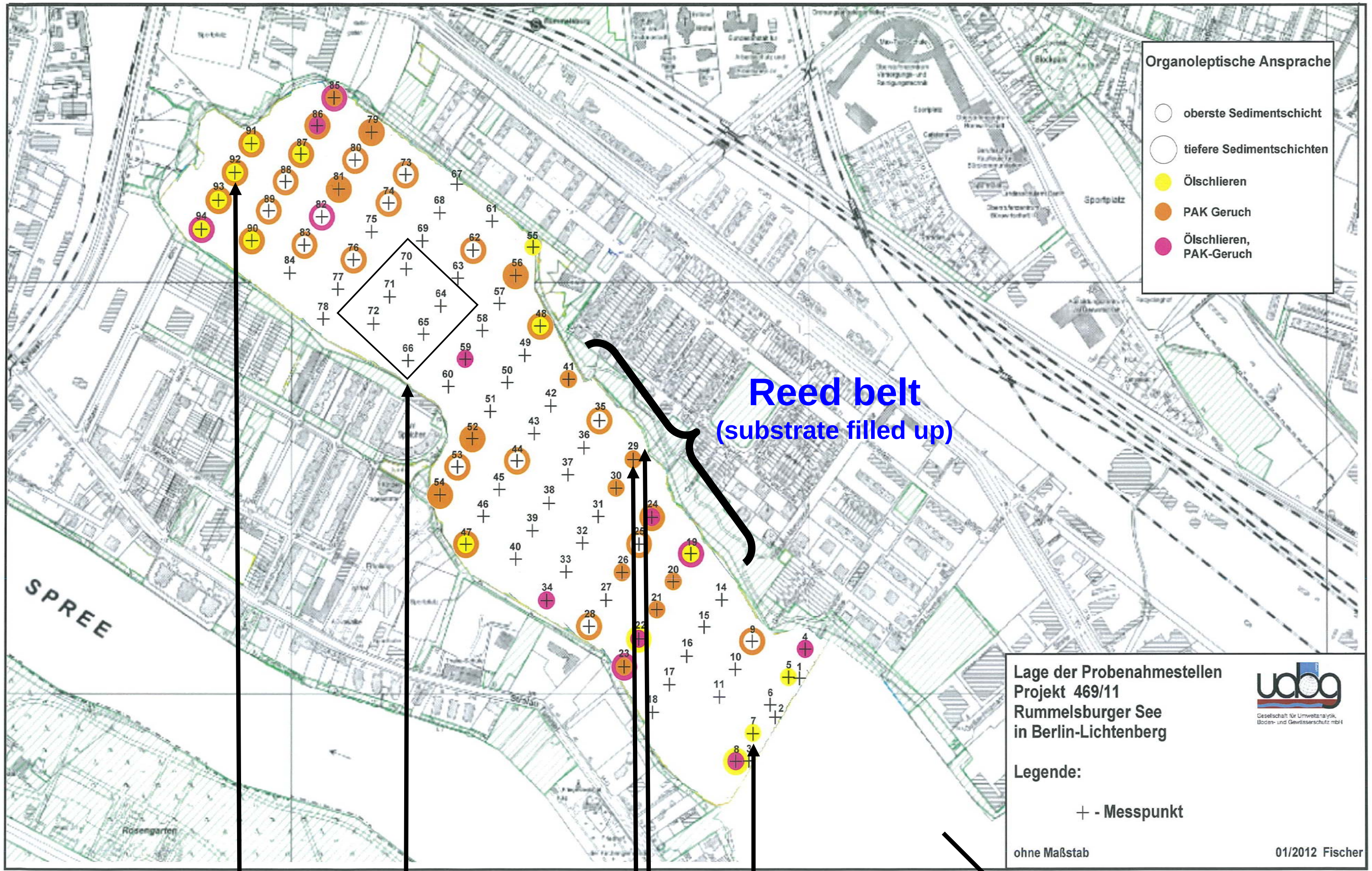
Nitrate



Visibility depth



Sampling sites



120271

120265
sediment core
(only chem. anal.)

120263
120264

120262

120261
Spree „reference site“

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Chemical Analyses I

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Concentrations of organic contaminants
normalized to the <63 µm fraction of upper layer sediments:

400 – 1400 (1250)*	µg/kg sum of 7 PCBs,
90-700 (400)	µg/kg p,p'-DDD,
2500-6500 (2500)	µg/kg mineral oil hydrocarbons,
55-370 (160)	mg/kg sum of 16 EPA-PAKs,
1100-2400 (1500)	µg/kg Tributyltin and
9,7-76	ng I-TE/kg dioxin like activity.

* ( ) = „reference“

GC/MS-Screening showed also:

Long-chained hydrocarbons, alkylbenzenes, dichloro naphthalenes, phenyl naphthalenes, mono- to tetra-alkylated PAHs, heterocyclic compounds (furans, thiophenes quinolines), phenoles, plasticisers, flame retardants, steroids

Chemical Analyses II

Metals

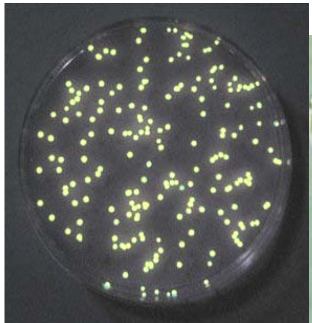
measured in the fine grained fraction < 63µm:

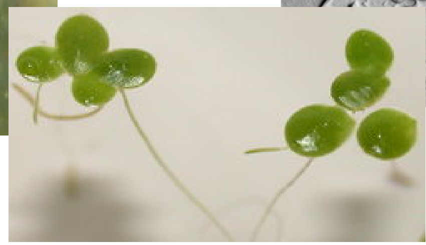
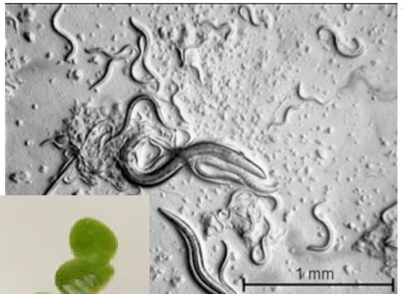
76-440	(76)*	mg/kg Cr
9-46	(9)	mg/kg Cd
2,2-4,1	(4,1)	mg/kg Hg
1000-6360	(6360)	mg/kg Cu
64-98	(64)	mg/kg Ni
1600-2700	(1600)	mg/kg Zn
340-830	(830)	mg/kg Pb
20-51	(51)	mg/kg As

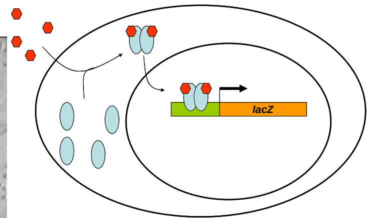
* ( ) = „reference“

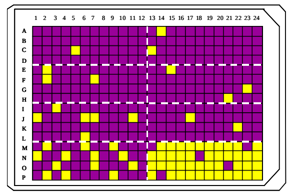
Biotest battery

Biotest	Organism	Toxicity endpoint	Acute / chronic exposure	Samples	Standard
Luminescent bacteria test	*Aliivibrio fischeri*	Inhibition of Bioluminescence	Acute (30 min)	Pore water Elutriate	DIN EN ISO 11348-2
Green algae test	*Desmodesmus subspicatus*	Growth inhibition	Chronic (72 hrs)	Pore water Elutriate	DIN 38412-33
Daphnia test	*Daphnia mangna*	Immobilisation	Acute (24 hrs)	Pore water Elutriate	DIN 38412-30
Lemna test	*Lemna minor*	Growth inhibition	Acute (7 d)	Pore water Elutriate	DIN EN ISO 20079
Myriophyllum test	*Myriophyllum aquaticum*	Growth inhibition	Acute (10 d)	Sediment	ISO 16191
Nematode test	*Caenorhabditis elegans*	Growth inhibition, fertility, reproduction	Chronic (96 hrs)	Pore water Elutriate Sediment	DIN ISO 10872
YES	*Saccharomyces cerevisiae*	ER activation	28 hrs	Pore water, elutriates, extracts	ISO NWIP in preparation
Ames test	*Salmonella typhimurium*	Mutagenicity	48 hrs	Pore water, elutriates, extracts	ISO 11350







Ecotoxicological sediment classification (BfG-guidelines)

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highest dilution without effect	dilution factor as exponential fraction	pT-value	toxicity classes		management categories	
			index	designation	toxicity class	designation
original sample	2^{0}	**0**	**0**	non-detectable toxicity	**0**	not contaminated
1:2	2^{-1}	**1**	**I**	very slightly toxic	**I**	non-hazardously contaminated
1:4	2^{-2}	**2**	**II**	slightly toxic	**II**	
1:8	2^{-3}	**3**	**III**	moderately toxic	**III**	critically contaminated
1:16	2^{-4}	**4**	**IV**	distinctly toxic	**IV**	
1:32	2^{-5}	**5**	**V**	highly toxic	**V**	hazardously contaminated
≤ (1:64)	$\leq 2^{-6}$	**≥ 6**	**VI**	extremely toxic	**VI**	

Classification of the ecotoxicological potential for dredged material and sediments with the pT-value system (Krebs 1988 & 2005)

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Algae, Luminescent bacteria, Daphnia toxicity

Sample No.	Sample	Physico-chemical parameters				Green Algae DIN 38412-33		Luminesc. bact. DIN EN ISO 11348-2		Daphnia DIN 38412-30		Toxicity class
		pH	NH_4^+-N [mg/l]	O_2 [mg/l]	Cond. [µS/cm]	Inhib.. in G1 [%]	pT-Value	Inhib. in G1 [%]	pT-Value	Inhib.. in G1 [%]	pT-Value	
120261	PW	7,4	1,7	7,2	0,79	-11,5	0	32	1	0	0	II
120261	E					-28	0	37	2	30	1	
120262	PW	7,7	10,7	7,2	0,83	-4,8	0	5	0	0	0	II
120262	E					-52	0	28	2	0	0	
120263	PW	7,3	23,7	6,0	0,88	-1,3	0	32	2	0	0	II
120263	E					-14	0	4	0	0	0	
120264	PW	7,5	5,7	6,1	0,75	-20,7	0	18	0	0	0	0
120264	E					-18	0	-7	0	0	0	
120265	PW	7,3	9,0	6,3	0,84	-8,8	0	-18	0	0	0	I
120265	E					-30	0	33	1	0	0	
120271	PW	7,3	19,8	6,4	1,11	2,8	0	30	1	0	0	III
120271	E					8	0	45	3	0	0	

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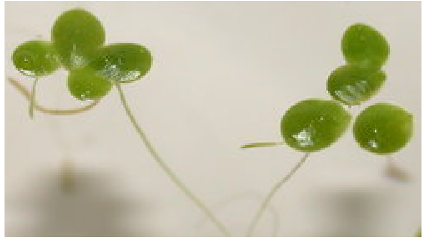
Lemna toxicity



Sample No.	Lemna (area)				Lemna (number)				pT-max	Toxicity-class
	Pore water		Elutriate		Pore water		Elutriate			
	I %	pT	I %	pT	I %	pT	I %	pT		
120261	18	**3**	19	**2**	10	**0**	21	**2**	3	**III**
120262	13	**4**	35	**2**	6	**4**	37	**2**	4	**IV**
120263	37	**2**	n.t.		19	**2**	n.t.		2	**II**
120264	5	**2**	14	**1**	-3	**0**	15	**1**	2	**II**
120265	21	**4**	34	**1**	15	**2**	17	**0**	4	**IV**
120271	40	**4**	16	**4**	24	**5**	9	**0**	5	**V**

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Toxicity on Nematodes (*C. elegans*)

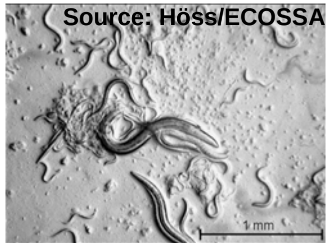
Sample No.	Nematodes								
	Pore water 100%				Elutriate 100%				
	Growth I %	Tox. Cat.	Reprod. I %	Tox. cat.	Growth I %	Tox. cat.	Reprod. I %	Tox. cat.	Toxicity-class
120261	81	3	100	3	35	2	91	3	3
120262	41	2	98	3	82	3	100	3	3
120263	n.d.*		n.d.*		68	3	100	3	3
120264	50	2	99	3	10	1	79	2	3
120265	41	2	95	3	65	3	99	3	3
120271	70	3	100	3	65	3	100	3	3

* Not measured

100 %-approach (not according to ISO)

Sample No.	Nematodes								
	Pore water 50%				Elutriate 50%				
	Growth I %	Tox. Cat.	Reprod. I %	Tox. cat.	Growth I %	Tox. cat.	Reprod. I %	Tox. cat.	Toxicity-class
120261	30	2	65	2	7	1	38	1	2
120262	40	2	94	3	50	2	92	3	3
120263	43	2	97	3	8	1	28	1	3
120264	29	2	85	3	1	1	23	1	3
120265	24	1	78	2	26	2	80	2	2
120271	89	3	100	3	32	2	97	3	3

Category (cat)	Description	Plants	Nematode Growth	Nematode Reproduction
1	no significant effect	< 20	< 25	< 50
2	medium effect	20-40	25-50	50-80
3	strong effect	> 40	> 50	> 80



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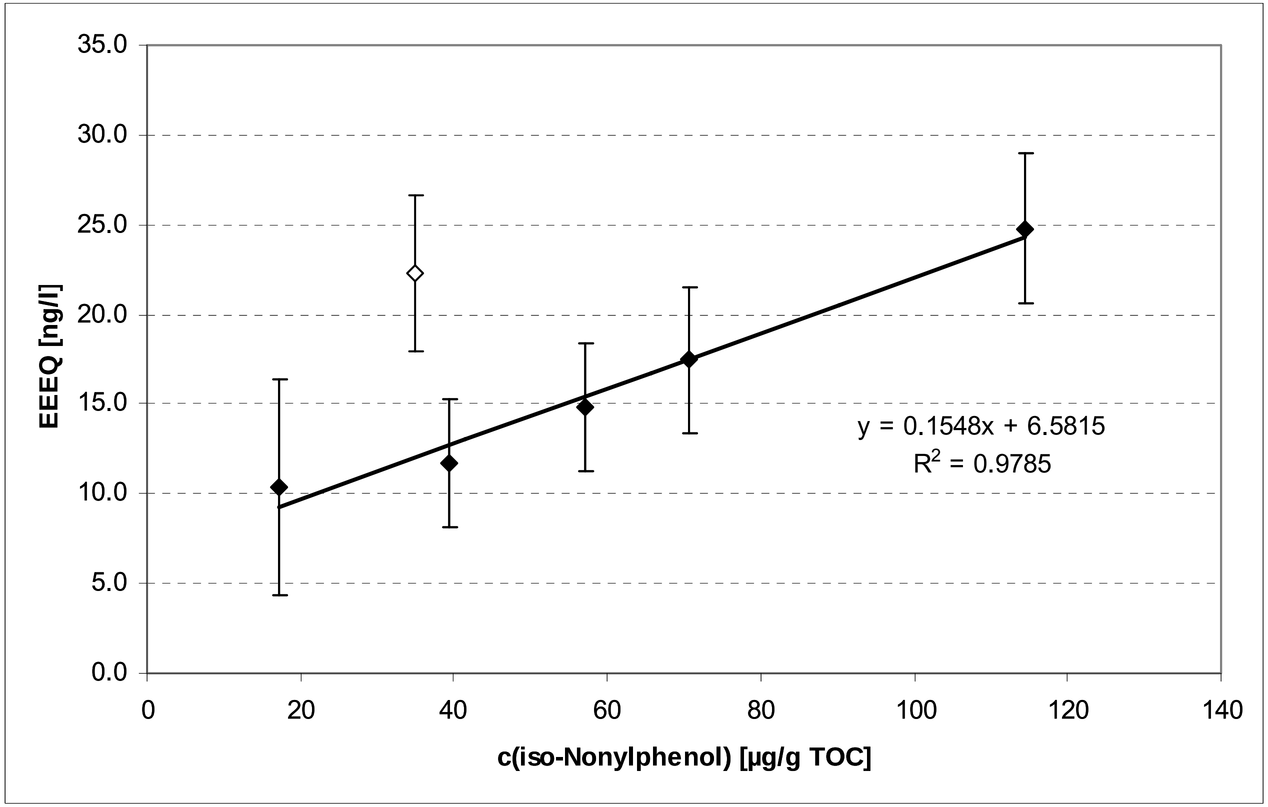
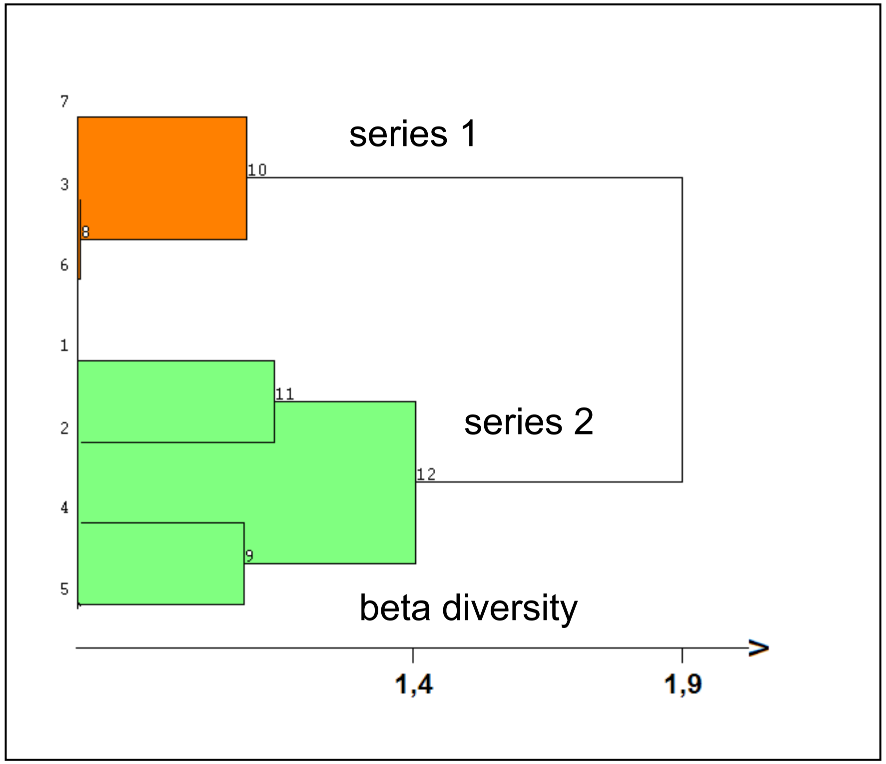
Correlation estrogenic effects in pore water with iso-nonylphenol



- c(iso-Nonylphenol) normalised to total organic carbon (TOC), to take availability for the water phase into account
- high correlation of chemical data and effect data
- sample 271 does not correlate → indication of other endocrine active compound(s)

Characteristical taxa depend on sediment structural parameters

Taxa	Series 1	Series 2
No of samples	3	4
Abu[Ind/m²]	619	25384
No of Taxa	2	22
Max Dom[%]	86,21	37,06
Sc	1.7±0.6	12.8±5.4
Beta-Diversity	=100/86,7=1,2	=100/73,0=1,4
characteristic Taxa	**Presence [%]**	
Oligochaeta	100,00	100,00
Chironomidae	66,67	100,00
Valvata piscinalis	0,00	100,00
Unio pictorum	0,00	100,00
Dreissena polymorpha	0,00	100,00
Pisidium sp.	0,00	75,00
Unio tumidus	0,00	75,00
Potamopyrgus antipodarum	0,00	50,00
Anodonta anatina	0,00	50,00
Gammarus fossarum	0,00	50,00
Unio sp.	0,00	50,00
Gammarus sp.	0,00	50,00



	MZB	rare	rare	rare	Shore area	"Reference"
		120271	120262	120265	120264	120261
		S3b	S1 (a)	S2c	S2b	S0b
	Series	1	1	1	2	2
F1 >2000	Gravel	0,6	8,6	5,3	5,9	2,7
F2 630-2000	Sand coarse	2,0	3,9	9,6	7,2	1,7
F3 200-630	Sand medium	1,8	2,1	5,1	33,7	3,7
F4 63-200	Sand fine	6,9	22,7	6,0	35,4	65,5
F5 63-20	Silt coarse	21,0	23,3	21,8	2,0	10,6
F6 <20	Silt fine /medium	62,0	32,3	43,9	12,1	11,0

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Occurence of SPEAR

Species/Taxon	SPEAR_pest*	Sensitivity*	120271 S3b	120262 S1 a	120265 S2c	120264 S2b	120261 S0b
Bithynia tentaculata	0	-1,82				24	
Oligochaeta	0	-1,10	24	48	128	2672	728
Helobdella stagnalis	0	-0,60					16
Valvata piscinalis	0	1,82				8	8
Unio tumidus	0	-2,09				64	
Unio pictorum	0	-2,09				1	8
Dikerogammarus haemobaphes	0	0,16				216	
Potamopyrgus antipodarum	0	-1,82				24	
Gammarus sp.	0	0,17				104	
Unio sp.	0	-2,09					8
Dreissena polymorpha	0	-2,09				216	8
Chironomidae	0	-0,39		8	24	232	384
Gammarus fossarum	0	0,16					8
Pisidium sp.	0	-2,09				8	16
Anodonta anatina	0	-2,09					1
Chelicorophium curvispinum	0	0,16					8

Amphipoda

Threshold: > -0,36

* Source: http://www.systemecology.eu/spear/

Meiobenthos

n = 3

Taxon	120261 S0b	120271 S3b
Nematoda	116533	728
No. Species	*15*	*3*
No. NemaSPEAR	*5*	*0*
Ostracoda	46905	291
Rotifera	18063	9031
Oligochaeta	17189	1894
Gastrotricha	1748	146
Phylopoda	1748	874
Harpacticoida	1602	0
Copepoda	1165	2476
Nauplius larvae	1165	146
Chironomidae	1020	0
Acari	583	437
Plathelminthes	583	0
Tardigrada	291	0
Ciliata	146	0
Daphnia eggs	18354	51712

Photos: FiftIMCo, University of Bielefeld, Senckenberg, and Getty images

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Sediment Quality Guidelines SQGs

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Meaning of

TEC: Threshold Effect Concentrations …if [ ] <: low toxicological risk
PEC: Probable Effect Concentrations …if [ ] >: high toxicological risk

- TECs are concentrations below which adverse effects on benthic invertebrates are unlikely to be observed

- PECs are concentrations above which harmful effects on benthic invertebrates are likely to be observed

- PEC-quotients may be used to assess sediments with a complex mixture of contaminants

MacDonald, 2000: "TECs, PECs and PEC-quotients offer a reliable basis to classifiy non-toxic and toxic sediments"

Basis: MacDonald, 2000 and DeDeckere, 2011

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Toxic potential (mean PEC-q) of the lake sediments

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Sample No.	**120261**	**120262**	**120263**	**120264**	**120265**	**120271**
Sampling location	**S0b**	**S1**	**S2a**	**S2b**	**S2c**	**S3b**
Number of substances	39	39	39	39	39	39
Substances >PEC	32	34	32	32	33	35
Mean PEC-Q	7,33	7,80	4,21	3,70	5,71	11,69
Max. PEC-Q	103,14	47,90	32,13	20,17	32,45	60,94
Max	Cu	PCB 28	Cu	Cu	PCB 28	*p,p*-DDD
2.	*p,p*-DDD	PCB 31	PCB 28	PCB 28	PCB 31	PCB 28
3.	PCB 170	*p,p*-DDD	PCB 31	PCB 31	*p,p*-DDD	PCB 31
						+ PAHs, MKWs, Cu

basis for evaluation: SQGs from de Deckere et al. (2011)

Sample No.	**120261**	**120262**	**120263**	**120264**	**120265**	**120271**
Sampling location	**S0b**	**S1**	**S2a**	**S2b**	**S2c**	**S3b**
Number of substances	21	21	21	21	21	21
Substances >PEC	18	18	17	16	18	18
Mean PEC-Q	4,72	3,07	3,14	2,64	2,30	5,51
Max. PEC-Q	41,53	8,48	12,94	8,12	5,46	12,04
Max	Cu	Cu	Cu	Cu	Cu	Pyrene
2.	Pb	Cd	Cd	Zn	Cd	Fluoranthene
3.	SumDDD	Zn	Zn	Cd	Zn	Benzo[a]anthracene

basis for evaluation: SQGs from McDonald et al. (2000)

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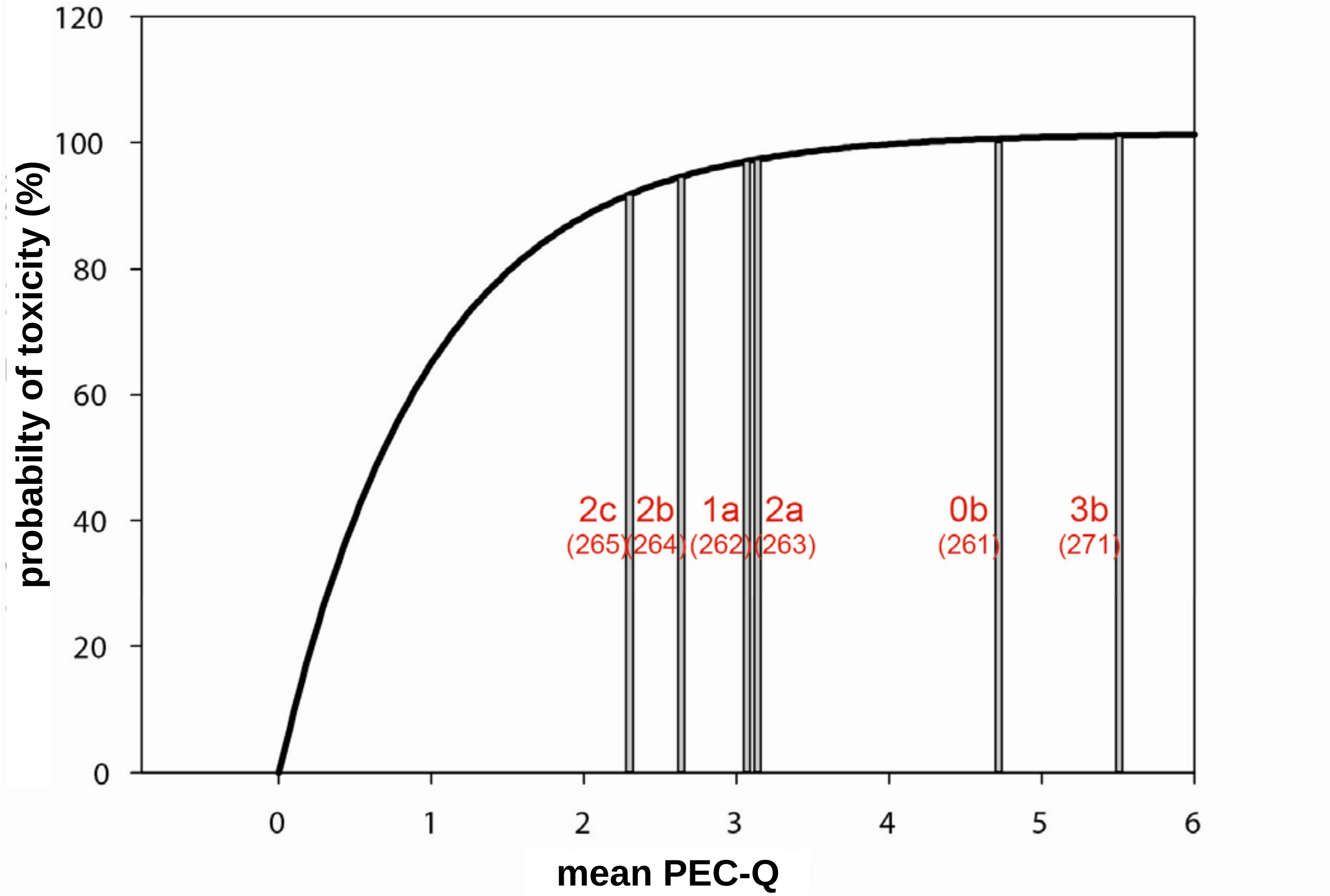
Probability of toxicity

for benthic organisms in Lake Rummelsburg



Curve adopted from MacDonald et al. (2000)

Summary I

- Sediments of Lake Rummelsburg are area-wide contaminated, mainly due to past industrial production.
- The „reference“ Spree is also contaminated, mainly by Cu and Pb, PCB and PAH (an alternative reference site is under investigation).
- The lake is influenced by the Spree.
- Green algae, daphnia, and luminescent bacteria tests show no to low toxicity.
- Lemna test shows low to high toxicity.
- C. elegans shows moderate to very high toxicity.

Summary II

- Estrogenicity: 10 to 25 ng /L EEQ [correlates with c(iso-nonylphenol) normalised to TOC] and is mainly particle bound.
- Mutagenicity: not detectable in pore water. Detectable in extracts. Increasing with the metabolic competence of the test strains (data not shown).
- Characteristical MZB taxa depend on sediment structural parameters.
- SPEAR organisms are rare and depend on the sediment structure.
- Mean PEC-Q values predict high toxicity at all sites.

Main conclusions I

The **combination** of

- **high chemical contamination** with persistent organic and inorganic chemicals,
- **toxicity** and
- **specific substrate composition**

makes a natural repopulation scenario for the improvement of the biological diversity extremely improbable.

Main conclusions II

The study suggests that a **significant improvement** of the habitat could only be achieved by either

• a very cost-intensive **removing of the sludges** or

Doing more with less?

• by **covering the sediments** with uncontaminated substrate of appropriate structure or

• a **combination of both measures.**

→ the study will we completed by the assessment of a „true“ reference site with comparable sediment structure and low chemical contamination

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Thank you for your attention !

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