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Long-term sediment contamination in the Elbe River floodplain, and an example of a limnological study

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Sediment research at the Faculty of Science

Why are we focused on floodplain and its water bodies?

- floodplain and old meanders = valuable ecosystems = biodiversity/stability of nature, protected species, retention potential, flood transformation, historical riverbed development
- anthropogenic pollution = contaminated suspension settles down under low water flow in old meanders/oxbow lakes = accumulation of pollution = old ecological load
  ➡ = risk of remobilization and reactivation of pollutants during hydrological events
- systematic quality monitoring - suspended matter and surface riverbed sediments (10 cm)
- Research: contamination of deeper sediments, spatial distribution of pollution = subaquatic sediment cores taken from oxbow lakes, floodplain cores
- extent of contamination = focus on the middle course of the Czech Elbe River
- comparison with riverbed sediment pollution development

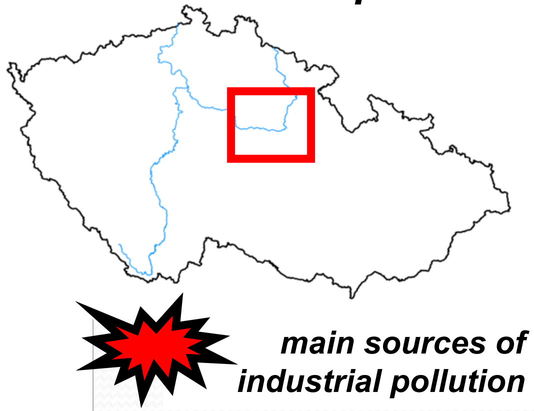
Differences among localities

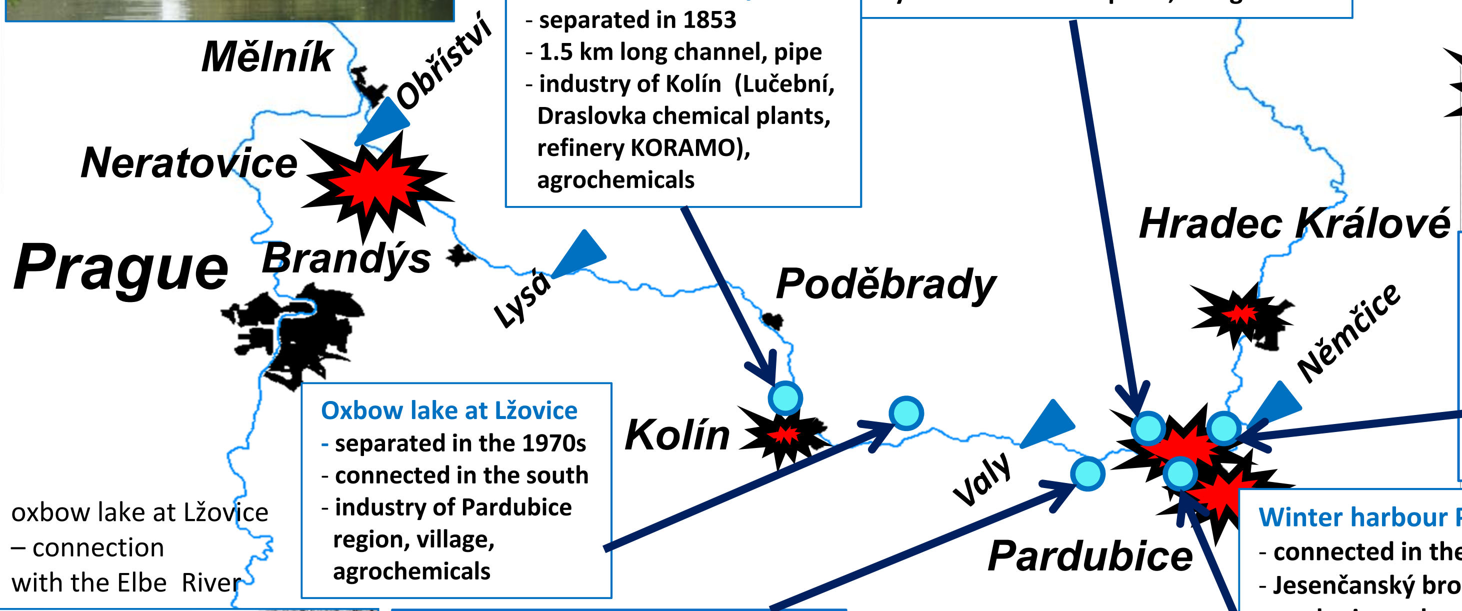
- age – separation of an oxbow lake from the river
- intensity of hydrological communication with the river
- location in the studied region
- distance from industrial sources of pollution
- landuse

Complex limnological research

- hydrological regime of oxbow lakes
- bathymetric measurements
- water quality – physical parameters in water column
- water quality – chemical analyses
- hydrobiology
- sediment quality – granulometry, chemical analyses

Study sites 1.





oxbow lake at Rosice (ELSA)
- meander divided by a dam with a pipe
- western part connected to the river
- waste pond in the inner part of the meander
- Synthesia chemical plant, village

oxbow lake Doleháj
- separated in 1853
- 1.5 km long channel, pipe
- industry of Kolín (Lučební, Draslovka chemical plants, refinery KORAMO), agrochemicals

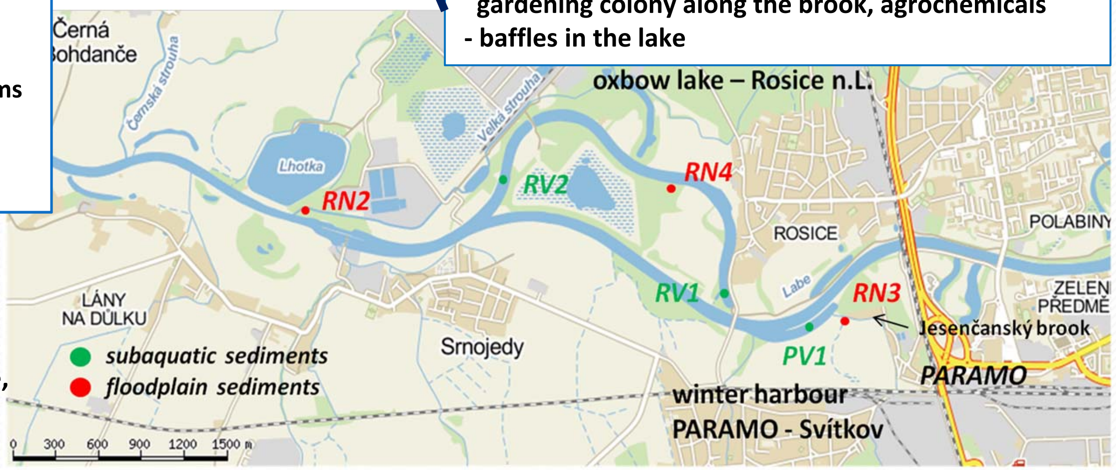
oxbow lake at Němčice
- separated in the 1920s
- channel, overflowing of flood dams
- agrochemicals, village, gardening colony , industry of Hradec Králové (FOMA – photographic industry), Opatovice power plant

Oxbow lake at Lžovice
- separated in the 1970s
- connected in the south
- industry of Pardubice region, village, agrochemicals

oxbow lake at Lžovice – connection with the Elbe River

Winter harbour PARAMO (ELSA)
- connected in the west
- Jesenčanský brook flowing from PARAMO refinery, gardening colony along the brook, agrochemicals
- baffles in the lake

Labiště beneath Opočínek
- separated in the 1920s
- channel, overflowing of flood dams
- industry of Pardubice region, agrochemicals, village
- natural monument



Main sources of pollution – Pardubice region:
Synthesia chemical plant - formerly Explosia, later VCHZ Synthesia, explosives, pigments, dyes, inorganic acids, and salts, nitrocellulose, pesticides, pharmaceuticals…
PARAMO refinery - lubricating oils, lubricants, asphalt products…

Study sites 2.

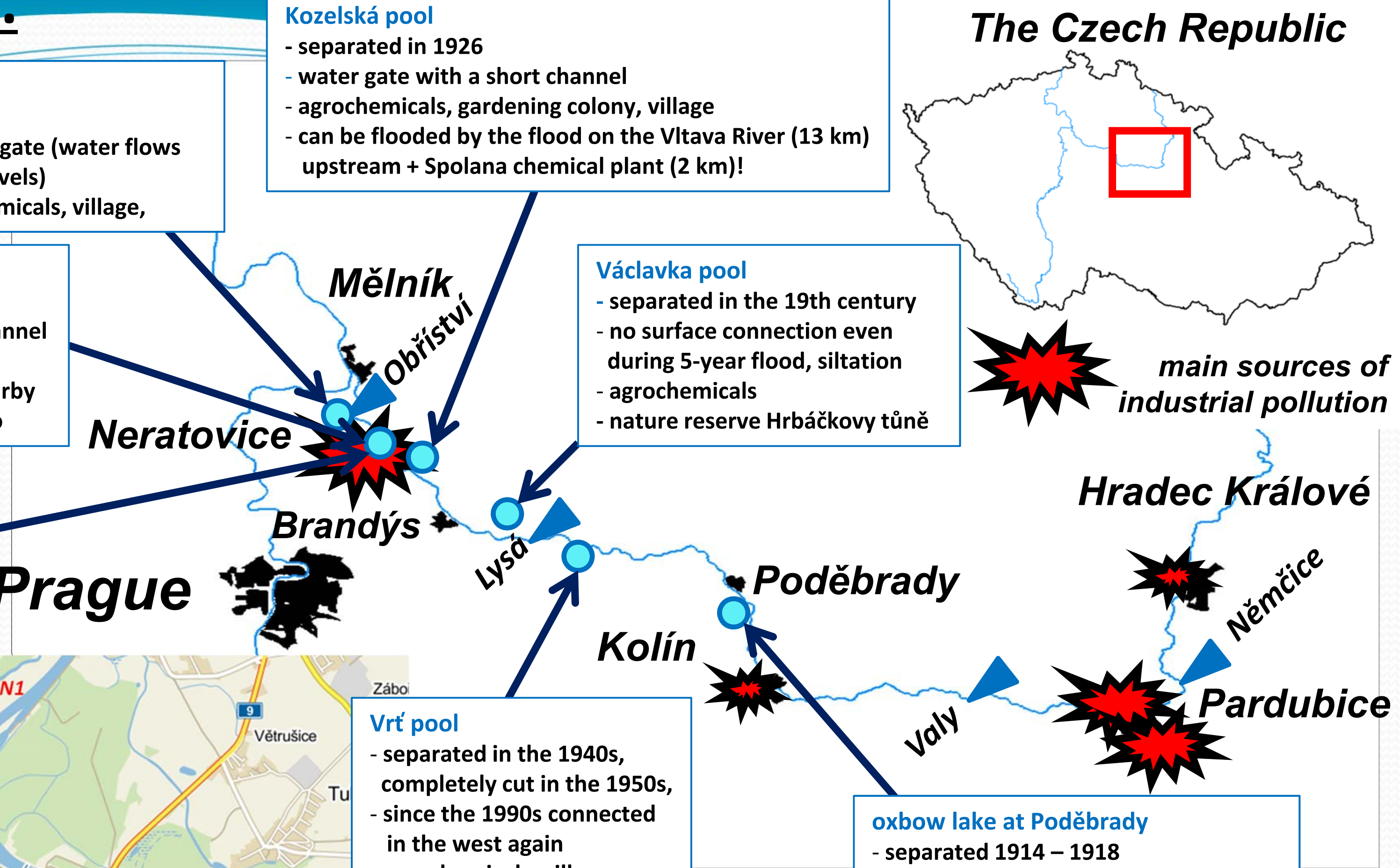
oxbow lake at Obříství (ELSA)
- separated 1908 – 1913
- tributary Černavka brook, water gate (water flows into the river at normal water levels)
- Spolana chemical plant, agrochemicals, village,

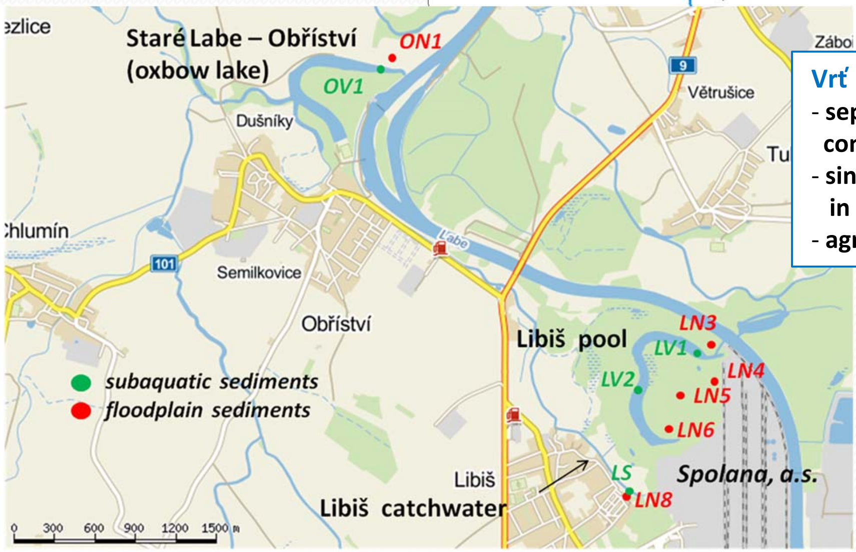
Kozelská pool
- separated in 1926
- water gate with a short channel
- agrochemicals, gardening colony, village
- can be flooded by the flood on the Vltava River (13 km) upstream + Spolana chemical plant (2 km)!

Libiš pool (ELSA)
- separated around 1830
- water gate with a short channel
- floodplain forest
- Spolana chemical plant nearby
- nature reserve Černínovsko

Václavka pool
- separated in the 19th century
- no surface connection even during 5-year flood, siltation
- agrochemicals
- nature reserve Hrbáčkovy tůně

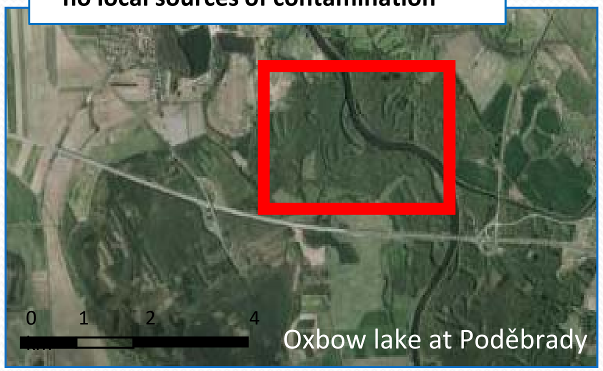
Libiš catchwater (ELSA)
- flowing from Spolana chemical plant
- 2004 extraction of contaminated sediment





Vrť pool
- separated in the 1940s, completely cut in the 1950s,
- since the 1990s connected in the west again
- agrochemicals, village

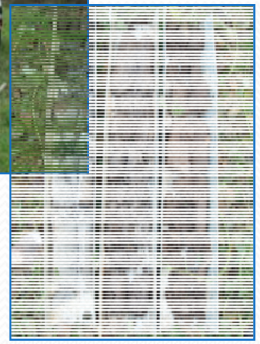
oxbow lake at Poděbrady
- separated 1914 – 1918
- connected by a large pipe in the north
- floodplain forest
- no local sources of contamination



Sources of pollution – Neratovice region:

Spolana chemical plant - PVC, caprolaktam, fertilizer SPOLSAN, inorganic acids, hydroxydes, amalgam production of chlorine (Hg!), DDT, lindan, dioxins from herbicides...

Methods



Sampling - sediment cores divided into sections = separate analyses

- subaquatic sediments - oxbow lakes - maximum possible depth

- from boats with the use of piston corer (Eijkelkamp)

2001, 2002, 2004 - 25-cm thick sections; 2007, 2015 - 7 cm upper section + 10-cm sections

2013, 2014 - 20-cm upper section + two 30-cm sections + remaining part

= concentration changes with depth = source & time of pollution

- sediments – floodplain - RDBS-1 hydraulic drilling machine, caterpillar chassis

- 2013 - 20-cm upper section + two 30-cm sections + remaining part to 150 cm

Granulometry

2001, 2002 sieving, sedimentation technics (FaSci UK) (Zavoral a kol., 1987)

2004 - lyophilization, wet, dry sieving (Pla) (Petřík, Heldes,1999)

2007 - (ASci) (ČSN CEN ISO / TS 17892-4, ČSN EN 933-1, ČSN ISO / TS 17 892-3)

2013, 2014, 2015, 2017 - laser granulometry (FaSci) (Gale, Hoare, 1991)

- majority sandy clay (ČSN EN ISO 14688-1 (721003), coarse material, colour changes exceptional

Chemical analyses - focus on Ag, As, Cd, Cu, Cr, Hg, Ni, Pb, Zn

(Ag not in 2004, 2013, 2014; As not in 2001,2002; Cr not in 2017; Fe not in 2013, 2014, 2015; Hg in Obr A 2007 only in 3 samples; Mn not in 2013, 2014, 2017; Al in 2004, 2017; C org in 2001, 2002, 2007; Al in 2005, 2017; B, Ba, Be, Co, Mo, P, Se, Sb, V in 2004; Ti in 2017)

- elements grain fraction 20µm

- *2001, 2002, 2007, 2015, 2017 - aqua regia leaching + FAAS/ICP MS/ICP OES (FaSci) (ISO 11466:1995; Weiss a kol., 1983)*
- *2017 total digestion + ICP OES (FaSci) (ISO 14869-1:2001)*

- *Hg - AMA 254 device (FaSci, Pla - 2013,2014)*
- *2004, 2013, 2014 – PLa (DIN 38406 - E22; ČSN EN ISO 15586; ČSN 757440)*
- *2013, 2014* - specific organic compounds in 2 mm grain fraction (Pla)

CONCENTRATION (mg.kg^{-1})/ ELEMENT	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
T & W (1961)	0,07	13	0,3	90	45	0,4	68	20	95
Wedepohl (1968)	*0,07*	*10*	*0,8*	*90*	*45*	*0,4*	*68*	*20*	*95*
Prange et al. (1997)	0,3	24	0,4	117	32	0,3	53	29	150
ICPER – lower threshold value (2014,2016)	-	7,9	0,22	26	14	0,15	3	25	200
ICPER – upper threshold value (2014,2016)	-	40	2,3	640	160	0,47	53	53	800

Contamination assessment

- ICPER assessment *(Heininger et al., 2014; ELSA, 2016) - environmental quality standards, 2 threshold limit values – Ag not determined*
- Indices of Geoaccumulation *(Muller, 1979) + 7 classes of contamination ; based on background values by:*

$$I_{geo} = log_2 \frac{C_n}{1,5 * B_n}$$

Turekian & Wedepohl (1961), Wedepohl (1968) – units of the Earth's crust, contents in shale sedimentary rocks

Prange et al. (1997) - unpolluted deep sediments in the Elbe River watershed

C_n = concentration in the sample B_n = background concentration

Results – ICPER assessment (Heininger et al., 2014; ELSA, 2016)

- the most contaminated cores marked in red; 3 max. concentrations marked in red; framed concentraintions exceeded the limit 3 times!

Sampling point	Year	Depth (cm)	Concentration (mg.kg^{-1})								
			Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Oxbow lake at Němčice - Nem 07	2007	67	2,3	20	0,8	121	61	0,44	31	76	478
Winter harbour Paramo - PV 13	2013	113		20	2,9	96	*215*	2,65	*55*	*272*	*1528*
Oxbow lake at Rosice - RV1 13	2013	96		14	2,1	161	65	0,48	39	72	422
Oxbow lake at Rosice - RV2 13	2013	115		10	1,6	211	90	0,90	42	123	648
Floodplain at Rosice - RN2 13	2013	150		37	0,5	79	21	0,68	*45*	47	243
Floodplain at Rosice - RN3 13	2013	150		38	0,3	75	24	0,30	39	69	221
Floodplain at Rosice - RN4 13	2013	150		40	0,3	60	10	0,20	36	44	148
Labiště beneath Opočínek - Opo 01	2001	50	*15,6*		4,0	*255*	87	1,78	*45*	114	*1022*
Labiště beneath Opočínek - Opo 02	2002	50	*14,6*		3,4	214	101	1,50	*51*	117	768
Oxbow lake at Lžovice - Lz A 07	2007	151	11,2	20	*4,6*	*232*	*209*	3,99	38	89	563
Oxbow lake at Lžovice - Lz B 07	2007	103	8,5	20	2,2	137	97	2,66	33	84	557
Doleháj - Dol 01	2001	30	*13,0*		2,3	94	34	0,41	33	72	168
Doleháj - Dol A 02	2002	30	10,9		1,0	101	37	0,41	36	100	206
Doleháj - Dol B 02	2002	30	3,3		1,3	85	42	0,16	41	108	239
Oxbow lake at Poděbrady - Pod 07	2007	204	2,5	37	1,8	113	85	1,80	34	96	483
Oxbow lake at Poděbrady - Pod A 15	2015	87	3,9	*90*	2,9	144	110	2,67	32	114	474
Oxbow lake at Poděbrady -Pod B 15	2015	77	1,2	*91*	1,6	119	63	0,81	28	128	347
Vrť pool - Vrt 17	2018	59	6,7	40	2,2		48	0,41	35	68	226
Václavka pool - Vac 7	2007	67	0,4	20	0,2	22	58	1,17	30	50	310
Kozelská pool - Koz 17	2018	57	9,9	*86*	*6,1*		125	3,58	42	166	808
Libiš pool - Lib A 04	2004	60		43	3,3	119	90	2,80	42	109	869
Libiš pool - LV1 13	2013	115		18	2,9	130	118	*6,05*	44	146	*1037*
Libiš pool - LV2 13	2013	56		11	0,6	59	39	0,93	35	72	258
Libiš catchwater - LS 14	2014	50		65	1,5	75	*179*	*8,60*	*51*	117	582
Floodplain at Libiš - LN3 13	2013	140		35	0,5	73	38	0,55	42	66	246
Floodplain at Libiš - LN4 13	2013	150		30	0,2	68	16	0,42	41	55	179
Floodplain at Libiš - LN6 13	2013	150		25	0,3	62	13	0,55	38	46	172
Floodplain at Libiš - LN8 13	2013	150		19	0,2	60	28	0,46	39	53	145
Oxbow lake at Obříství - Obr 01	2001	60			4,3	*241*	133	*5,80*	*45*	*184*	943
Oxbow lake at Obříství - Obr 02	2002	60	8,4		*6,4*	210	115	3,58	35	*376*	777
Oxbow lake at Obříství - Obr A 07	2007	163	5,8	25	3,1	125	121	1,36*	43	124	594
Oxbow lake at Obříství - Obr B 07	2007	187	1,6	22	1,6	46	79	3,41	29	79	629
Oxbow lake at Obříství - OV1 13	2013	83		10	2,8	121	137	3,40	36	107	427
Floodplain at Obříství - ON1 13	2013	150		47	1,4	108	71	1,88	*45*	116	398

concentrations below the lower threshold value | concentrations between lower and upper threshod value | concentrations exceeding upper threshold value

Results – Geoaccumulation indices (Muller, 1979) + background values (T&W, 1968)

Sampling point	Year	Depth (cm)	IGEO based on background values by Turekian and Wedepohl (1968)								
			Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Oxbow lake at Němčice - Nem 07	2007	67	4,45	0,04	0,83	-0,16	-0,15	-0,45	-1,72	1,34	1,75
Winter harbour Paramo - PV 13	2013	113		0,04	2,69	-0,49	1,67	2,14	-0,89	3,18	3,42
Oxbow lake at Rosice - RV1 13	2013	96		-0,48	2,22	0,25	-0,05	-0,32	-1,39	1,26	1,57
Oxbow lake at Rosice - RV2 13	2013	115		-0,96	1,83	0,64	0,42	0,58	-1,28	2,04	2,19
Floodplain at Rosice - RN2 13	2013	150		0,92	0,15	-0,77	-1,68	0,18	-1,18	0,65	0,77
Floodplain at Rosice - RN3 13	2013	150		0,96	-0,58	-0,85	-1,49	-1,00	-1,39	1,20	0,63
Floodplain at Rosice - RN4 13	2013	150		1,04	-0,58	-1,17	-2,75	-1,58	-1,50	0,55	0,05
Labiště beneath Opočínek - Opo 01	2001	50	7,22		3,15	0,92	0,37	1,57	-1,18	1,93	2,84
Labiště beneath Opočínek - Opo 02	2002	50	7,12		2,92	0,66	0,58	1,32	-1,00	1,96	2,43
Oxbow lake at Lžovice - Lz A 07	2007	151	6,74	0,04	3,35	0,78	1,63	2,73	-1,42	1,57	1,98
Oxbow lake at Lžovice - Lz B 07	2007	103	6,34	0,04	2,29	0,02	0,52	2,15	-1,63	1,49	1,97
Doleháj - Dol 01	2001	30	6,95		2,35	-0,52	-0,99	-0,55	-1,63	1,26	0,24
Doleháj - Dol A 02	2002	30	6,70		1,15	-0,42	-0,87	-0,55	-1,50	1,74	0,53
Doleháj - Dol B 02	2002	30	4,97		1,53	-0,67	-0,68	-1,91	-1,31	1,85	0,75
Oxbow lake at Poděbrady - Pod 07	2007	204	4,57	0,92	2,00	-0,26	0,33	1,58	-1,58	1,68	1,76
Oxbow lake at Poděbrady - Pod A 15	2015	87	5,22	2,21	2,69	0,09	0,70	2,15	-1,67	1,93	1,73
Oxbow lake at Poděbrady -Pod B 15	2015	77	3,51	2,22	1,83	-0,18	-0,10	0,43	-1,87	2,09	1,28
Vrť pool - Vrt 17	2018	59	6,00	1,04	2,29		-0,49	-0,55	-1,54	1,18	0,67
Václavka pool - Vac 7	2007	67	1,93	0,04	-1,17	-2,62	-0,22	0,96	-1,77	0,74	1,12
Kozelská pool - Koz 17	2018	57	6,56	2,14	3,76		0,89	2,58	-1,28	2,47	2,50
Libiš pool - Lib A 04	2004	60		1,14	2,87	-0,18	0,42	2,22	-1,28	1,86	2,61
Libiš pool - LV1 13	2013	115		-0,12	2,69	-0,05	0,81	3,33	-1,21	2,28	2,86
Libiš pool - LV2 13	2013	56		-0,83	0,42	-1,19	-0,79	0,63	-1,54	1,26	0,86
Libiš catchwater - LS 14	2014	50		1,74	1,74	-0,85	1,41	3,84	-1,00	1,96	2,03
Floodplain at Libiš - LN3 13	2013	140		0,84	0,15	-0,89	-0,83	-0,13	-1,28	1,14	0,79
Floodplain at Libiš - LN4 13	2013	150		0,62	-1,17	-0,99	-2,08	-0,51	-1,31	0,87	0,33
Floodplain at Libiš - LN6 13	2013	150		0,36	-0,58	-1,12	-2,38	-0,13	-1,42	0,62	0,27
Floodplain at Libiš - LN8 13	2013	150		-0,04	-1,17	-1,17	-1,27	-0,38	-1,39	0,82	0,03
Oxbow lake at Obříství - Obr 01	2001	60			3,26	0,84	0,98	3,27	-1,18	2,62	2,73
Oxbow lake at Obříství - Obr 02	2002	60	6,32		3,83	0,64	0,77	2,58	-1,54	3,65	2,45
Oxbow lake at Obříství - Obr A 07	2007	163	5,79	0,36	2,78	-0,11	0,84	1,18	-1,25	2,05	2,06
Oxbow lake at Obříství - Obr B 07	2007	187	3,93	0,17	1,83	-1,55	0,23	2,51	-1,81	1,40	2,14
Oxbow lake at Obříství - OV1 13	2013	83		-0,96	2,64	-0,16	1,02	2,50	-1,50	1,83	1,58
Floodplain at Obříství - ON1 13	2013	150		1,27	1,64	-0,32	0,07	1,65	-1,18	1,95	1,48

I_{geo} Value	I_{geo} Class	Sediment Pollution
< 0	0	no contamination
< 1	I	no - moderate contamination
< 2	II	moderate contamination
< 3	III	moderate - strong contamination
< 4	IV	strong contamination
< 5	V	strong - very strong contamination
≥ 5	VI	very strong contamination

Results – Geoaccumulation indices (Muller,1979) + background values (Prange et al.,1997)

Sampling point	Year	Depth (cm)	IGEO based on background values by Prange et al. (1997)								
			Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Oxbow lake at Němčice - Nem 07	2007	67	2,35	-0,85	0,42	-0,54	0,35	-0,03	-1,36	0,80	1,09
Winter harbour Paramo - PV 13	2013	113		-0,85	2,27	-0,87	2,16	2,56	-0,53	2,64	2,76
Oxbow lake at Rosice - RV1 13	2013	96		-1,36	1,81	-0,12	0,44	0,09	-1,03	0,73	0,91
Oxbow lake at Rosice - RV2 13	2013	115		-1,85	1,42	0,27	0,91	1,00	-0,92	1,50	1,53
Floodplain at Rosice - RN2 13	2013	150		0,04	-0,26	-1,15	-1,19	0,60	-0,82	0,11	0,11
Floodplain at Rosice - RN3 13	2013	150		0,08	-1,00	-1,23	-1,00	-0,58	-1,03	0,67	-0,03
Floodplain at Rosice - RN4 13	2013	150		0,15	-1,00	-1,55	-2,26	-1,17	-1,14	0,02	-0,60
Labiště beneath Opočínek - Opo 01	2001	50	5,12		2,74	0,54	0,86	1,98	-0,82	1,39	2,18
Labiště beneath Opočínek - Opo 02	2002	50	5,02		2,50	0,29	1,07	1,74	-0,64	1,43	1,77
Oxbow lake at Lžovice - Lz A 07	2007	151	4,64	-0,85	2,94	0,40	2,12	3,15	-1,06	1,03	1,32
Oxbow lake at Lžovice - Lz B 07	2007	103	4,24	-0,85	1,87	-0,36	1,01	2,56	-1,27	0,95	1,31
Doleháj - Dol 01	2001	30	4,85		1,94	-0,90	-0,50	-0,13	-1,27	0,73	-0,42
Doleháj - Dol A 02	2002	30	4,60		0,74	-0,80	-0,38	-0,13	-1,14	1,20	-0,13
Doleháj - Dol B 02	2002	30	2,87		1,12	-1,05	-0,19	-1,49	-0,96	1,31	0,09
Oxbow lake at Poděbrady - Pod 07	2007	204	2,47	0,04	1,58	-0,64	0,82	2,00	-1,23	1,14	1,10
Oxbow lake at Poděbrady - Pod A 15	2015	87	3,12	1,32	2,27	-0,29	1,20	2,57	-1,31	1,39	1,07
Oxbow lake at Poděbrady -Pod B 15	2015	77	1,42	1,34	1,42	-0,56	0,39	0,85	-1,51	1,56	0,63
Vrť pool - Vrt 17	2018	59	3,90	0,15	1,87		0,00	-0,13	-1,18	0,64	0,01
Václavka pool - Vac 7	2007	67	-0,17	-0,85	-1,58	-3,00	0,27	1,38	-1,41	0,20	0,46
Kozelská pool - Koz 17	2018	57	4,46	1,26	3,35		1,38	2,99	-0,92	1,93	1,84
Libiš pool - Lib A 04	2004	60		0,26	2,46	-0,56	0,91	2,64	-0,92	1,33	1,95
Libiš pool - LV1 13	2013	115		-1,00	2,27	-0,43	1,30	3,75	-0,85	1,75	2,20
Libiš pool - LV2 13	2013	56		-1,71	0,00	-1,57	-0,30	1,05	-1,18	0,73	0,20
Libiš catchwater - LS 14	2014	50		0,85	1,32	-1,23	1,90	4,26	-0,64	1,43	1,37
Floodplain at Libiš - LN3 13	2013	140		-0,04	-0,26	-1,27	-0,34	0,29	-0,92	0,60	0,13
Floodplain at Libiš - LN4 13	2013	150		-0,26	-1,58	-1,37	-1,58	-0,10	-0,96	0,34	-0,33
Floodplain at Libiš - LN6 13	2013	150		-0,53	-1,00	-1,50	-1,88	0,29	-1,06	0,08	-0,39
Floodplain at Libiš - LN8 13	2013	150		-0,92	-1,58	-1,55	-0,78	0,03	-1,03	0,28	-0,63
Oxbow lake at Obříství - Obr 01	2001	60			2,84	0,46	1,47	3,69	-0,82	2,08	2,07
Oxbow lake at Obříství - Obr 02	2002	60	4,22		3,42	0,26	1,26	2,99	-1,18	3,11	1,79
Oxbow lake at Obříství - Obr A 07	2007	163	3,69	-0,53	2,37	-0,49	1,33	1,60	-0,89	1,51	1,40
Oxbow lake at Obříství - Obr B 07	2007	187	1,83	-0,71	1,42	-1,93	0,72	2,92	-1,45	0,86	1,48
Oxbow lake at Obříství - OV1 13	2013	83		-1,85	2,22	-0,54	1,51	2,92	-1,14	1,30	0,92
Floodplain at Obříství - ON1 13	2013	150		0,38	1,22	-0,70	0,56	2,06	-0,82	1,42	0,82

I_{geo} Value	I_{geo} Class	Sediment Pollution
< 0	0	no contamination
< 1	I	no - moderate contamination
< 2	II	moderate contamination

< 3	III	moderate - strong contamination
< 4	IV	strong contamination
< 5	V	strong - very strong contamination
≥ 5	VI	very strong contamination

Results – Comparison with the Elbe River

Comparison of the Elbe River monitoring profiles – Němčice, Valy, Lysá, Obříství (2000-2017)

- avg. concentrations exceeding ICPER upper threshold value *– in red*
- comparison of avg. concentrations of all assessed elements among the monitoring profiles

NĚMČICE - *Hg (0,51 mg.kg-1), Pb (66 mg.kg-^{1})*/ *max Ni (44 mg.kg^{-1})*
VALY - *Hg (1,01 mg.kg^{-1}), Pb (68 mg.kg^{-1})* / *max Ag (2,3 mg.kg^{-1}), Cr (104 mg.kg^{-1})*
LYSÁ - *Hg (1,05 mg.kg^{-1}), Pb (76 mg.kg^{-1})* /
max As (28 mg.kg^{-1}), Cd (1,9 mg.kg^{-1}), Cu (72 mg.kg^{-1}), Hg (1,05 mg.kg^{-1}), Pb (76 mg.kg^{-1}), Zn (431 mg.kg^{-1})
OBŘÍSTVÍ - *Hg (0,99 mg.kg^{-1}), Pb (73 mg.kg^{-1})* / *no max*

- comparison of avg. concentrations 2000-2007 vs. 2000-2017*(As, Cd, Cu, Cr, Hg, Ni, Pb, Zn)*

NEMČICE - decrease in all measured elements
VALY - decrease in all measured elements except for the same value of Cu
LYSÁ – increase in content of As, Cu, Zn, the same value for Pb
OBŘÍSTVÍ – increase in content of As, the same value for Zn

Most risky elements: Hg, Pb + As, Cd, Ni (Ag)

Comparison of oxbow lake cores and the development in the Elbe River monitoring profiles

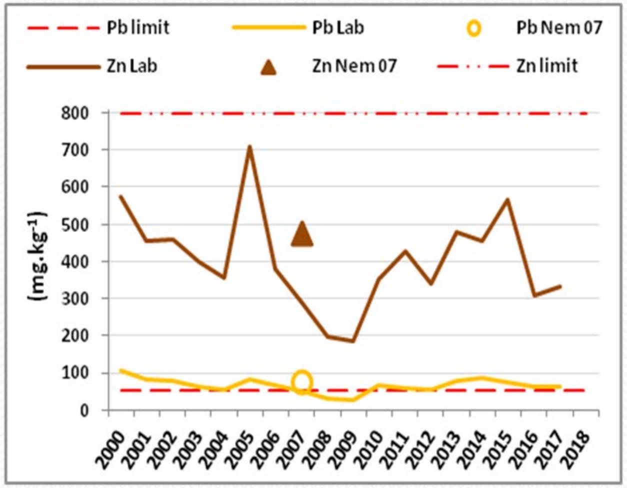
- comparison of avg. concentrations in the cores with concentration changes in the nearest Elbe monitoring profiles

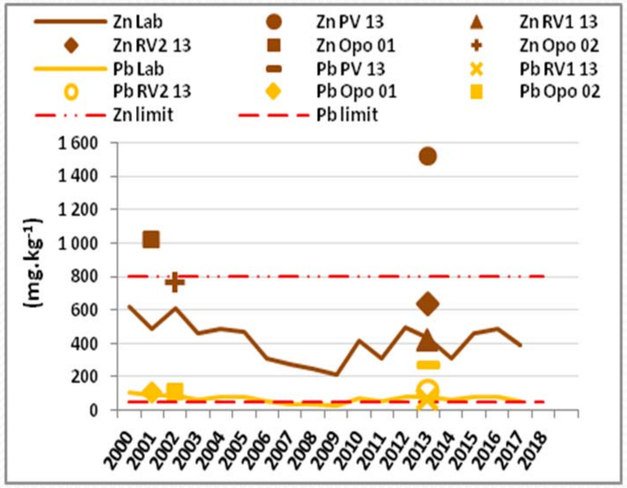
NĚMČICE monitoring station – Nem 07
VALY monitoring station – RV1 13, RV2 13, RN2 13, RN3 13, RN4 13, PV 13, Opo 01, Opo 02, Lz A 07, Lz B 07, Dol 01, Dol A 02, Dol B 02,
LYSÁ monitoring station – Pod 07, Pod A 15, Pod B 15, Vrt 17, Vac 07
OBŘÍSTVÍ monitoring station – Koz 17, Lib A 04, LV1 13, LV2 13, LS 14, LN3 13, LN4 13, LN6 13, LN8 13, Obr 01, Obr 02, Obr A 07, Obr B 07, OV1 13, ON1 13

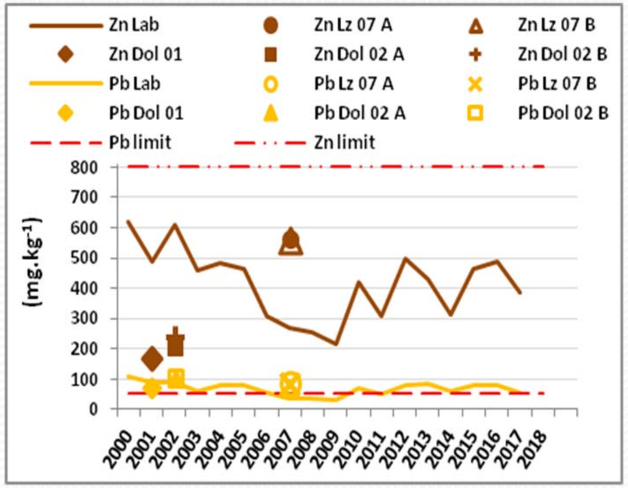
Results – Comparison with the Elbe River

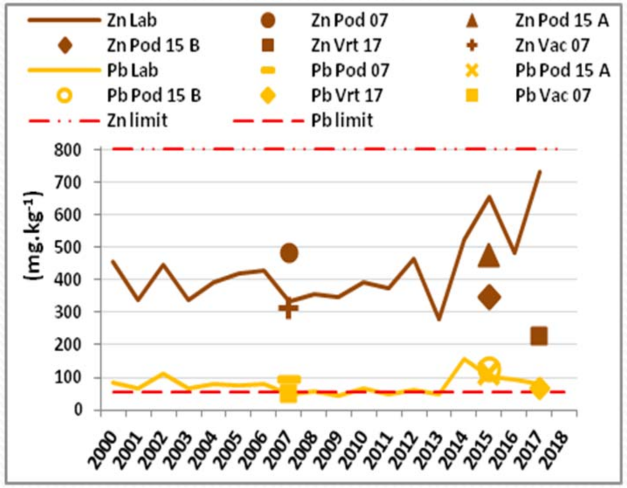
Comparison of the Elbe River monitoring profiles – Němčice, Valy, Lysá, Obříství (2000-2017)

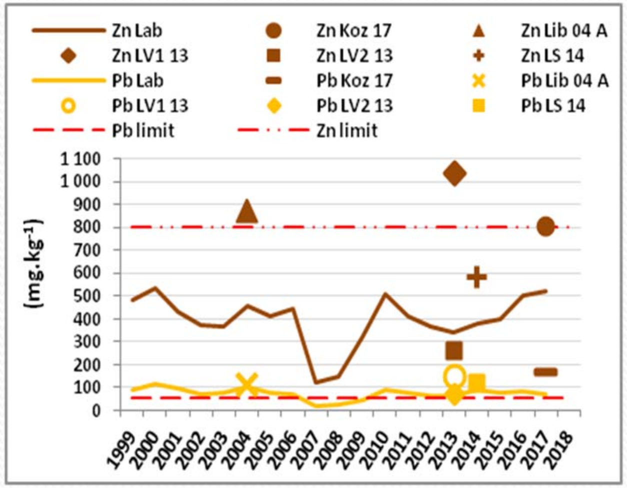
- development of concentrations of Pb and Zn in the Elbe River in comparison with avg. concentrations in the cores

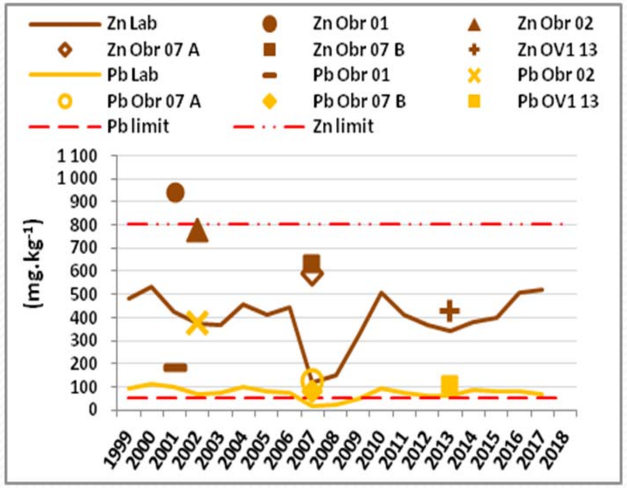








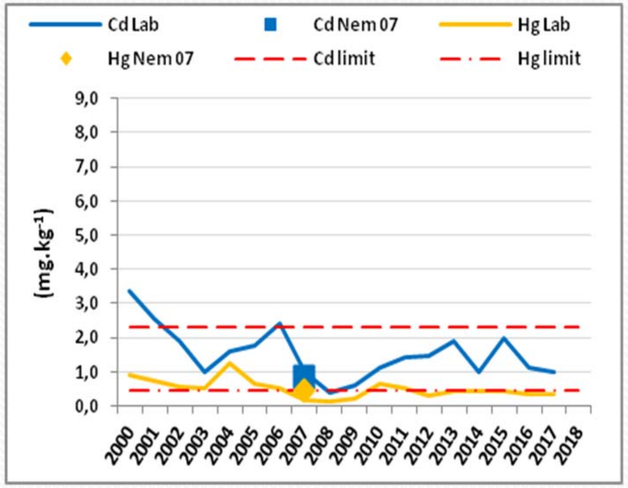


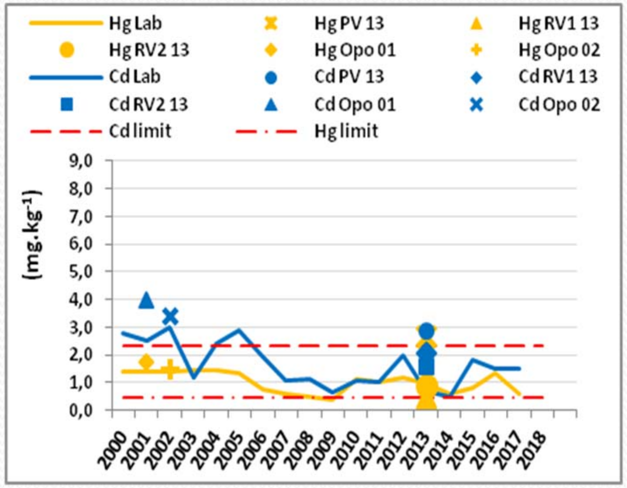


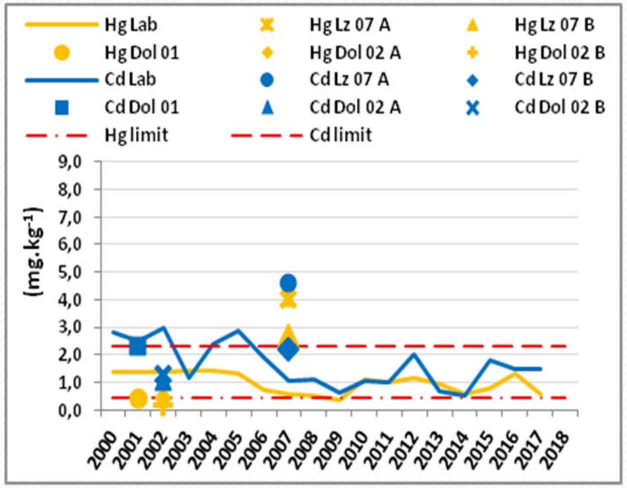
Results – Comparison with the Elbe River

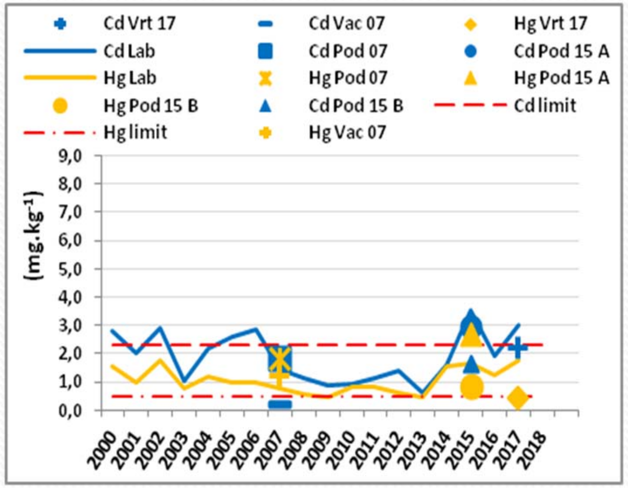
Comparison of the Elbe River monitoring profiles – Němčice, Valy, Lysá, Obříství (2000-2017)

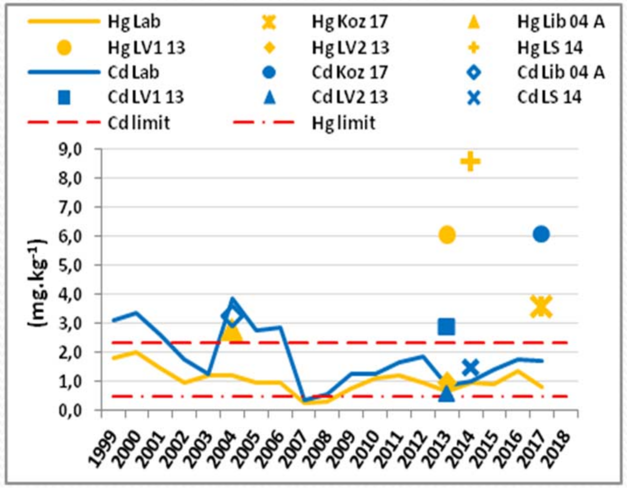
- development of concentrations of Cd and Hg in the Elbe River in comparison with avg. concentrations in the cores

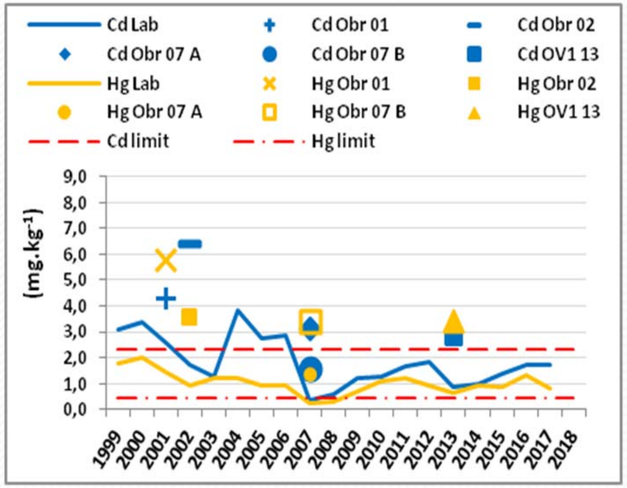








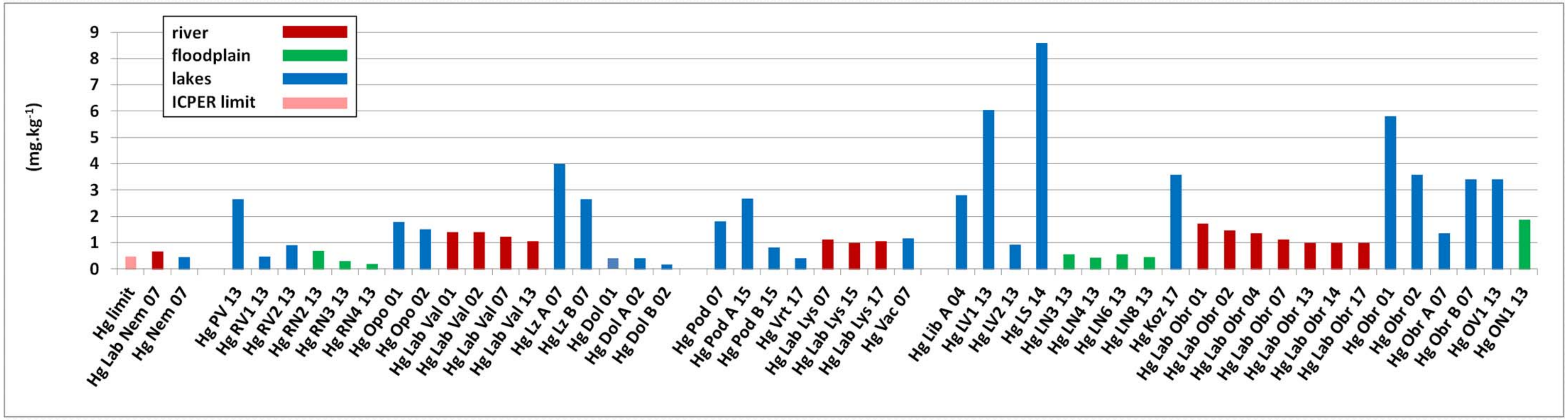


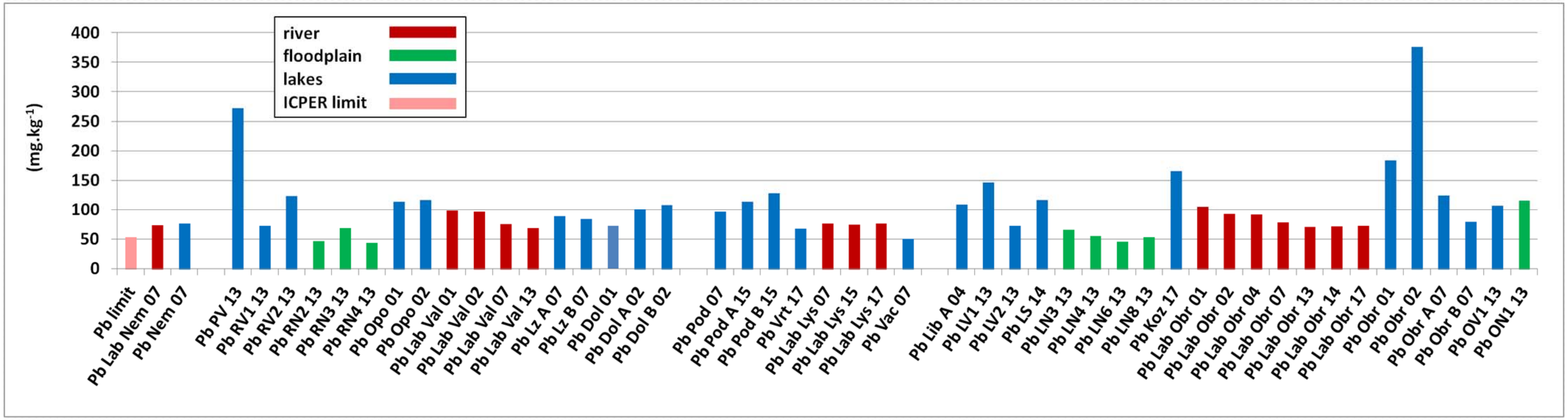


Results – Comparison with the Elbe River

Comparison of oxbow lake sediments, floodplain cores and the Elbe River monitoring profiles

- comparison of avg. concentrations in the cores and avg. concentrations at the nearest Elbe monitoring profiles (period from 2000 to the year of lake/floodplain sampling inclusive)

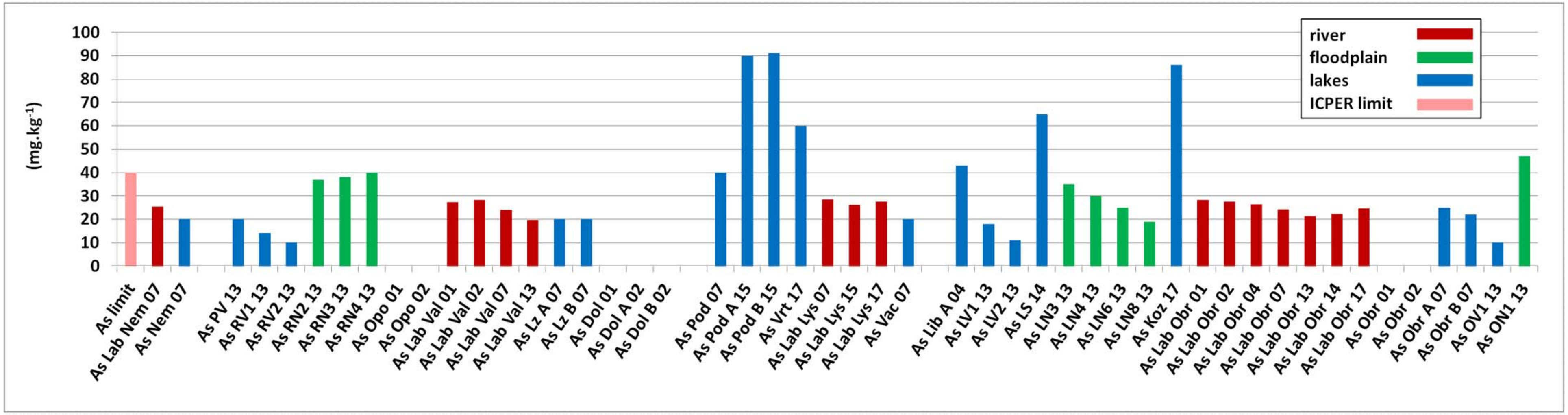


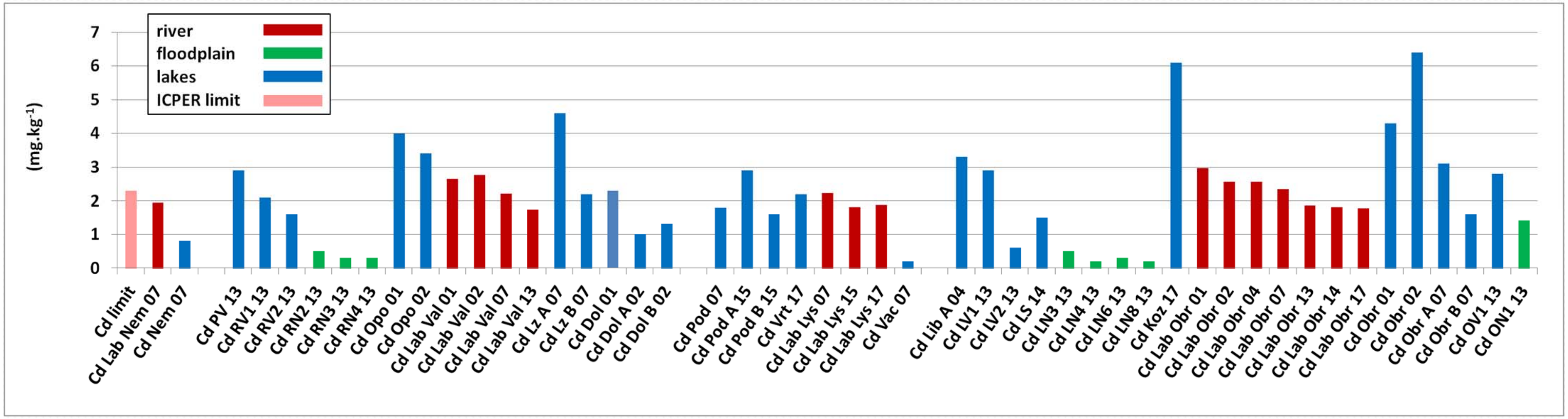


Results – Comparison with the Elbe River

Comparison of oxbow lake sediments, floodplain cores and the Elbe River monitoring profiles

- **comparison of avg. concentrations in the cores and avg. concentrations at the nearest Elbe monitoring profiles (period from 2000 to the year of lake/floodplain sampling inclusive)**





Results – summary floodplain vs. oxbow lakes vs. the Elbe River

Comparison between oxbow lake sediments, floodplain and the Elbe River monitoring profiles

- comparison with the average concentrations in the Elbe River *(period from 2000 to the year of oxbow lake/floodplain sampling inclusive)*

1. Floodplain sediments (8 cores):

- the Elbe River concentrations exceeded for: As (7 cores), Ni (5 cores), Hg (1 core), Pb (2 core), Cu, Cr and Zn (1 core)
  - higher values found especially in cores: ON1 13 *(As, Cr, Cu, Hg Ni, Pb, Zn)*, and RN3 13 *(As, Ni, Pb)*

= floodplain sediments show higher concentrations especially for As, and Ni, other elements mostly lower values than the Elbe River averages

2. Oxbow lake sediments (26 cores):

- the Elbe River concentrations exceeded for: Pb (23 cores; 2 cores 3-fold), Zn (19 cores; 1 cores 3-fold) Cr (17 cores), Cu (17 cores; 2 cores 3-fold), Hg (17 cores; 7 cores 3-fold), Ag (15 cores; 13 cores 3-fold), Cd (15 cores; 1 core 3-fold), As (9 cores; 3 cores 3-fold), Ni (4 cores),

= oxbow lake sediments show higher concentrations especially for Pb, Zn, Cr, Cu, Hg, Ag, and Cd

= higher values found especially in cores:

Opo 01 – Ag (3-fold), Cd, Cr, Cu, Hg, Pb, Zn
Opo 02 - Ag (3-fold), Cd, Cr, Cu, Hg, Pb, Zn
PV 13 – As, Cd, Cu (3-fold), Hg, Ni, Pb (3-fold), Zn (3-fold)
Lz 07 A – Ag (3-fold), Cd, Cr, Cu, Hg (3-fold), Pb, Zn
Lz 07 B - Ag (3-fold), Cd, Cr, Cu, Hg, Pb, Zn
Pod 07 - Ag (3-fold), As, Cr, Cu, Hg, Pb, Zn
Pod 15A - Ag, As (3-fold), Cd, Cr, Cu, Hg, Pb, Zn

Lib 04 A – As, Cd, Cr, Cu, Hg, Pb, Zn
LV1 13 – Cd, Cr, Cu, Hg (3-fold), Ni, Pb, Zn
LS 14 – As, Cr, Cu (3-fold), Hg (3-fold), Ni, Pb, Zn
Koz 17 – Ag (3-fold), As (3-fold), Cd (3-fold), Cu, Hg (3-fold), Pb, Zn
Obr 02 – Ag (3-fold), Cd, Cr, Cu, Hg, Pb (3-fold), Zn –sampling after the flood in 2002
Obr 07 A - Ag (3-fold), As, Cd, Cr, Cu, Hg, Pb, Zn

SUMMARY:

= the lowest contamination in the cores taken from the lakes with restricted hydrological communication with the river *(oxbow lake Doleháj, Václavka pool – example of Vrť pool)*, and in the floodplain cores

= contamination and the amount of sediment usually higher closer to the river *(Lz A 07 vs. Lz B 07; LV 1 13 vs. LV2 13)*

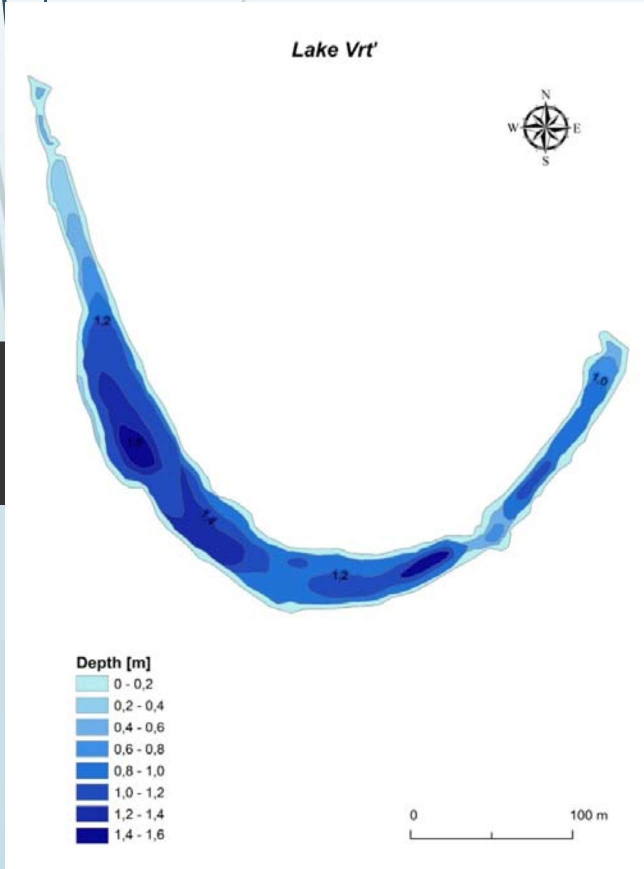
= significance of location due to sources of pollution and flow direction *(oxbow lake at Rosice X Kozelská pool – upstream contamination during floods on the Vltava River!!!)*

= the most risky localities: Winter Harbour Paramo, Labiště beneath Opočínek, oxbow lake at Lžovice, oxbow lake near Poděbrady, Kozelská pool, Libiš pool, Libiš chatchwater, oxbow lake at Obříství

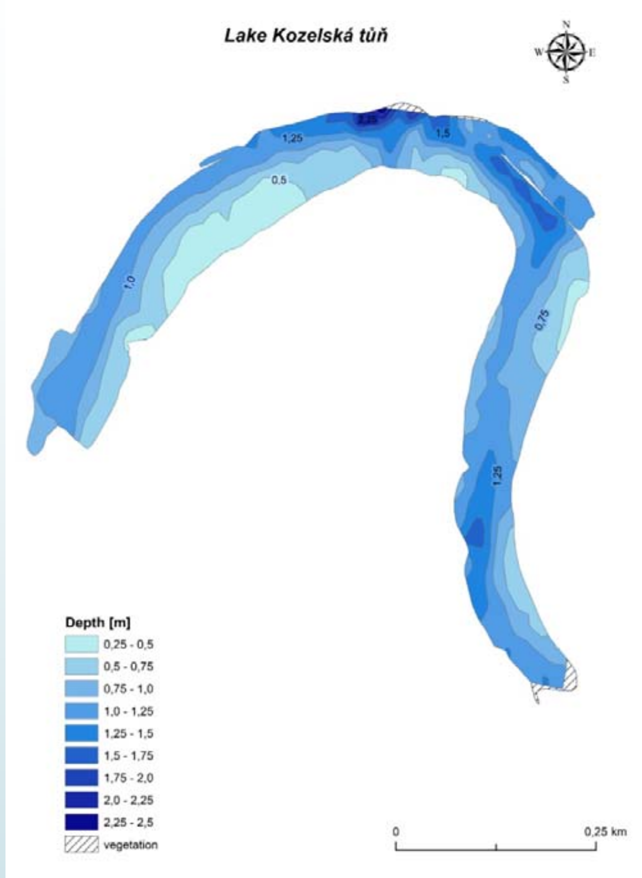
RISK OF REMOBILIZATION during hydrological events – next steps: speciation and mobility of elements, bioavailability, modelling of resuspendation, intensity of siltation, dating, identification of source of pollution...)

Case studies Kozelská oxbow lake and Vrť pool

- Morfometric characteristics
- Chemical and physical parameters of water
- Analyses of phytoplankton and zooplankton
- Grain analysis of sediment
- Metals and As determination in sediments



RiverSurveyor (photo L. Beranová)

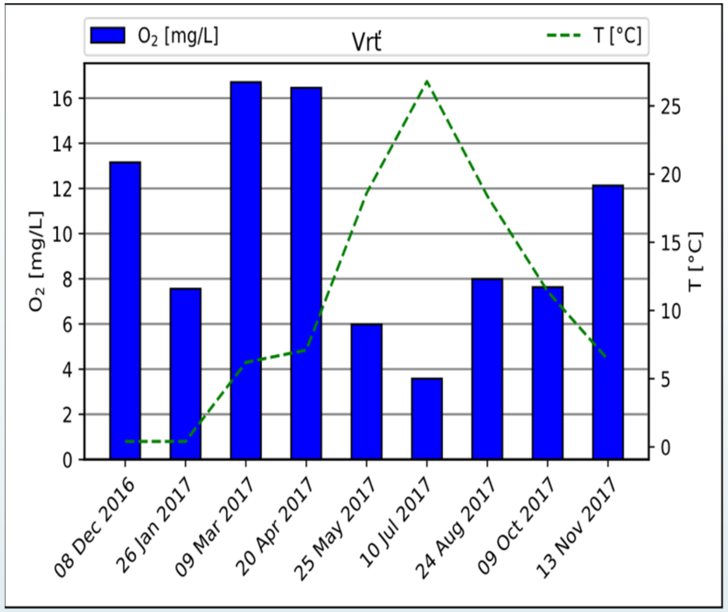


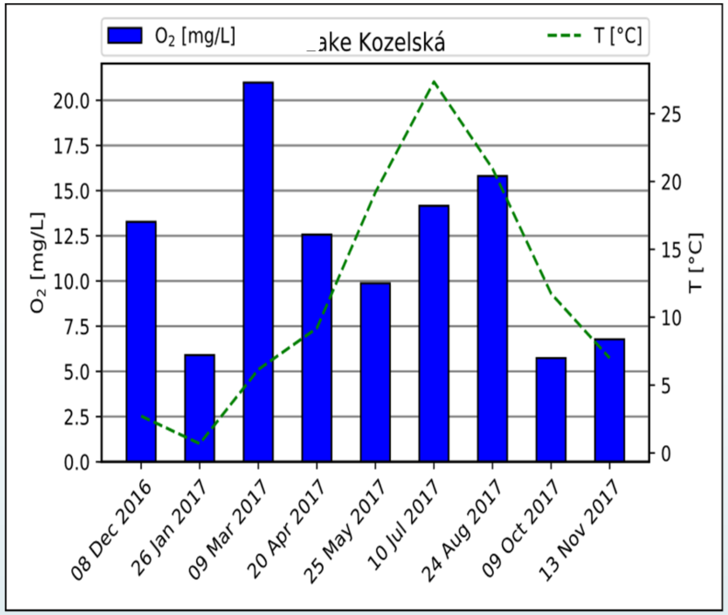
Bathymetry

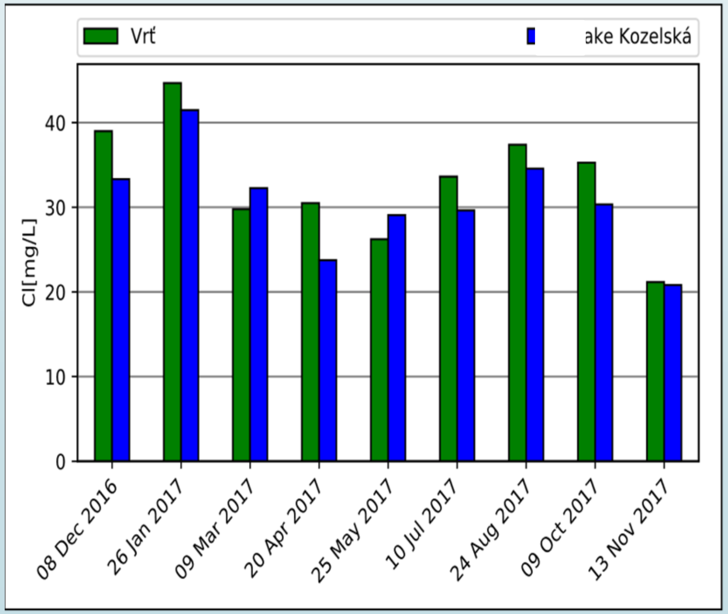
- RiverSuveyor - depths of lake
- Bank line – Garmin GPS

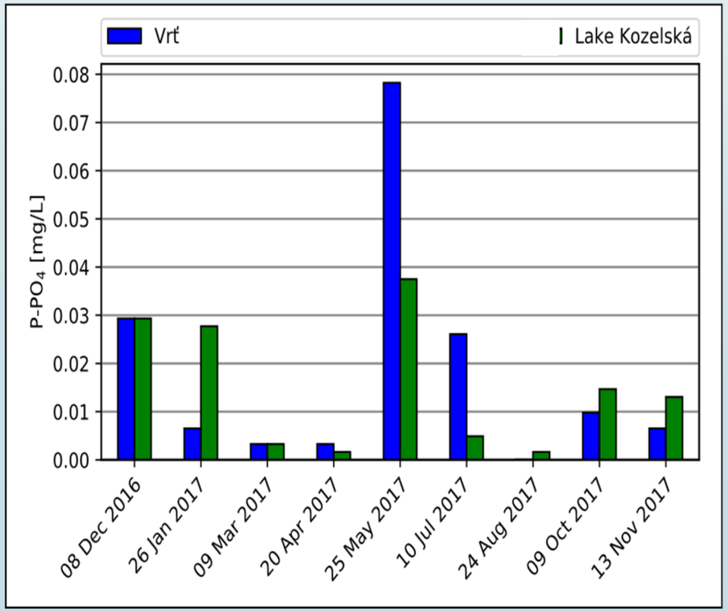
Chemical and physical parameters of surface water

- temperature
- COD_{Mn}
- BOD_5
- $N\text{-}NH_4$
- $N\text{-}NO_2$
- $N\text{-}NO_3$
- $P\text{-}PO_4$
- Cl^-
- dissolved oxygen
- Ca
- Fe
- Mn
- water hardness
- alkalinity
- pH
- conductivity







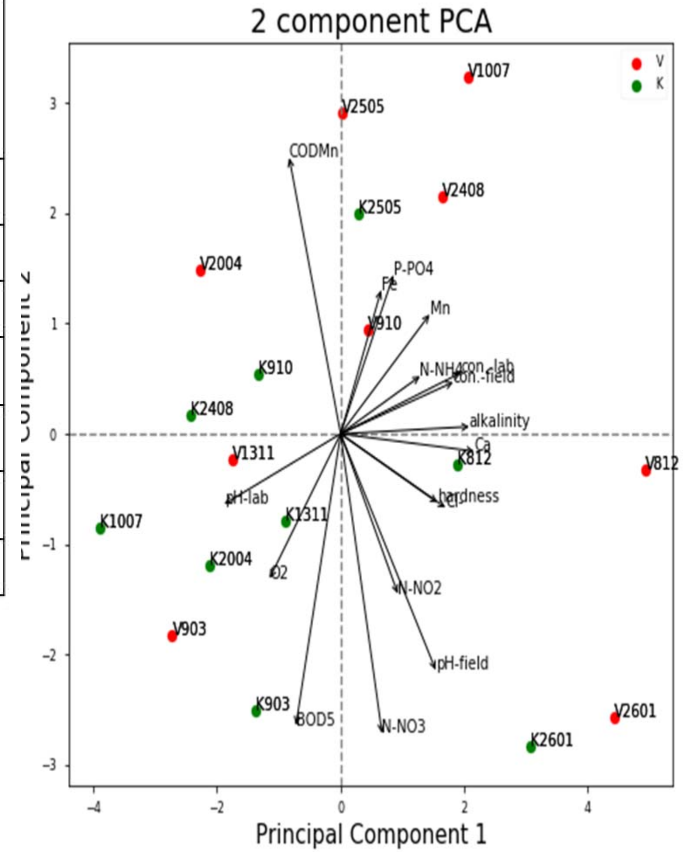


Comparison of water quality with the Elbe River oxbow lakes

Comparison with the Elbe oxbow lakes (in $mg.L^{-1}$, conductivity in $mS.m^{-1}$)

Parameter	Kozelská 2017	Vrť 2017	Vrť 2004 - 2007	Němčice 2006 - 2007	Lžovice 2006 - 2007	Poděbrady 2006 - 2007	Václavka 2006 - 2007
O_2	11,68	10,13	**16,60**	8,27	9,86	8,67	9,66
BOD_5	5,59	2,77	4,70	4,50	3,70	3,50	5,20
COD_{Mn}	7,27	9,36	8,20	10,11	5,61	5,40	6,69
$N\text{-}NO_3$	2,27	2,24	2,58	2,10	2,10	2,60	0,10
$N\text{-}NH_4$	**0,36**	**0,45**	0,15	0,18	0,08	0,09	0,05
$P\text{-}PO_4$	0,015	0,018	0,021	**0,540**	0,080	0,040	0,040
conductivity	49,68	52,76	45,00	81,30	46,30	46,50	53,80

Parameter	Obříství 2006 - 2007	Semín 2004 - 2007	Votoka 2004 - 2007	Doleháj 2003	Labiště p.O. 2002	Libiš 2007
O_2	11,46	12,30	12,00	11,47	5,48	7,30
BOD_5	6,30	5,80	5,20	**9,23**	**17,73**	5,80
COD_{Mn}	7,98	9,30	8,30	**25,57**	**20,12**	**18,10**
$N\text{-}NO_3$	**3,10**	0,50	2,67	2,60	0,87	1,50
$N\text{-}NH_4$	0,11	0,08	0,07	1,20	0,59	0,40
$P\text{-}PO_4$	0,070	0,003	0,004	0,020	**0,410**	0,110
conductivity	**69,40**	44,80	**78,10**	49,50	39,50	**129,00**



PCA analysis of chemical parameters correlation
- Kozelská oxbow lake and Vrť pool

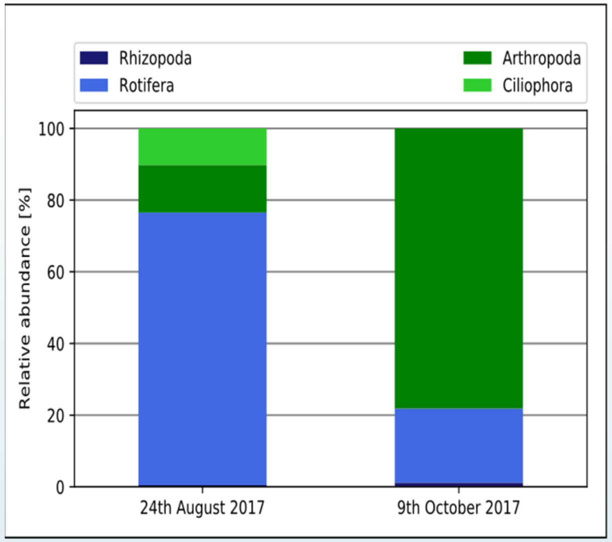
Analyses of phytoplankton and zooplankton

- Plankton net of 40 µm mesh size
- 200x magnification
- Methods by assoc. prof. J. Říhová Ambrožová
- ČSN 75 7712
- Semi - quantitative method

Bosmina longirostris, Arthropoda

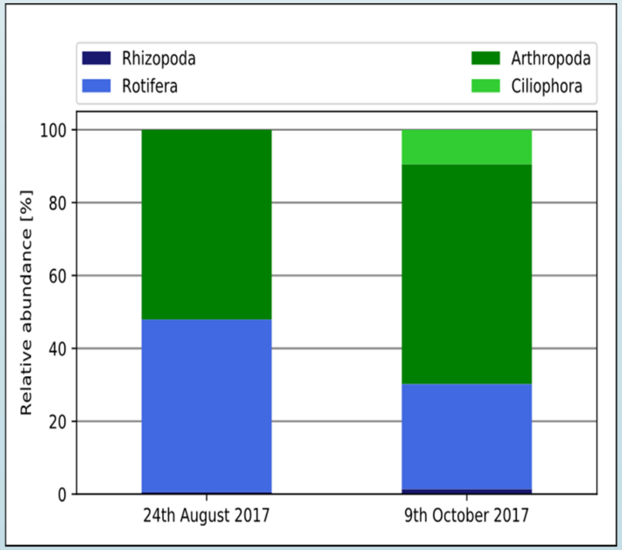
Analysis of zooplankton

Vrť



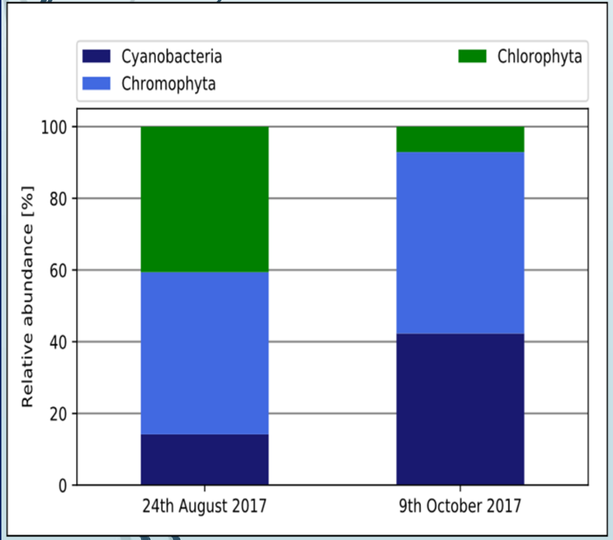
Relative abundance of zooplankton in Vrť and Kozelská pool

Lake Kozelská

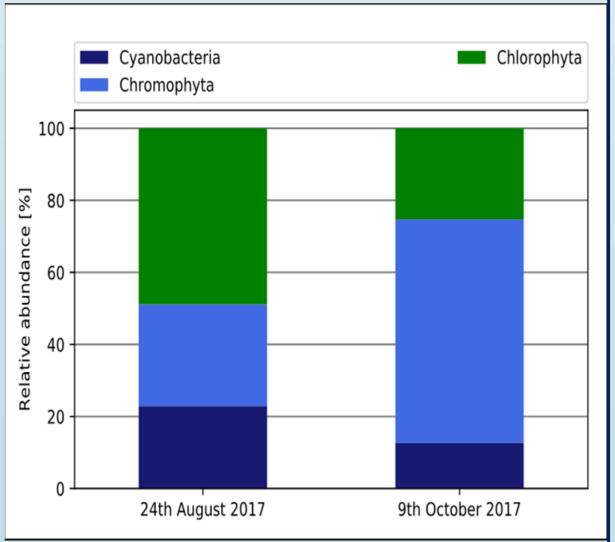


Analysis of phytoplankton

Lake Kozelská



Vrť



Relative abundance of zooplankton in Kozelská and Vrť oxbow lake

Chemical analysis of sediments

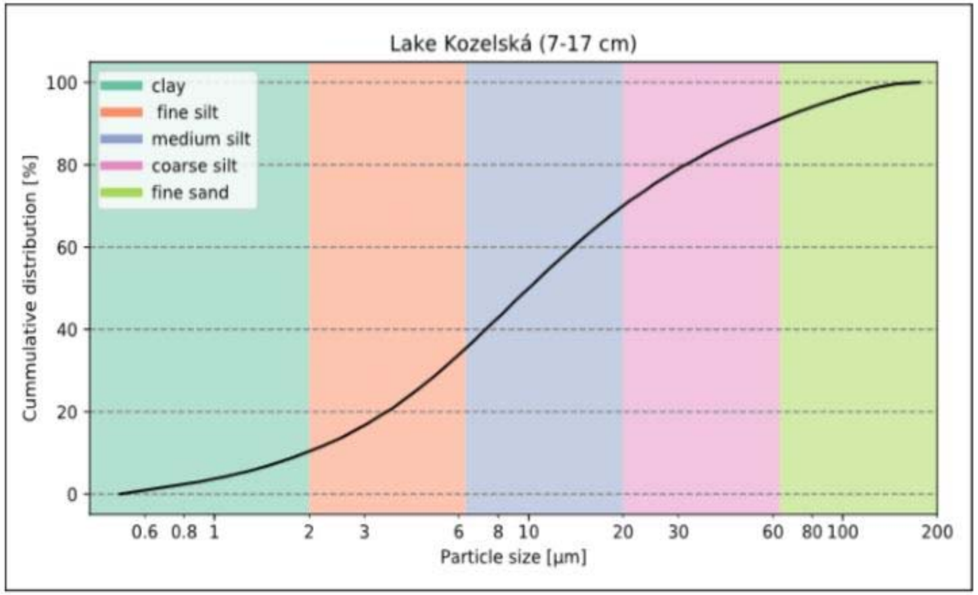
Classification of sediment contamination according to Igeo

Element	GHW - **Kozelská** *total digestion*	GHW - **Kozelská** *aqua regia*	GHW - **Vrť** *aqua regia*	T & W **-Kozelská** *total digestion*	T & W- **Kozelská** *aqua regia*	T & W- **Vrť** *aqua regia*
Ag	4,01	4,76	4,47	6,11	6,84	6,57
Al	-1,18	-2,43	-2,33	-1,04	-2,29	-2,18
As	1,48	1,26	0,06	2,37	2,14	0,94
Cd	3,60	3,36	1,97	4,02	3,78	2,39
Cu	1,33	1,38	-0,04	0,84	0,89	-0,53
Fe	-0,52	-0,58	-1,12	-0,50	-0,57	-1,11
Ni	-0,87	-0,93	-1,17	-1,23	-1,29	-1,53
Pb	1,95	1,93	-5,51	2,48	2,47	1,15
Ti	-1,62	-4,02	-4,29	-1,26	-3,66	-3,93
Zn	1,81	1,85	-0,03	2,47	2,50	0,63

Sediment core (photo L.Beranová)

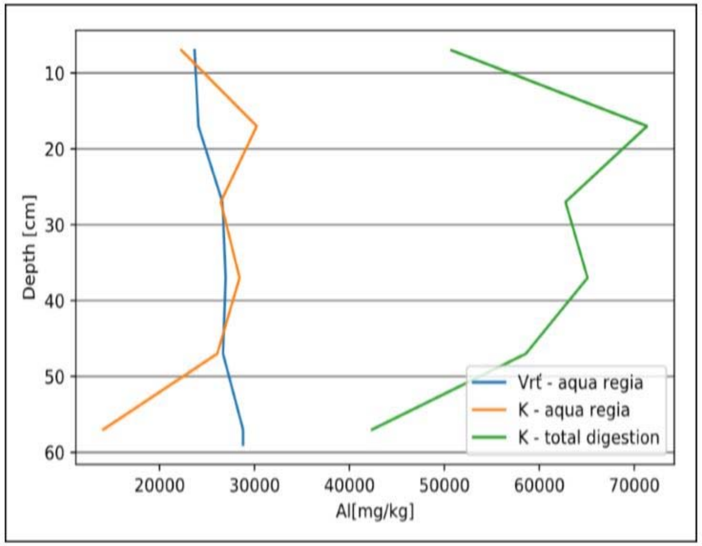
Classification EN ISO 14668-1

Comparison:
- aqua regia leaching
- total digestion
- background values:
  - Turekian & Wedepohl (1961)
  - GHW Elbe – Prange (1997)



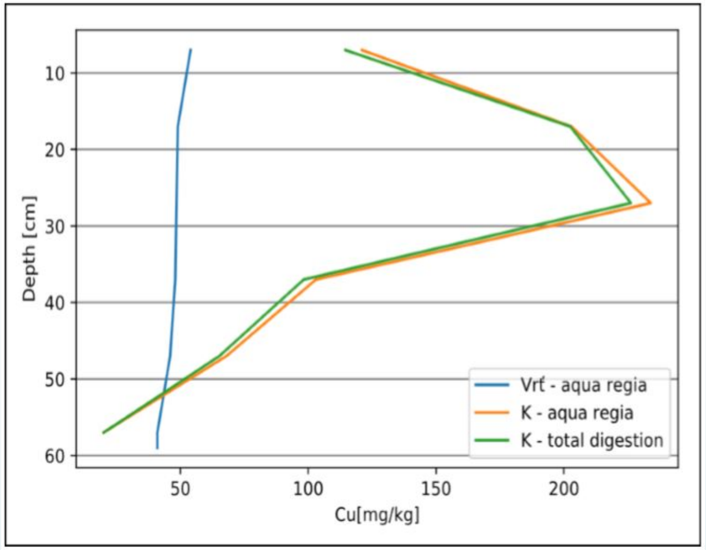
Grain size curve of sediments in Kozelská oxbow lake

Al



Concentration of Al in sediments

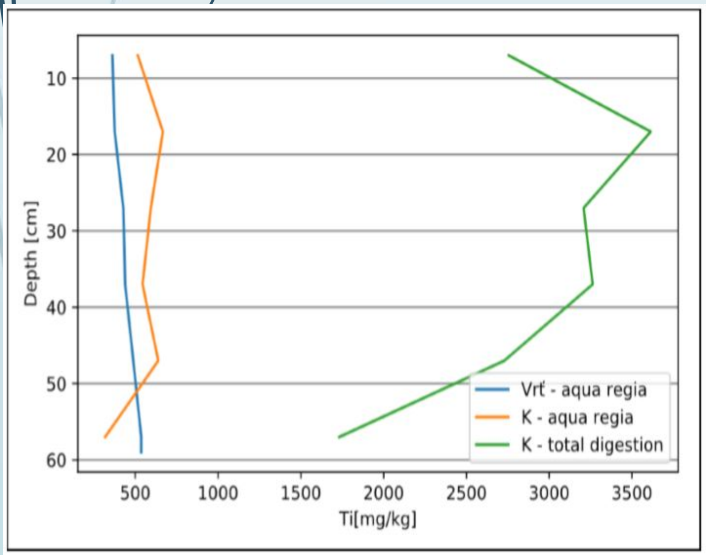
Cu



Concentration of Cu in sediments

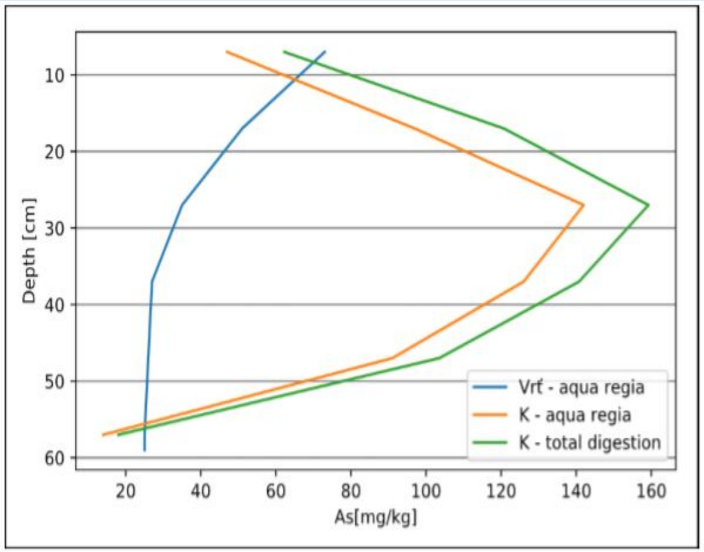
Vrť – aqua regia
Kozelská – aqua regia
Kozelská – total digestion

Ti



Concentration of Ti in sediments

As



Concentration of As in sediments

SUMMARY

Water quality

- Since 1990 – less pollution from point sources
- Nonpoint sources– still a problem
- Higher concentration of **N-NO_3 and N-NH_4**
- Water quality → typical fluvial lakes, **eutrophic** lakes

Zooplankton

- Number of species – influence of **pelagial** (vs. litoral)
- Kozelská oxbow lake – *Arthropoda* (absence of fish), Poděbrady
- Vrť pool – *Rotifera* (August), *Arthropoda* (October) – Semín, Votoka, Vrť 2004-2007

Sediment quality

- Differences between aqua regia leaching and total digestion **were not so significant**
- Pollution level was **higher** when using **T&W background values**
- **Vrť** – lower concentration of metals and As, small differences in concentrations with depth
- **Kozelská** – **higher** concentrations, big **differences** in concentrations with **depth**
  → **dredged** sediments, infuence of **flood**, transport of material
  → **Spolana**, a.s. in Neratovice

Thank you for your attention!

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