Hot Topics in Physical Geography

Winter term 1/1 Ex + C, 5 ECTS

Water and Sediment Pollution in the Czech Republic

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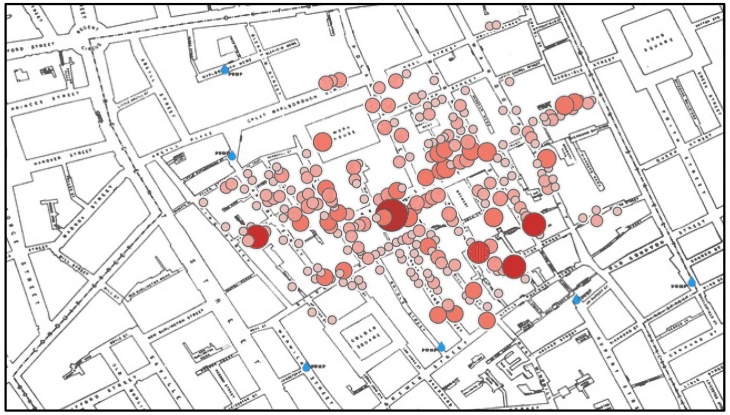
Content:

- Introduction - water use and the development of pollution in the world and in Czechia
- Water resources in the Czech Republic – general overview
- Sources of pollution – point/non-point, linear sources
- Water, suspended matter and sediment quality parameters
  - – physical, inorganic, organic, radioactive, microbial pollution, saprobity, trophy
- Water, suspended matter and sediment monitoring
- Water, suspended matter, sediment, and biota quality database
- Water quality development in the Czech Republic
- Suspended matter and sediment pollution
- Sediment pollution risks – old loads (deep sediments) case studies the Elbe River

Introduction – water use and the development of pollution in the world

- ancient civilizations – drinking water and irrigation (Egypt, Mesopotamia) → salinity
  - water level monitoring, hydrological regime of rivers → agriculture
- the Medieval Ages – deforestation → change of erosion-accummulation processes → siltation,
  - minor flood protection measures → embankments
  - minor navigability improvement
- 19th century – industrialization → anthropogenic industrial contamination
  - increase of inhabitants in cities + insufficient hygiene measures → epidemics
  - waste water treatment needed

Cholera epidemic in London 1854 – Soho, Broad Street
– Dr. John Snow
– spreading with water
– bacterium Vibrio cholerae



- 20th century – anthropogenic contamination

Minamata disease 1956 – Japan
– methylmercury in wastewater from the Chisso Corporation's chemical factory (1932 to 1968) – mercury poisoning from fish

– neurological syndrome – ataxia, muscle weakness, damage to hearing and speech insanity, coma, death, congenital disease

Introduction – water use and the development of pollution in Czechia

- 20th century – increase of anthropogenic contamination – especially 2nd half of the 20th century
  - industrial, agricultural and municipal pollution → maximum in the 1980s
  - environmentally unfriendly technologies, wastewater treatment missing, non-compliance
  - significant changes in water courses – straightening, deepening → faster drainage
  - construction of dams
  - floodplain drainage (in the 1970th) → arable land gaining
  - increase of water consumption (1965 – 5,5 km^3, 1990 – 21 km^3)
  - use of underground resources
- after 1989 – water quality improvement in connection with political changes → decrease in industrial, municipal and agricultural pollution production
  - environmental technologies, end of fertilizers overuse, waste water treatment plants construction
  - price of water
  - decrease in water consumption (1993=343; 2000=245; 2010=138; 2016=132 l/capita/day)
  - international cooperation – International Commission for the Protection of the Elbe River Protection (ICPER)
  - European measures
- end of the 20th century – healthy ecosystems – biodiversity, stability

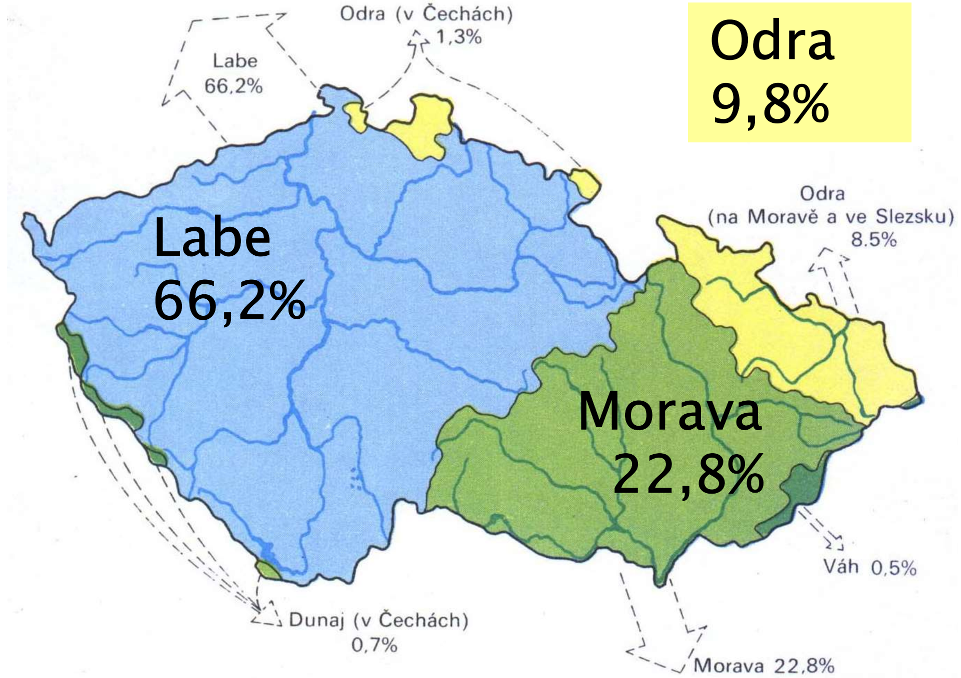
Libiš catchwater – outflow from Spolana chemical plant

Retention reservoir Lhotka – Synthesia chemical plant

Water resources in the Czech Republic – general overview

- in central Europe in the source area of European rivers (we are on the roof of Europe)
- main European watershead contour – 3 separate sea-drainage areas:

North sea – catchement of Labe	66,2%
Black sea – catchement of Dunaj	24,0%
Baltic sea – catchement of Odra	9,8%



Total lenght of streams in Czechia	76 000 km
– basic net of streams (over 5 km²)	36 865 km
Modified streams – 25% of total lenght	18 784 km
Lenght of artificial canals	578 km
Lenght of flood banks	586 km
Total volume of 114 big reservoirs (over 1000 m³)	**3,141 km³**
– water-supply reservoirs	0,934 km³
Total area of reservoirs (including small water bodies)	264 km²

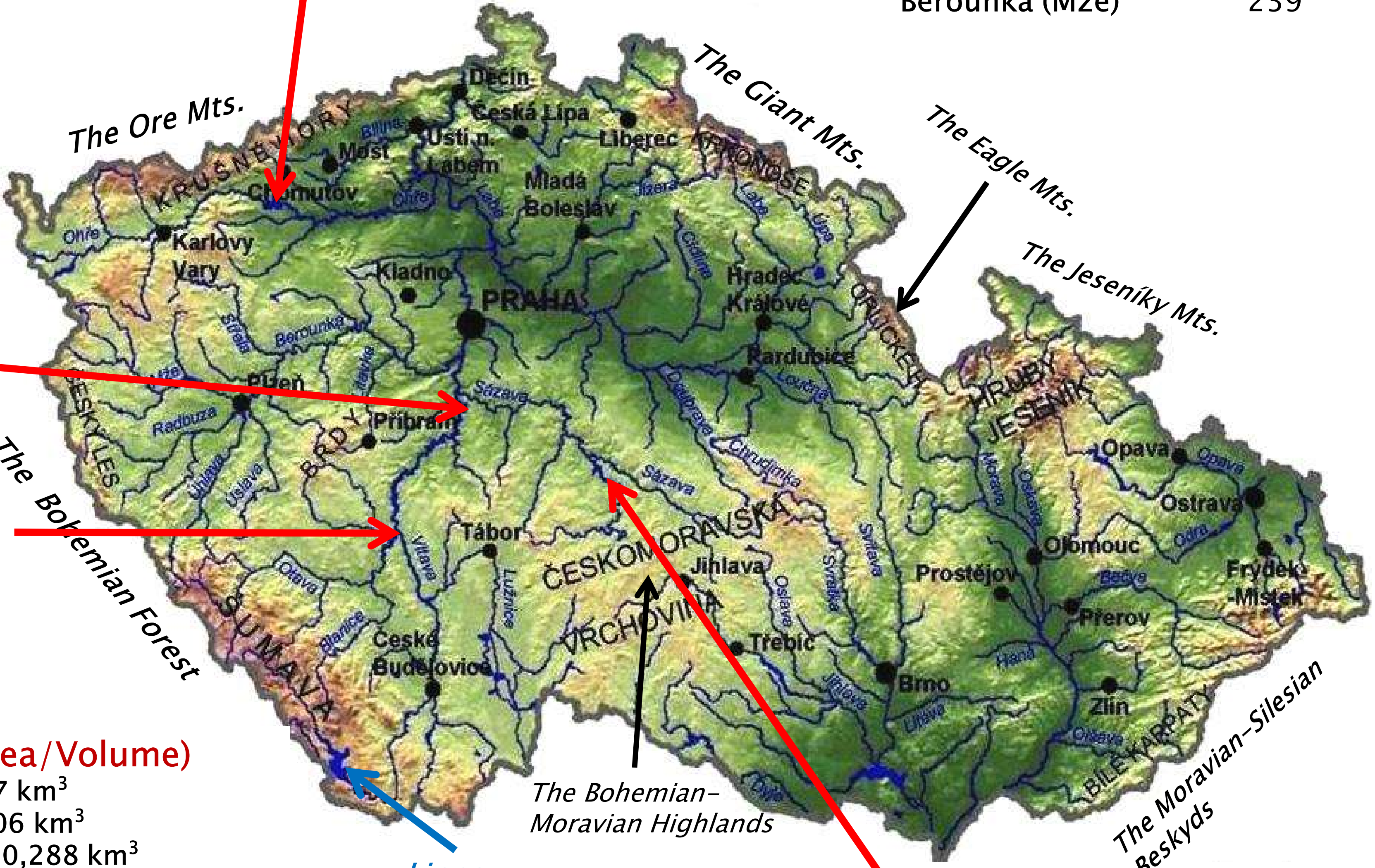
Water resources in the Czech Republic – general overview

River discharge ($m^3.s^{-1}$)

Labe (Elbe)	308
Vltava (Moldau)	150
Morava	115
Dyje (Thaya)	44,1
Odra (Oder)	43,3
Ohře (Eger)	37,9
Berounka	36,0
Otava	26,0
Sázava	25,5
Lužnice	24,4
Jizera	24,0

Lenght of rivers (km)

Vltava	433
Labe	357
Morava	352
Dyje (Mor.)	304
Ohře	291
Berounka (Mže)	239



Biggest reservoirs (Area/Volume)

Orlík – 2545,54 ha / 0,717 km^3
Lipno I – 4909,76 ha / 0,306 km^3
Nechranice – 1307,77 ha / 0,288 km^3
Slapy – 1241,15 ha / 0,269 km^3
Švihov (Želivka) 1337,55 ha / 0,266 km^3

Pollution of aquatic ecosystems

Water quality

- naturally high concentrations – change of water quality is a result of natural processes = background concentrations higher

geology : mineralization of underground waters (spa), leaching of heavy metals in acid waters

Jáchymov
– thermal and radioactive water (Rn)
– musculoskeletal diseases

Karlovy Vary – thermal and carbonic water
– diseases of digestive tract

Confluence of the Morava River and the Dyje River (left), Hohenau

What influences water, suspended load and sediment quality

geomorphology: erosion-accumulation processes
shape of terrain, length of slope,

soil character: proportioin of clay and sand (permeability), physical character (possibility to bind nutrients, humus)

climate : temperature (bacterial activity in decomposition), evaporation, precipitation – character of vegetation (interception), wind transport

Pollution of aquatic ecosystems

Sources of pollution

- anthropogenic pollution – change of water quality is a result of human activities
  agricultural, industrial or municipal production of pollution, waste waters etc.

non-point sources of pollution:

atmospheric deposition, washout from arable land – fertilizers, insecticides

solution is not easy

Arable land washout and erosion

Ouflow from Synthesia chemical plant

point sources of pollution:

localized outflow of raw or wastewaters

industrial plants, water treatment plants

easier to solve (new technologies…)

Seepage of mining waters – Oloví, the Ore Mountains

difuse sources of pollution:

number of small point sources of pollution,

dumps, villages

solution is not easy

line sources of pollution:

traffic – roads

solution is not easy

Prague orbital motorway

Water, suspended matter and sediment quality parameters

- <u>Physical parameters</u>

Temperature (°C): *each 10 minutes, influences oxygen regime and biochemical processes, aquatic organisms, drinking water optimum 8-12°C*
thermal pollution – power plants – cooling waters → *aquatic life*

pH: *logarithmic scale of acidity or basicity of water (reaction of water solutions), values between 0 and 14*
pH = -log [H^+]
acids release H^+, alkalis accept H^+
acidic substances <7, alkaline substances >7, neutral = 7
surface water 4,5 – 8,3
underground water 5,5 – 7,5
precipitation 5-6
influences chemical reactions, aquatic life
measured with a glass electrode in situ or in a laboratory

forest affected by acid rain (the Ore Mts.)

<u>Anthropogenic acidification</u>
releases of SO_2 and NO_x and other substances into the atmosphere
source: combustion processes (combustion of coal, traffic etc.)
acid rains

Content of suspended solids ($mg.L^{1}$): *general water contamination, weight difference after evaporation at 105 °C*
Increases with pollution

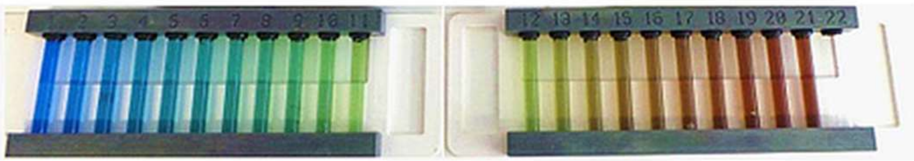
Conductivity ($mS.m^{-1}$; $1S=\Omega^{-1}$): *ability (of water) to conduct an electric current, reciprocal of electric resistivity*
depends linearly on total dissolved solids amount in water (cations and anions), temperature
measured by determining the resistance of the solution between two flat electrodes separated by a fixed distance
measurements in situ (conductometer) or in a laboratory
Increases with pollution

Water hardness(1°N): *content of calcium and magnesium in water,*
1°N = 10mg CaO in 1 liter, resp. 7,2 mg MgO in 1 litre
nowadays, analytical content of individual substances preferred

Water, suspended matter and sediment quality parameters

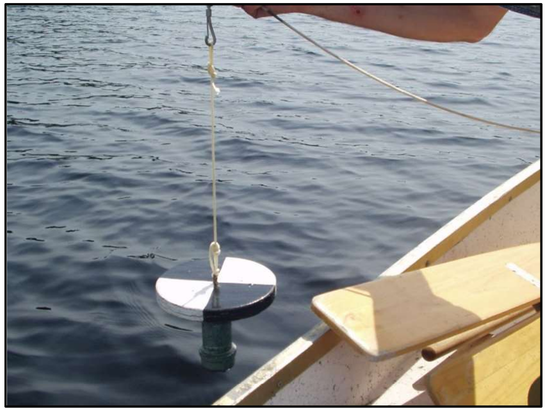
Smell: *tested by sense at 20°C and 60°C, 6 levels (grade 6 = not drinkable)*
Pollution

Colour: *given by the unabsorbed component of the visible spectrum of radiation + dissolved substances, pollution*
clear water in 1 m depth – blue colour
comparison with standards – Forel-Ule scale



Turbidity (FTU): *decrease of radiation intensity (340 nm) due to scattering and absorption*
caused by clay minerals, Fe and Mn oxides, bacteria, plankton dispersed in water
increases with circulation, pollution
1 FTU = turbidity of suspension of 1.25 mg.L^{-1} hydrazine sulfate and 12.5 mg. L^{-1} hexamethylenetetraamine in 1 L of water

Transparency (cm):
Secchi disk, depth where it is not possible to distinguish between black and white
Increases with pollution – eutrophication



- <u>Chemical parameters</u>

Oxygen: *one of the most important parameters of water quality!*
influences biochemical processes (decomposition processes!)
sources: diffusion from air, photosynthesis (day variability)
higher values in unpolluted upper river courses with cascades ets.
in lower river courses enhanced values due to planktonic photosynthesis (lakes)
measurements in situ – oximeters: ***dissolved oxygen (mg.L^{-1})*** *or* ***saturation (%)***
<u>Decrease:</u> higher temperature and salinity (inorganic pollution)
bacterial decomposition of organic material (industrial, agricultural and municipal pollution)
oxidation of organic substance
oxidation of nitrite (N-NO_2) and ammonium nitrogen (N-NH_4) into nitrate nitrogen (N-NO_3)
(nitrate fertilizers, ammonium – chemical industry)
respiration
oxidation of upper sediment layers and products of anaerobic decomposition
oxidation of pollutants!!! – decreases saturation significantly!!!

Temperature	Concentration (mg.L^{-1})
0 °C	14,621
10 °C	11,288
20 °C	9,092
30 °C	7,559

Water, suspended matter and sediment quality parameters

Main nutrients – N + P

Nitrogen compounds: *atmospheric – N_2, organic – N_{org}(sewage, slurry), ammonium N-NH_4 , nitrite N-NO_2 , nitrate N-NO_3, cyanides CN^-*

Biochemical transformations -N cycle in aquatic systems::

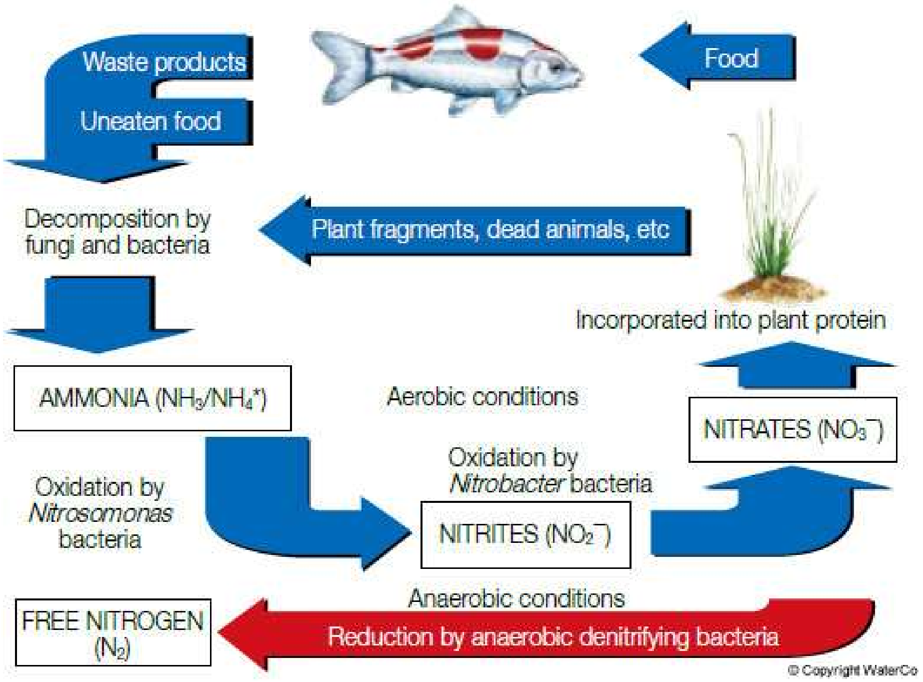
ammonium nitrogen – fast oxidation
produced by microorganisms – decomposition processes
indicates feacal pollution (8g per capita/day), toxic to fish
sources: municipal and industrial waste waters
immission standards:2,99 mg.L^{-1} natural waters 0,5 mg.L^{-1} driking water

E.g. maximum concentration in outflow in 1998: Water treatment plant Děčín 363 mg.L^{-1}

nitrite nitrogen – fast oxidation, underground water

nitrate nitrogen – final product of nitrogenous organic compounds decomposition (nitrification)
toxic to humans, especially infants (methaemoglobin)
immission standards:50 mg.L^{-1} drinking water 15 mg.L^{-1} baby water
sources: nitrogenous fertilizers (esp. industrial fertilizers-washout)
Highest values autumn/winter – washout, melting!!!
Low concentration – vegetation period (uptake)

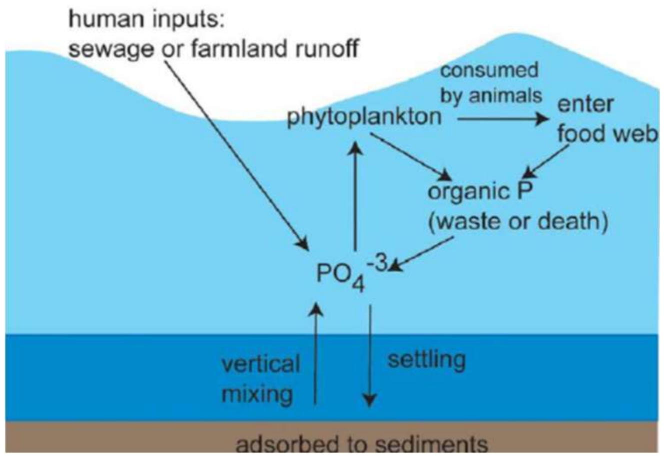
E.g. Forest brook : N-NO_3 39 mg.L^{-1} N-NH_4 0,1 mg.L^{-1} Sewer : N-NO_3 4 mg.L^{-1} N-NH_4 >20 mg.L^{-1}



www.kentfish.com.au

cyanides – highly toxic, industrial pollution, energetics

Phosphorus compounds:
organic P (1,5g per capita/day), inorganic P-PO_4
solid phosphorus -95% of total P
phosphates well soluble (uptake by organisms)
sources: minerals and rocks, phosphate fertilizers, chemical and textile industry, detergents, sediments – releases in anoxic conditions:
$FePO_4$ (Fe^{3+}) dissolution after Fe reduction PO_4^{3-} (Fe^{2+})
total P – all forms together 1,5 mg.L^{-1} drinking water



Eutrophication starter!
Effects: water bloom, organic matter, decomposition, oxygen shortage, decrease of biodiversity – degradation

Water, suspended matter and sediment quality parameters

Sulphur: *sulphates S–SO_4 –soluble, causes corrosion of concrete*
sources: geological subsoil, industrial waste waters, mining waters, atmospheric deposition (fossil fuels)
Acidification!
Calcium – *precipitation of CaO at higher temperature – pipeline clogging*
Magnesium – *corrosion of concrete, positive effects on human health*
Halogens –low concentration, elevated values = anthropogenic pollution
Chlorine –sources: municipal waste waters (9 g of chlorides/capita/day), animal production, chemical industry and traffic (wintersalting); bacterial disinfection of drinking water (minimum 0,05 $mg.L^{-1}$)
Fluorine – lack in drinking water may cause dental caries/excessive concentrations cause fluorosis

Heavy metals – density > 5000 $kg.m^{-3}$
toxic for aquatic organism, in small amounts essential to humans
chronic and acute toxicity, carcinogenicity
bioaccumulation, adsorbed on suspended matter ⟶ accumulation in sediments! – ENVIRONMENTAL RISKS
= OLD LOADS! = remobilization!!!

E.g. thousend times higher values of Hg in sediments – the Elbe River watershed

sources: geological subsoil, metalliferous areas, anthropogenic enrichment – mining, ore processing, chemical industry, fossil fuels, traffic

Pb sources: lead pipeline! Admixture for gasoline (not anymore),
chemical industry, metallurgy, polygraphy, accumulators
effects: brain damages
drinking water limit: 0,05 $mg.L^{-1}$
Cd high toxicity, bioaccumulation, together with Zn
sources: metalliferous areas, chemical industry, polygraphy, PVC, fossil fuels
effects: infertility, bone decalcification, carcinogenic
drinking water limit: 0,005 $mg.L^{-1}$
Hg high toxicity, bioaccumulation,
sources: metalliferous areas, chemical industry – electrolysis, metalworking industry, fossil fuels, pesticides, fungicides, dental amalgam
effects: nervous, digestive, immune system, damages of organs, fetal development
drinking water limit: 0,001 $mg.L^{-1}$
Zn toxicity for aquatic organisms, improvement of human immunity!!!
sources: metalliferous areas, metalworking industry, accumulators, fossil fuels,
drinking water limit: 5 $mg.L^{-1}$
Cu toxicity for aquatic organisms, essential to humans, not so high bioaccumulation
sources: metalliferous areas, metalworking industry,
drinking water limit: 0,1 $mg.L^{-1}$

Water, suspended matter and sediment quality parameters

Organic compounds

sources: natural leaching of humic substances from soil and sediments, municipal, agricultural and industrial pollution

hundreds of substances $\longrightarrow$ *common determination*

BOD $_5$ ($mg.L^{-1}$) – biological oxygen demand

decrease of oxygen concentration after 5 days due to decomposition of biodegradable organic matter

municipal waste waters, agricultural pollution – e.g. animal producuction, less commonly industrial pollution – e.g. Food production, paper mills etc.

$$C_t = C_0.e^{-K_1 t}$$

C_t – concentration after 5 days

C_0 – concnetration day 0

t = 5 days

K_1 – degradation constant (Industrial wastewater 0,1 – 0,87)

E.g. maximum concentration in outflow in 1998: Bioferm Kolín (destillery and yeast factory) 964 $mg.L^{-1}$

unpolluted surface water $BOD_5 < 2,0$ $mg.L^{-1}$

COD ($mg.L^{-1}$) – chemical oxygen demand,

decrease of oxygen concentration due to chemical oxidation of organic pollution using oxidizing agent:

industrial pollution – e.g. persistent organic pollutants, municipal pollution – e.g. detergents

A. potassium dichromate $K_2Cr_2O_7$ – industrial wastewaters

B. potassium permanganate $KMnO_4$ – drinking water, surface waters

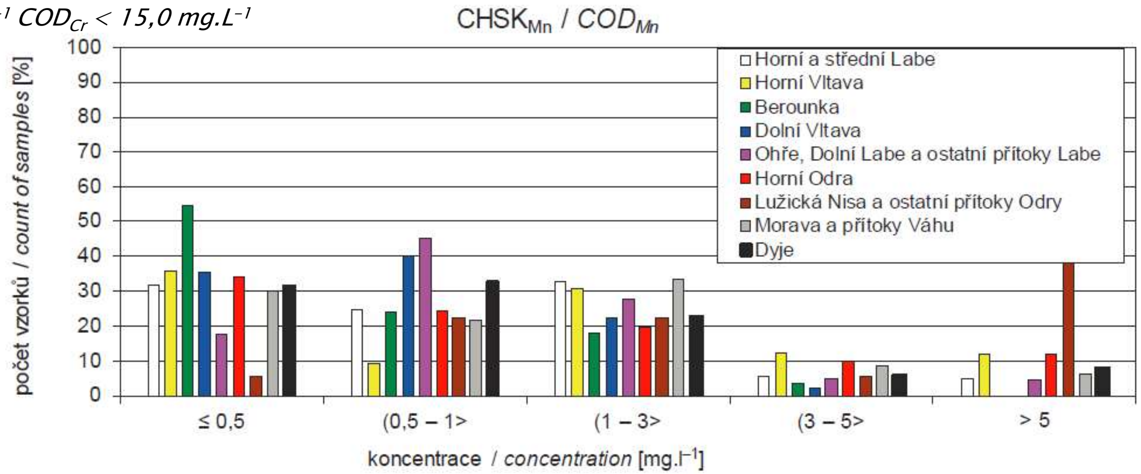
drinking water limit: 3,0 $mg.L^{-1}$ unpolluted surface water $COD_{Mn} < 6,0$ $mg.L^{-1}$ $COD_{Cr} < 15,0$ $mg.L^{-1}$

E.g. maximum concentration in outflow in 1992 :
Fruta Kralupy (food production, cannery 5701 $mg.L^{-1}$

Waste water source	BOD_5 ($mg.L^{-1}$)	COD_{Cr} ($mg.L^{-1}$)
Paper mills	500	1000
Breweries and malting plants	850	1700
Tanning industry	1000	2000
Sugar refinery	1000	1500
Yeast factory	2200	3500
Fluid pig excrements	20000	40000

Langhammer, 2006: Water quality course, FaSci, UC

Comparison of organic pollution in Czech watersheds in 2015



TOC (C_{org}) – oxidation of all organic substances and production of CO_2 and H_2O

A. Wet combustion – strong oxidizing agent

B. Thermic combustion

determination of produced CO_2

$$BOD_5 \leq COD_{Mn} \leq COD_{Cr} \leq TOC$$

unpolluted surface water TOC< 7,0 $mg.L^{-1}$

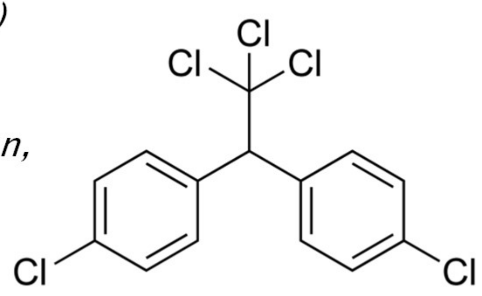
Water, suspended matter and sediment quality parameters

Specific organic compounds = xenobiotics

sources: anthropogenic production – industrial wastes, industrial accidents (petroleum substances), pesticides – purposefully released in the environment
toxic, carcinogenic, mutagenic
Persistent (POPs – persistent organic pollutants), hardly soluble in water, soluble in fat, adsorbed on suspended matter
__accumulation in sediments!__ ⟶ *ENVIRONMENTAL RISKS = OLD LOADS! = remobilization!!!*

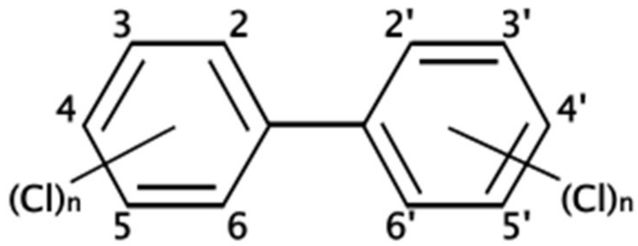
__Pesticides__ – herbicides (weed killers), insecticides (insects killers), fungicides (fungi killers)
*washout from areas of application, **sediments**, bioaccumulation*
***Chlorinated organic compounds**:*
__DDT (dichlorodiphenyltrichloroethane (DDE, DDD)__ – persistent insecticide, bioaccumulation, food chain, carcinogenicity
massive application all over the world (1950s, 1960s)
In Czechoslovakia forbidden in 1975
__Lindan (HCH – Y hexachlorocyclohexane)__ – persistent insecticide, forbidden
__HCB (Hexachlorobenzene)–__ persistent fungicide, volatile, forbidden

unpolluted surface water HCH < 3,0 $ng.L^{-1}$



***Organophosphorus pesticides**: common nowadays*
***Nitrophenol pesticides**: herbicides, insecticides, toxic to nervous system of animals*
***Carbamides** :fertilizer, herbicide, not so toxic*
Nitrogen heterocyclic pesticides

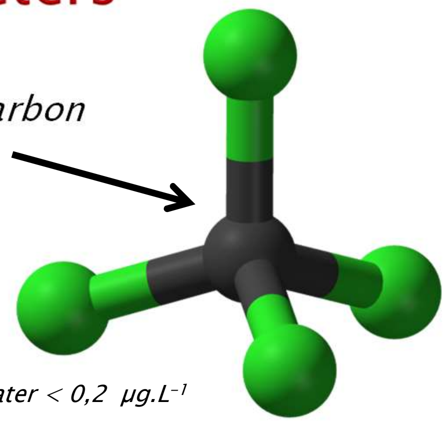
__PCB – polychlorinated biphenyls__ – 209 substance – especially 17 congeners very toxic
non-flammable, insoluble in water, soluble in fat,
electrical insulating, good heat conductivity
production: dyes, plastics, asphalt, insulating coating
sources: wastes, industrial accidents, black dumps
*bioaccumulation, persistence, **accumulation in sediments!!!***
carcinogenicity, infertility, mutagenity, teratogenity,
disruption of the hormonal system
In Czechoslovakia forbidden in 1981



unpolluted surface water PCB < 5,0 $ng.L^{-1}$
Sum of PCB 28, 51, 101, 138, 153, 180

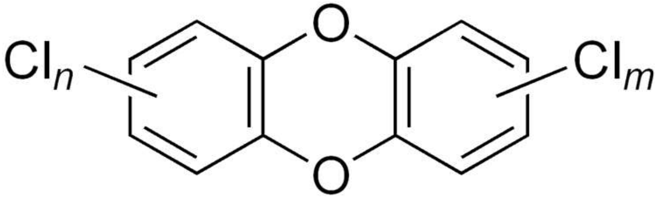
Water, suspended matter and sediment quality parameters

__AOX__ – adsorbable organically bound halogens (mostly chlorinated)
common parameter determinating total amount of AOX in water adsorbed on activated carbon
large group of compounds: trichloromethane, 1,2-dichloromethane, tetrachloromethane
chlorobenzene, dichlorobenzene, dioxins
sources: paper and cellulose production, organic syntheses,
synthetic fibres, coatings, cleaning agents, solvents,
persistent, insoluble in water, soluble in fat – accumulation
carcinogenic, nervous system damage, skin irritation

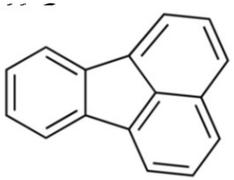


unpolluted surface water < 0,2 μg.L^{-1}

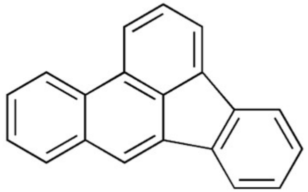
__Dioxins__ (PCDD – polychlorinated dibenzodioxines, PCDF -polychlorinated dibenzofurans)
*– highly toxic and persistent, **suspended matter, sediments**, accumulation in fat (meat, milk, eggs!)*
__by-products__ during production of pesticides (Agent Orange),
combustion processes
liver and skin damage, carcinogenicity, teratogenity



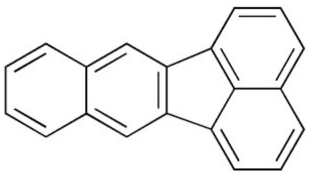
__PAHs__ – polycyclic aromatic hydrocarbons
sources: __by-products__ during combustion processes, asphalt, tar, aluminium production, coking plants,
leaching or evaporating from materials containing PAU
white or yellow crystalline substances, insoluble in water, soluble in fat, volatile, persistent, long transport
some PAHs carcinogenic, mutagenic, teratogenic
PA



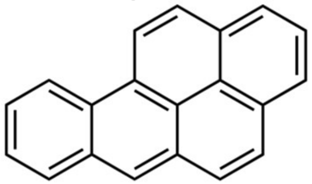
fluoranthene



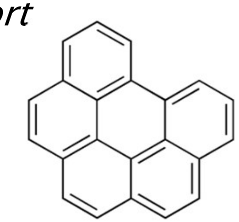
benzo(b)fluoranthene



benzo(k)fluoranthene

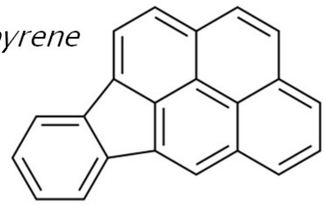


benzo(a)pyrene



benzo(ghi)perylene

indeno(1,2,3-d,c)pyrene

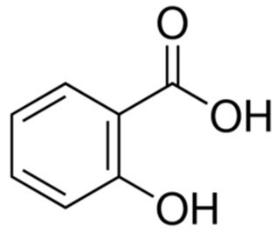


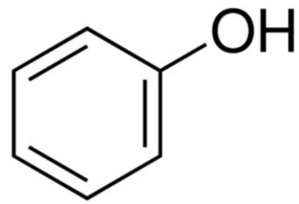
unpolluted surface water PAU 5< 10,0 ng.L^{-1}
Sum of fluoranthene, benzo(a)pyrene, benzo(b)fluoranthene,
benzo(g,h,i)perylene, indeno(1,2,3-c,d,)pyrene

Water, suspended matter and sediment quality parameters

__Phenols__

__Phenol__ – monocyclic, white crystalline substance, slightly soluble in water = yellow/brown water
toxic to aquatic organisms (esp. fish), higher concentration can damage human organs
sources: natural (vegetation, animals), volatile,
wastewater from coal processing, petrochemical industry
production: disinfectants, pesticides, salicylic acid (aspirin)

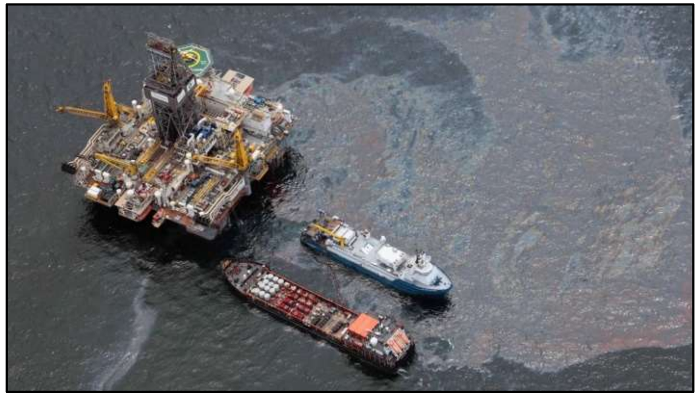




chlorinated phenols – anthropogenic, toxic, bioaccumulation

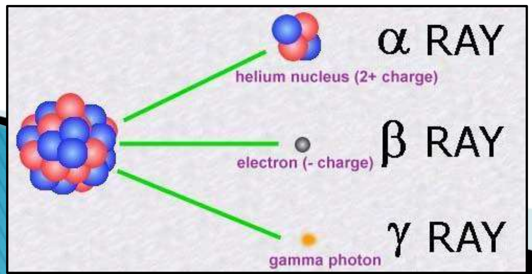
__Tensides and detergents__ – prevent gas exchange between water an the atmosphere, self-cleaning processes, foam

__Petroleum substances__ – accidents (tankers), traffic,
layer on water surface prevents gas exchange (50 L of oil = 1km^2),
respiration of aquatic organisms, bioaccumulation



- Radioactivity

__Radioactivity (Bq.L^{-1}, Bq.kg^{-1})__
energetically unstable atomic nuclei emit radiation (particles or waves) to create more stable forms (new elements or the same elements with a different number of nuclear particles – ISOTOPES
not detectable by senses
__-natural radioactivity__ – produces by cosmic radiation in the atmosphere/geological subsoil
__-artificial radioactivity__ – nuclear reaction induced by bombing nuclei with other radiation/particles (neutrons –^{137} Cs)
Radiation:



Danger: artificial radioactivity (nuclear weapons, nuclear power plants, nuclear waste repositories, bioaccumulation, food chain…

Measuremensts: α, β, ϒ activities, uranium concentration (μg.L^{-1})

Water, suspended matter and sediment quality parameters

Relative Abundance of the Natural Isotopes

Isotope		%		%		%
1	H	99.985				
2	H	0.015				
3			He	0.000137		
4			He	99.999863		
5						
6					Li	7.5
7					Li	92.5
8						
9	Be	100				
10			B	19.9		
11			B	80.1		
12					C	98.90
13					C	1.10
14	N	99.643				
15	N	0.366				
16			O	99.762		
17			O	0.038		
18			O	0.200		
19					F	100
20	Ne	90.48				
21	Ne	0.27				
22	Ne	9.25				
23			Na	100		
24					Mg	78.99
25					Mg	10.00
26					Mg	11.01
27	Al	100				
28			Si	92.23		
29			Si	4.67		
30			Si	3.10		
31					P	100
32	S	95.02				
33	S	0.75				
34	S	4.21				
35			Cl	75.77		
36	S	0.02			Ar	0.337
37			Cl	24.23		
38					Ar	0.063
39	K	93.2581				
40	K	0.0117	Ca	96.941	Ar	99.600
41	K	6.7302				
42			Ca	0.647		
43			Ca	0.135		
44			Ca	2.086		
45					Sc	100
46	Ti	8.0	Ca	0.004		
47	Ti	7.3				
48	Ti	73.8	Ca	0.187		
49	Ti	5.5				
50	Ti	5.4	V	0.250	Cr	4.345
51			V	99.750		
52					Cr	83.789
53					Cr	9.501
54	Fe	5.8			Cr	2.365
55			Mn	100		
56	Fe	91.72				
57	Fe	2.2				
58	Fe	0.28			Ni	68.077
59			Co	100		
60					Ni	26.223

Isotope		%		%		%
61					Ni	1.140
62					Ni	3.634
63	Cu	69.17				
64			Zn	48.6	Ni	0.926
65	Cu	30.83				
66			Zn	27.9		
67			Zn	4.1		
68			Zn	18.8		
69					Ga	60.108
70	Ge	21.23	Zn	0.6		
71					Ga	39.892
72	Ge	27.66				
73	Ge	7.73				
74	Ge	35.94	Se	0.89		
75					As	100
76	Ge	7.44	Se	9.36		
77			Se	7.63		
78	Kr	0.35	Se	23.78		
79					Br	50.69
80	Kr	2.25	Se	49.61		
81					Br	49.31
82	Kr	11.6	Se	8.73		
83	Kr	11.5				
84	Kr	57.0	Sr	0.56		
85					Rb	72.165
86	Kr	17.3	Sr	9.86		
87			Sr	7.00	Rb	27.835
88			Sr	82.58		
89					Y	100
90	Zr	51.45				
91	Zr	11.22				
92	Zr	17.15	Mo	14.84		
93					Nb	100
94	Zr	17.38	Mo	9.25		
95			Mo	15.92		
96	Zr	2.80	Mo	16.68	Ru	5.52
97			Mo	9.55		
98			Mo	24.13	Ru	1.88
99					Ru	12.7
100			Mo	9.63	Ru	12.6
101					Ru	17.0
102	Pd	1.02			Ru	31.6
103			Rh	100		
104	Pd	11.14			Ru	18.7
105	Pd	22.33				
106	Pd	27.33	Cd	1.25		
107					Ag	51.839
108	Pd	26.46	Cd	0.89		
109					Ag	48.161
110	Pd	11.72	Cd	12.49		
111			Cd	12.80		
112	Sn	0.97	Cd	24.13		
113			Cd	12.22	In	4.3
114	Sn	0.65	Cd	28.73		
115	Sn	0.34			In	95.7
116	Sn	14.53	Cd	7.49		
117	Sn	7.68				
118	Sn	24.23				
119	Sn	8.59				
120	Sn	32.59	Te	0.096		

Isotope		%		%		%
121					Sb	57.36
122	Sn	4.63	Te	2.603		
123			Te	0.908	Sb	42.64
124	Sn	5.79	Te	4.816	Xe	0.10
125			Te	7.139		
126			Te	18.95	Xe	0.09
127	I	100				
128			Te	31.69	Xe	1.91
129					Xe	26.4
130	Ba	0.106	Te	33.80	Xe	4.1
131					Xe	21.2
132	Ba	0.101			Xe	26.9
133			Cs	100		
134	Ba	2.417			Xe	10.4
135	Ba	6.592				
136	Ba	7.854	Ce	0.19	Xe	8.9
137	Ba	11.23				
138	Ba	71.70	Ce	0.25	La	0.0902
139					La	99.9098
140			Ce	88.48		
141					Pr	100
142	Nd	27.13	Ce	11.08		
143	Nd	12.18				
144	Nd	23.80	Sm	3.1		
145	Nd	8.30				
146	Nd	17.19				
147			Sm	15.0		
148	Nd	5.76	Sm	11.3		
149			Sm	13.8		
150	Nd	5.64	Sm	7.4		
151					Eu	47.8
152	Gd	0.20	Sm	26.7		
153					Eu	52.2
154	Gd	2.18	Sm	22.7		
155	Gd	14.80				
156	Gd	20.47	Dy	0.06		
157	Gd	15.65				
158	Gd	24.84	Dy	0.10		
159					Tb	100
160	Gd	21.86	Dy	2.34		
161			Dy	18.9		
162	Er	0.14	Dy	25.5		
163			Dy	24.9		
164	Er	1.61	Dy	28.2		
165					Ho	100
166	Er	33.6				
167	Er	22.95				
168	Er	26.8	Yb	0.13		
169					Tm	100
170	Er	14.9	Yb	3.05		
171			Yb	14.3		
172			Yb	21.9		
173			Yb	16.12		
174			Yb	31.8	Hf	0.162
175	Lu	97.41				
176	Lu	2.59	Yb	12.7	Hf	5.206
177					Hf	18.606
178					Hf	27.297
179					Hf	13.629
180	Ta	0.012	W	0.13	Hf	35.100

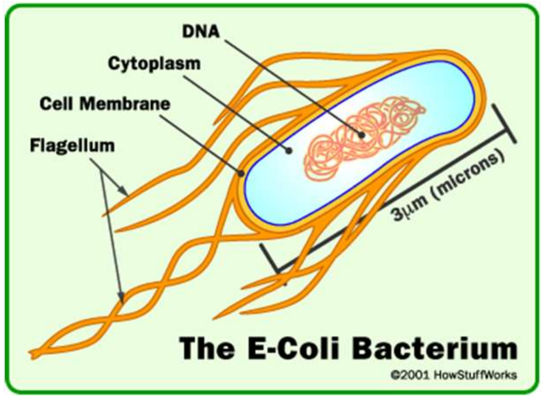
Isotope		%		%		%
181	Ta	99.988				
182			W	26.3		
183			W	14.3		
184	Os	0.02	W	30.67		
185					Re	37.40
186	Os	1.58	W	28.6		
187	Os	1.6			Re	62.60
188	Os	13.3				
189	Os	16.1				
190	Os	26.4			Pt	0.01
191			Ir	37.3		
192	Os	41.0			Pt	0.79
193			Ir	62.7		
194					Pt	32.9
195					Pt	33.8
196	Hg	0.15			Pt	25.3
197			Au	100		
198	Hg	9.97			Pt	7.2
199	Hg	16.87				
200	Hg	23.10				
201	Hg	13.18				
202	Hg	29.86				
203					Tl	29.524
204	Hg	6.87	Pb	1.4		
205					Tl	70.476
206			Pb	24.1		
207			Pb	22.1		
208			Pb	52.4		
209	Bi	100				
210						
211						
212						
213						
214						
215						
216						
217						
218						
219						
220						
221						
222						
223						
224						
225						
226						
227						
228						
229						
230						
231	Pa	100				
232	Th	100				
233						
234	U	0.0055				
235	U	0.7200				
236						
237						
238	U	99.2745				

"Isotopic Compositions of the Elements 1989" Pure Appl. Chem., Vol. 63, No. 7, pp. 991-1002, 1991. © 1991 IUPAC

PERKIN ELMER SCIEX

Water, suspended matter and sediment quality parameters

- <u>Microbiological and biological paremeters</u>

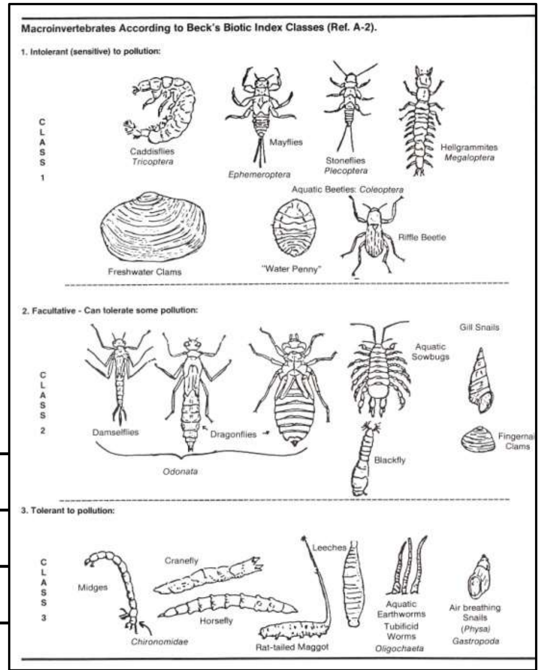


<u>abundance of thermotolerant coliform bacteria (number of bacteria/volume)</u>
Escherichia coli – commonly in the lower intestine of warm-blooded organisms
maintains bacterial balance in intestines and contributes to the synthesis of vitamins (K)
indicates feacal pollution

drinking water = zero in 100ml

<u>abundance of enterococci (number of bacteria/volume)</u>
E. faecalis (90-95%) a E. faecium (5-10%) commonly in intestines
indicates feacal pollution
bacteral deseases

<u>chlorophyll a (μg.L^{-1})</u>
– photosynthetic pigment, green colour, reflects the amount of photosynthetically active organisms in water (plants, cyanobacteria and some algae)
<u>saprobity</u> *– water quality evaluation based on presence of certain species (macrozoobenthos) indicating certain level of water pollution*
saprobic system comprises a wide range of organisms (indicators) – wide applications
presence of the indicator species corresponds to the level of <u>organic pollution</u> (BOD$_5$ values), <u>oxygen</u> concentrations, abundance of <u>bacteria</u> and prevailing <u>processes</u> (aerobic/anaerobic)
various systems
e.g. Kolkwitz and Marsson (1902,08,09): I. Catarobity II. Oligosaprobity III. ß-Mesosaprobity IV. α -Mesosaprobity V. Polysaprobity
Sládeček: catarobity, limnosaprobity, eusaprobity, transsaprobity



<u>trophy</u> *– evaluation based on nutrient supply available for plant growth*
trophic levels correspond to certain <u>contents of P</u> (P total), <u>N</u> (N total), <u>chlorophyll a</u>, <u>oxygen saturation</u> and water t<u>ransparency</u>
*(N)+P liminting factors – **<u>eutrophication</u>***
rough estimations of biological condition of a water body various systems

Chl a (μg.L^{-1})	P (tot) (mg.L^{-1})	Secchi disk depth (m)	Trophic Class
0—2.6	0—12	> 8—4	Oligotrophic
2.6—20	12—24	4—2	Mesotrophic
20—56	24—96	2—0.5	Eutrophic
56—155+	96—384+	0.5— < 0.25	Hypereutrophic

(Carlson ,1996)

Water, suspended matter and sediment monitoring

- **State monitoring networks** – state institutions

Czech Hydrometeorological Institute http://portal.chmi.cz/
- general network, selection of monitoring profiles, general databases
- forecasts, assessment – *Hydrological yearbook*

River basins administrators:
- sampling, own sampling stations, analyses
- since 2012 general databases of suspended matter and sediment quality

the Labe River Authority – http://www.pla.cz (Hradec Králové)14 976 km²
the Morava River Authority – http://www.pmo.cz (Brno) 21 133 km²
the Vltava River Authority http://www.pvl.cz (Praha) 27 580 km²
the Ohře River Authority – http://www.poh.cz (Chomutov) 10 098 km²
the Odra River Authority – http:www-pod.cz (Ostrava) 7 246 km²

Forests of the Czech Republic– http://www.lesycr.cz (Hradec Králové)
- 94 % of streams
- 6 % municipalities, national parks, military areas

- **Purpose monitoring** – *e.g. monitoring after an industrial accident, remediation of polluted water bodies*

T.G.M Water Research Institute ASCI CR,
Research Instittute for Soil and Water Conservation ASCI CR
Czech Geological Survey, universities,
environmental institutions, private environmental companies,
restoration companies
nongovernmental organisations etc...

Messstellen des Internationalen Messprogramms Elbe (Stand: 2015)
Měrné profily Mezinárodního programu měření Labe (stav: 2015)

Bearbeiter: / Zpracováno: Bundesanstalt für Gewässerkunde (BfG), Koblenz / Spolkový ústav hydrologický (BfG), Koblenz
Tschechisches Hydrometeorologisches Institut (ČHMÚ), Prag / Český hydrometeorologický ústav (ČHMÚ), Praha
Internationale Kommission zum Schutz der Elbe (IKSE), Magdeburg / Mezinárodní komise pro ochranu Labe (MKOL), Magdeburg

- **International monitoring programmes**

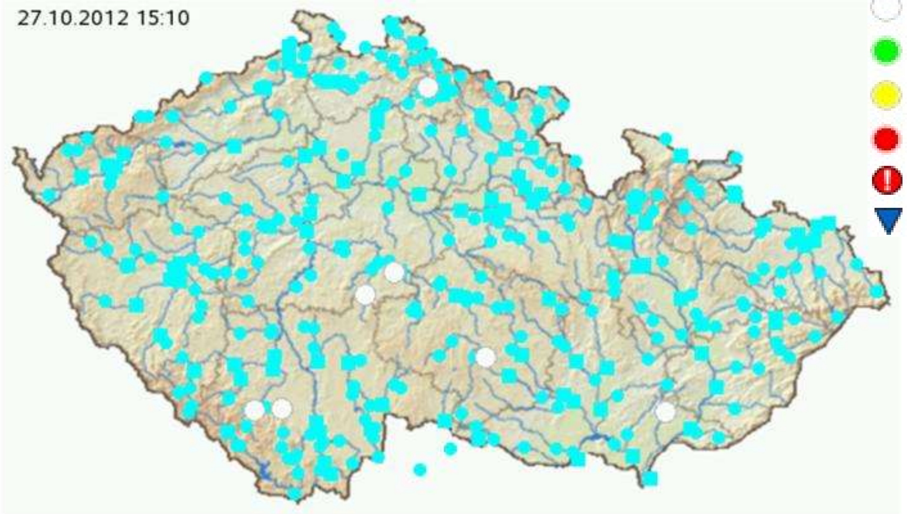
e.g. International Commission for the Protection of the Elbe River
international sampling stations on teh Elbe River (since 1993)

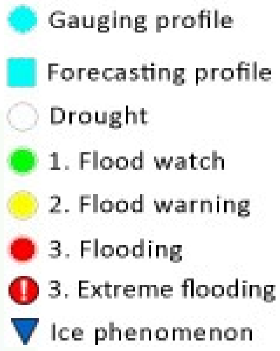
Water, suspended matter and sediment monitoring

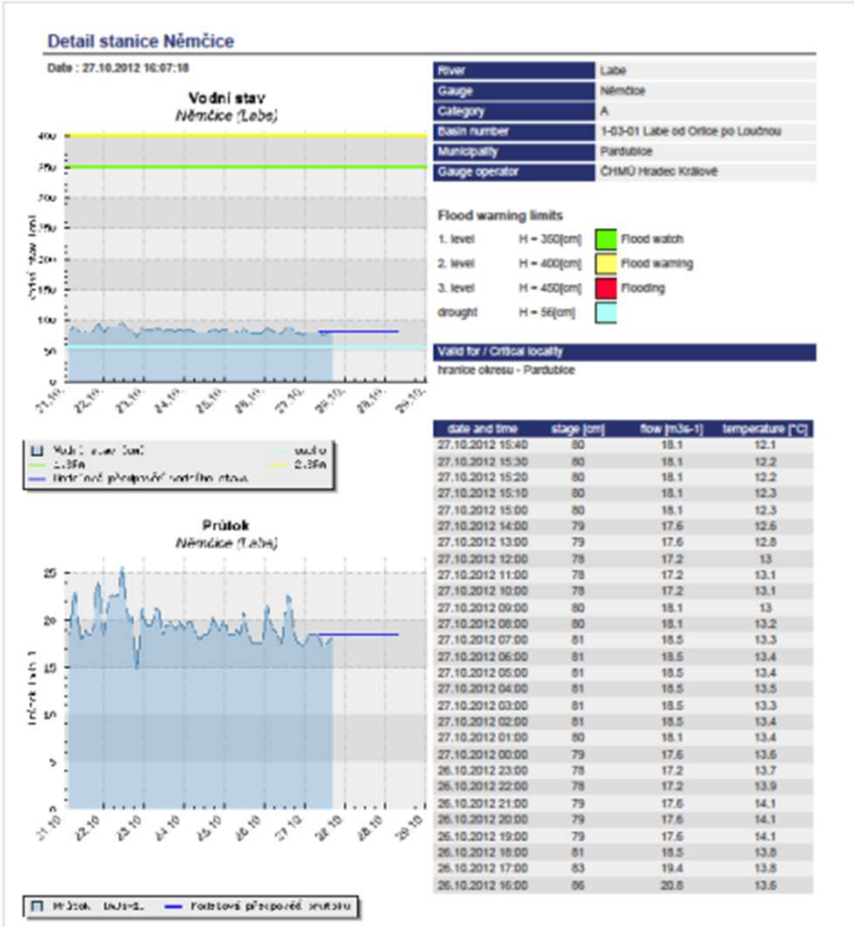
- **Details of monitoring – hydrological balance of water quantity and quality assessment**

__water quantity__ – cca 430gauging stations
water level (m a.s.l.)
discharge Q ($m^3 .s^{-1}$)
precipitation, snow, temperature
measurements each 10 minutes

www.chmi.cz – Czech Hydrometeorological Institute
Flood forecasting service (CHMI) http://hydro.chmi.cz/hpps/index.php



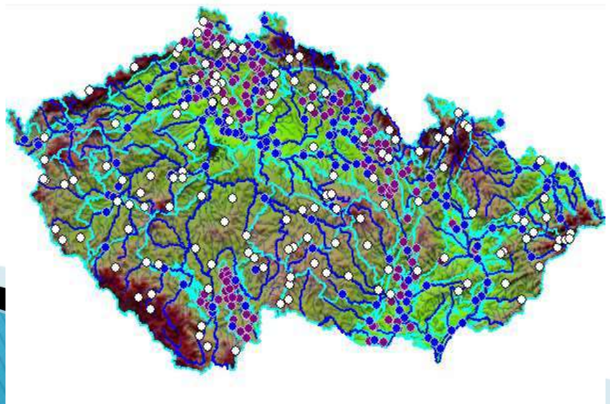




River	Labe
Gauge	Němčice
Category	A
Basin number	1-03-01 Labe od Orlice po Loučnou
Municipality	Pardubice
Gauge operator	ČHMÚ Hradec Králové

date and time	stage [cm]	flow [m3s-1]	temperature [°C]
27.10.2012 15:40	80	18.1	12.1
27.10.2012 15:30	80	18.1	12.2
27.10.2012 15:20	80	18.1	12.2
27.10.2012 15:10	80	18.1	12.3
27.10.2012 15:00	80	18.1	12.3
27.10.2012 14:00	79	17.6	12.6
27.10.2012 13:00	79	17.6	12.8
27.10.2012 12:00	78	17.2	13
27.10.2012 11:00	78	17.2	13.1
27.10.2012 10:00	78	17.2	13.1
27.10.2012 09:00	80	18.1	13
27.10.2012 08:00	80	18.1	13.2
27.10.2012 07:00	81	18.5	13.3
27.10.2012 06:00	81	18.5	13.4
27.10.2012 05:00	81	18.5	13.4
27.10.2012 04:00	81	18.5	13.5
27.10.2012 03:00	81	18.5	13.3
27.10.2012 02:00	81	18.5	13.4
27.10.2012 01:00	80	18.1	13.4
27.10.2012 00:00	79	17.6	13.6
26.10.2012 23:00	78	17.2	13.7
26.10.2012 22:00	78	17.2	13.9
26.10.2012 21:00	79	17.6	14.1
26.10.2012 20:00	79	17.6	14.1
26.10.2012 19:00	79	17.6	14.1
26.10.2012 18:00	81	18.5	13.8
26.10.2012 17:00	83	19.4	13.8
26.10.2012 16:00	86	20.8	13.6

__surface water quality sampling__
since 1963, 12× or 24× year, cca 200 sampling stations,
cca 80 paramteters
e.g. in 2015 resutls available from 1673 sampling points
historically over 350 parameters)



__underground water quality sampling__
175 springs
221 shallow udergroundwater (Holocene)
267 deep hydrogeological wells

Water, suspended matter and sediment monitoring

- Details of monitoring – hydrological balance of water quantity and quality assessment

suspended matter sampling

quantity since 1984, cca 38 sampling stations,
concentration c (mg.L^{-1}), discharge of suspended matter Qsm (kg.s^{-1}),
suspended matter runoff Gsm (t), specific suspended matter runoff (t.km^{-2})
quality since 1999, 4× year, cca 47 sampling stations, 127 parameters
granulometry (sedimentation techniques, laser)
total C and P, fraction <20μm heavy metals
fraction <2 mm specific organic compounds

Suspended matter samplers

sediment sampling

since 1999, 2 × year , cca 47 sampling stations, 127 parameters
surface riverbed sediments, granulometry (sieving, sedimentation techniques)
fraction <20μm heavy metals,
total C and P
fraction <2 mm specific organic compounds

Sediment samplers

biota

22 sampling stations, 1 × year
biofilm, fish, juvenile fish, benthos
– Dreissena polymorpha, Hydropsyche sp., Erpobdella sp., Gammarus sp.

Water, suspended matter and sediment monitoring

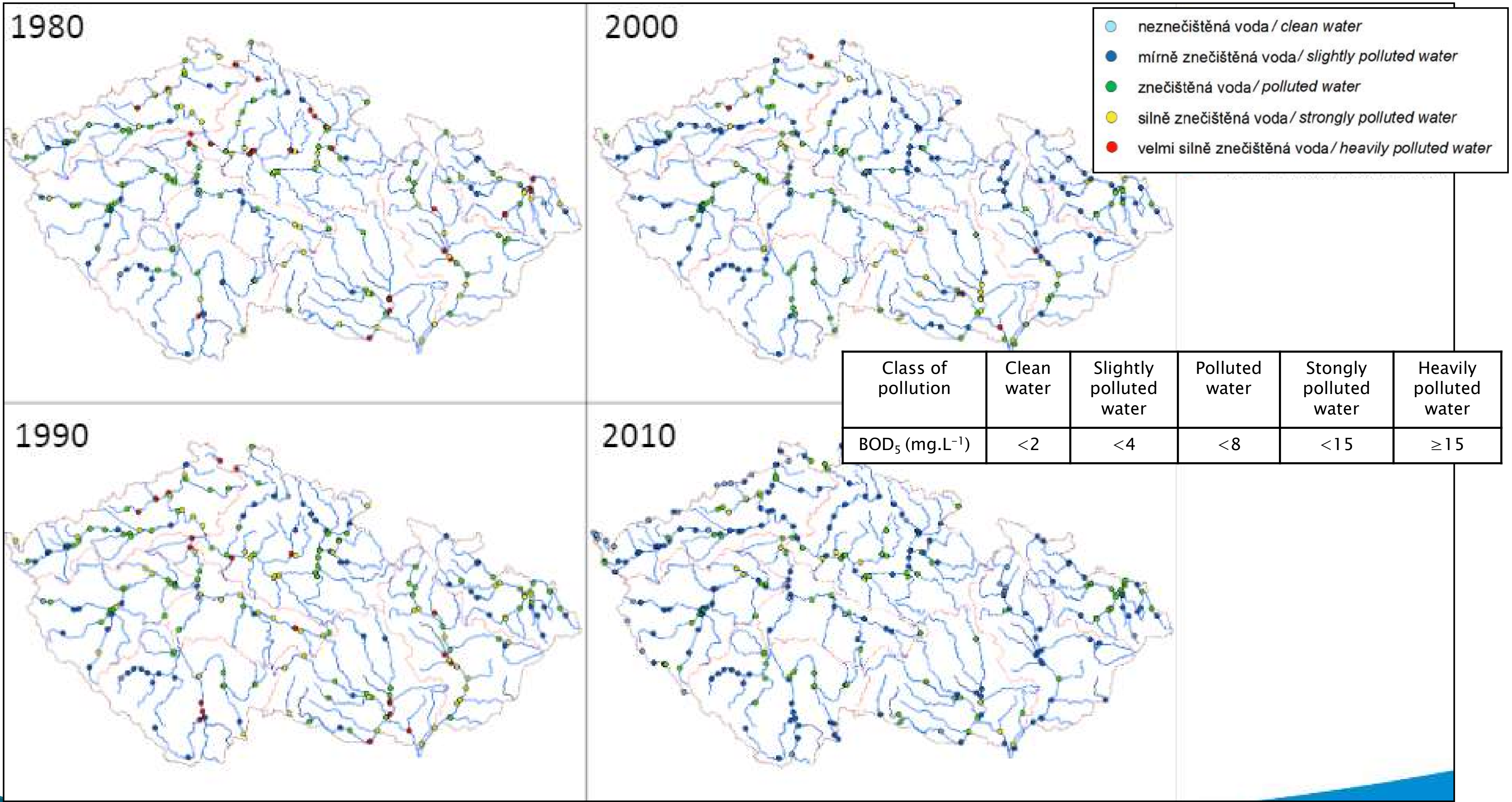
Laboratories of Povodí Labe s.p. (the Elbe River Authority) – analytical methods – suspended matter, sediments

PARAMETER_DETAIL	SOP	SOP-POPIS	unit
zinc	AK12B	Determination of metals and phosphorus ICP/OES - DIN 38406 - E22	mg/kg
nickel	AK12B	Determination of metals and phosphorus ICP/OES - DIN 38406 - E22	mg/kg
lead	AK12B	Determination of metals and phosphorus ICP/OES - DIN 38406 - E22	mg/kg
arsen	AK10B	Determination of metals AAS/ETA - ČSN EN ISO 15586	mg/kg
copper	AK12B	Determination of metals and phosphorus ICP/OES - DIN 38406 - E22	mg/kg
mercury	AK05B	Determination of mercury - ČSN 757440	mg/kg
cadmium	AK10B	Determination of metals and phosphorus ICP/OES - DIN 38406 - E22	mg/kg
chromium	AK12B	Determination of metals and phosphorus ICP/OES - DIN 38406 - E22	mg/kg
PCB congener 28	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
PCB congener 52	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
PCB congener 101	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
PCB congener 118	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
PCB congener 138	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
PCB congener 153	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
PCB congener 180	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
alfa-hexachlorcyklohexane	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
hexachlorobenzene	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
pentachlorobenzene	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
beta-hexachlorecyklohexane	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
gama-hexachlorecyklohexane	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
p,p-DDE	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
p,p-DDD	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
p,p-DDT	AO18B	Determination of PCB,OCP,PBDE,DEHP,mos.,pyrethr.,ch.alk.C10-13,C14-17-GC/MS/MS-ISO18856,22032	µg/kg
suma 6 cong. PAU	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
suma 5 cong. PAU	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
fenanthrene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
anthracene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
fluoranthene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
pyrene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
benzo(a)anthracene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
chrysene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
benzo(b)fluoranthen	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
benzo(k)fluoranthen	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
benzo(a)pyrene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
benzo(g,h,i)perylene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
indeno(1,2,3.c,d)pyrene	AO05B	Determination of PAU HPLC/FD - TNV 758055, EPA 8310	µg/kg
hydrocarbons C10-C40	AO14B	Determination of hydrocarbons C10-C40 GC/FID - ČSN EN 14039, ČSN EN ISO 16703	mg/kg
tributyltin	AO19B	Bestimmung von Organo-Zinn Stoffe GC/MSD - ČSN EN ISO 23161	µg/kg

Water quality development in the Czech Republic

- BOD$_5$

- pollution assessment according to Czech State Norm 75 7221



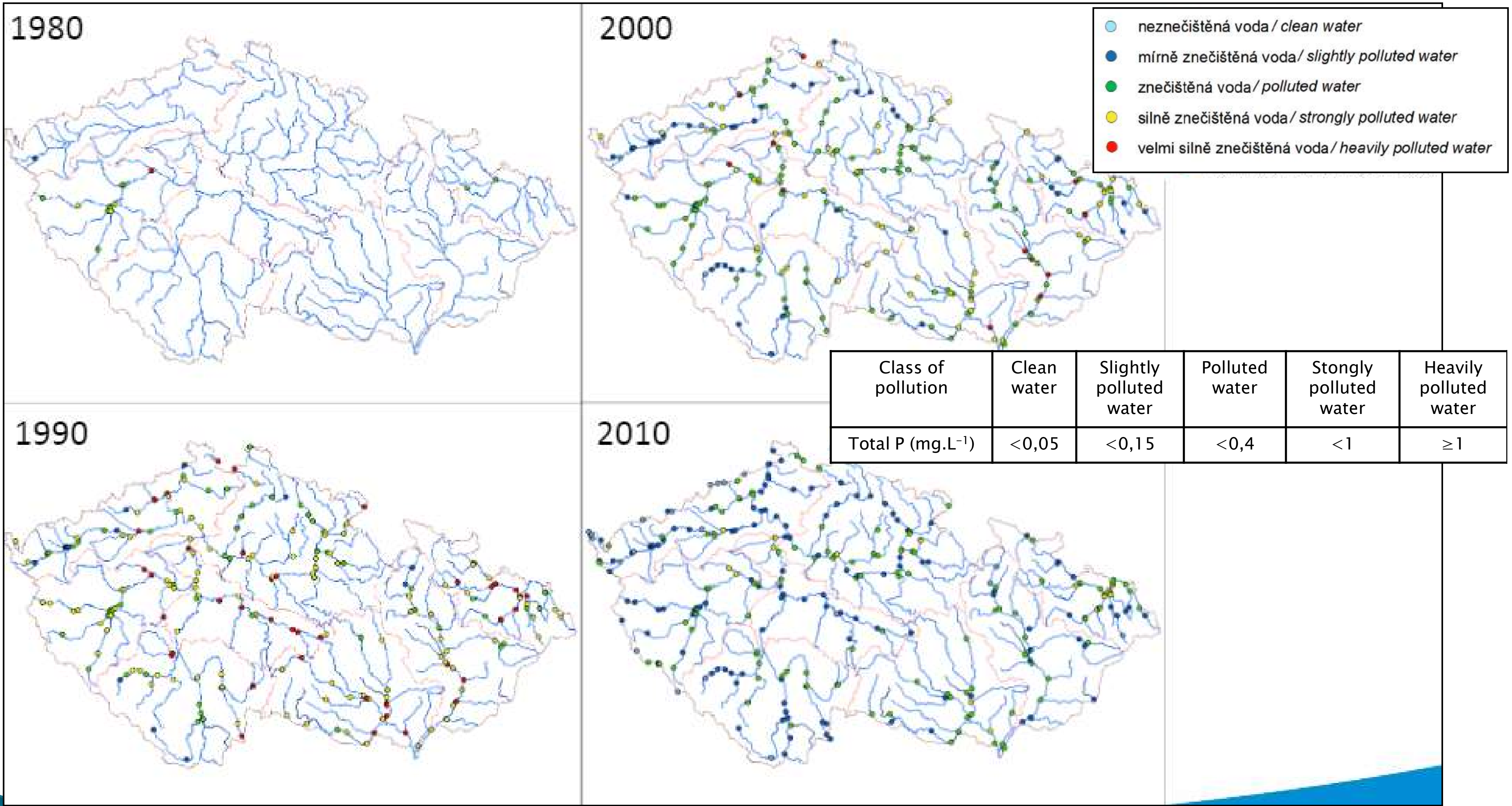
Class of pollution	Clean water	Slightly polluted water	Polluted water	Stongly polluted water	Heavily polluted water
BOD$_5$ (mg.L^{-1})	<2	<4	<8	<15	≥15

Source: Czech Hydrometeorological Institute

Water quality development in the Czech Republic

- **Total Phosphorus**

- pollution assessment according to Czech State Norm 75 7221



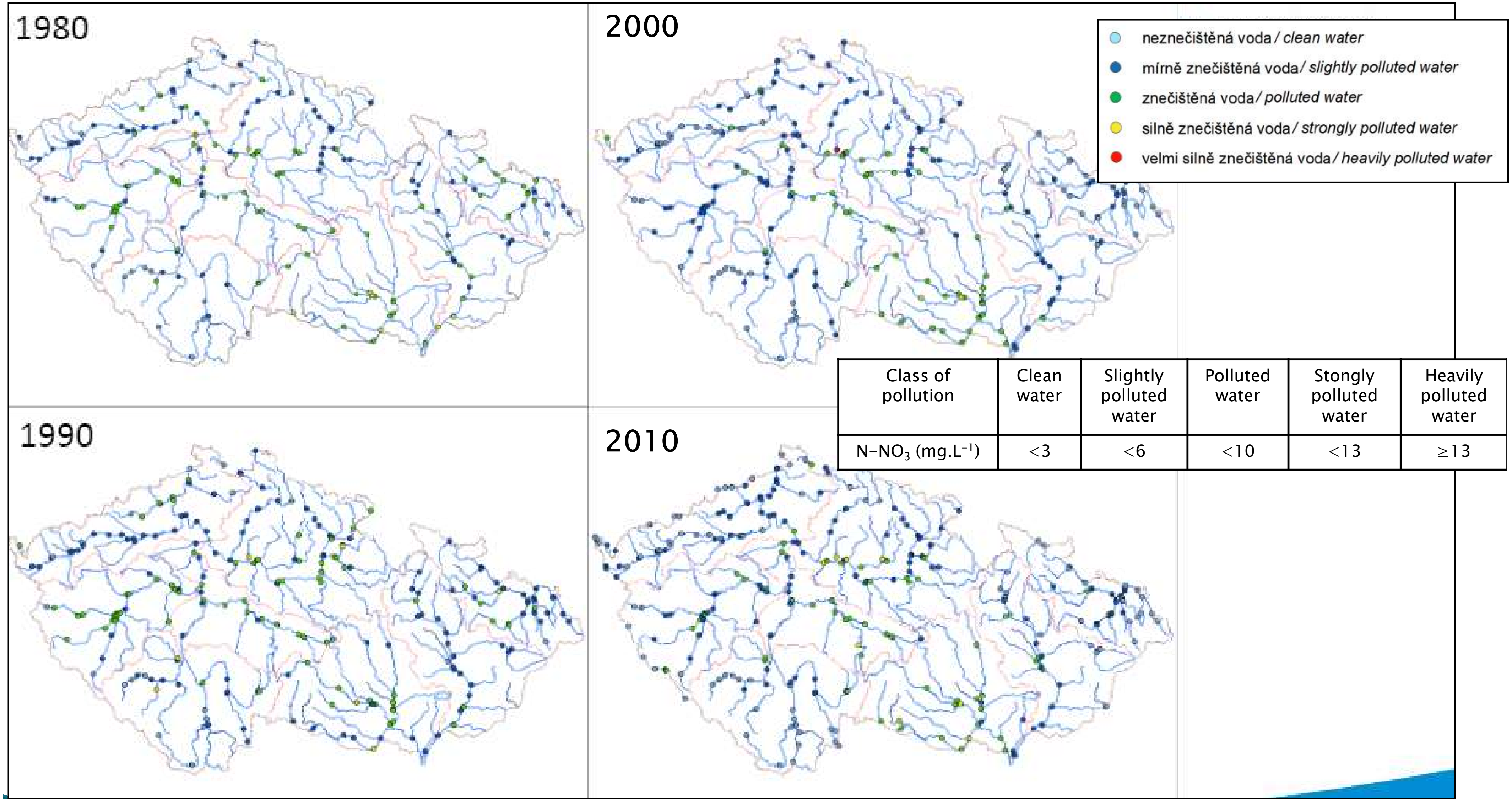
Class of pollution	Clean water	Slightly polluted water	Polluted water	Stongly polluted water	Heavily polluted water
Total P ($mg.L^{-1}$)	<0,05	<0,15	<0,4	<1	≥1

Source: Czech Hydrometeorological Institute

Water quality development in the Czech Republic

- N-NO_3

-pollution assessment according to C



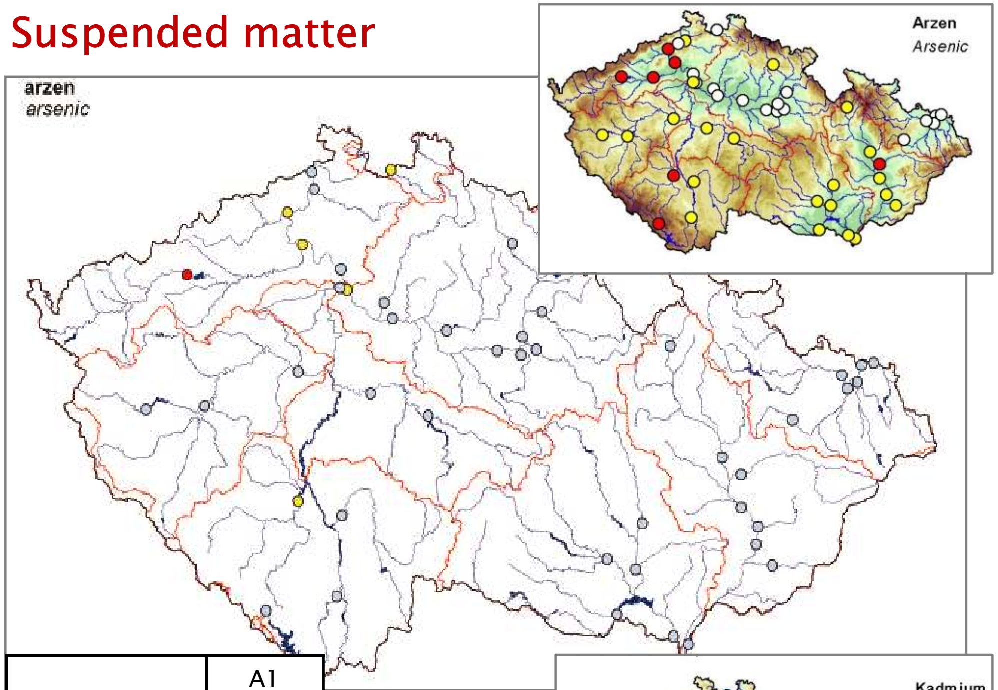
Class of pollution	Clean water	Slightly polluted water	Polluted water	Stongly polluted water	Heavily polluted water
N-NO_3 (mg.L^{-1})	<3	<6	<10	<13	≥13

Source: Czech Hydrometeorological Institute

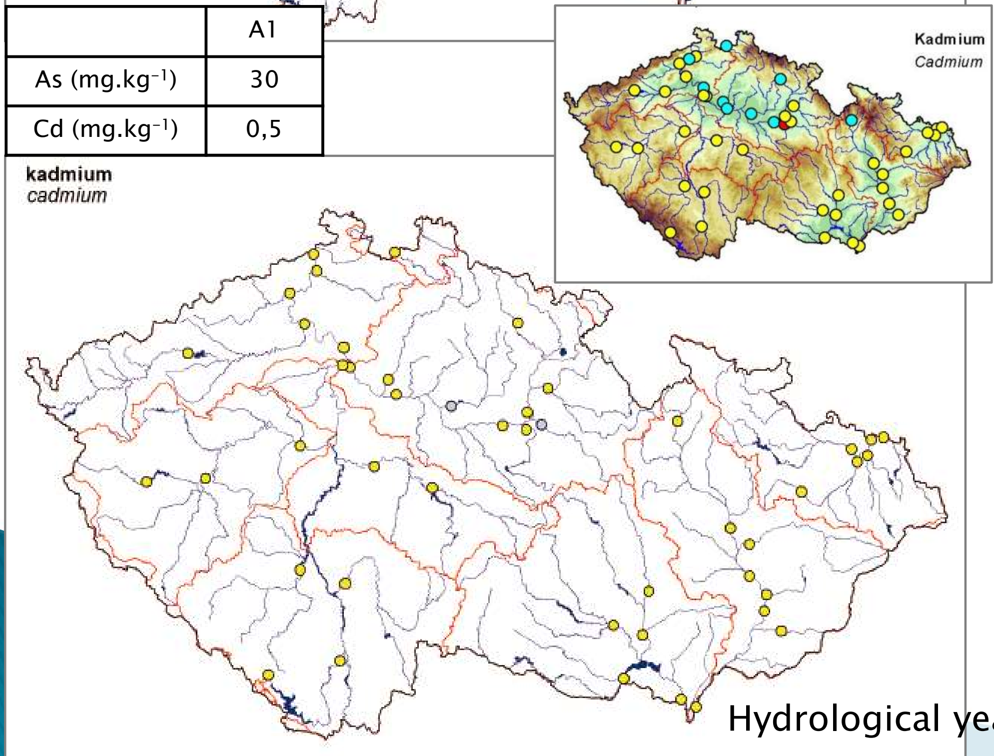
Suspended matter and sediment pollution

assessment according to the methodological instruction sof the Ministry of Environment of the Czech Republic „Kritéria znečištění zemin a podzemních vod“ 1996 in the meaning of „Analýza rizik kontaminovaného území Nr.. 9/2005

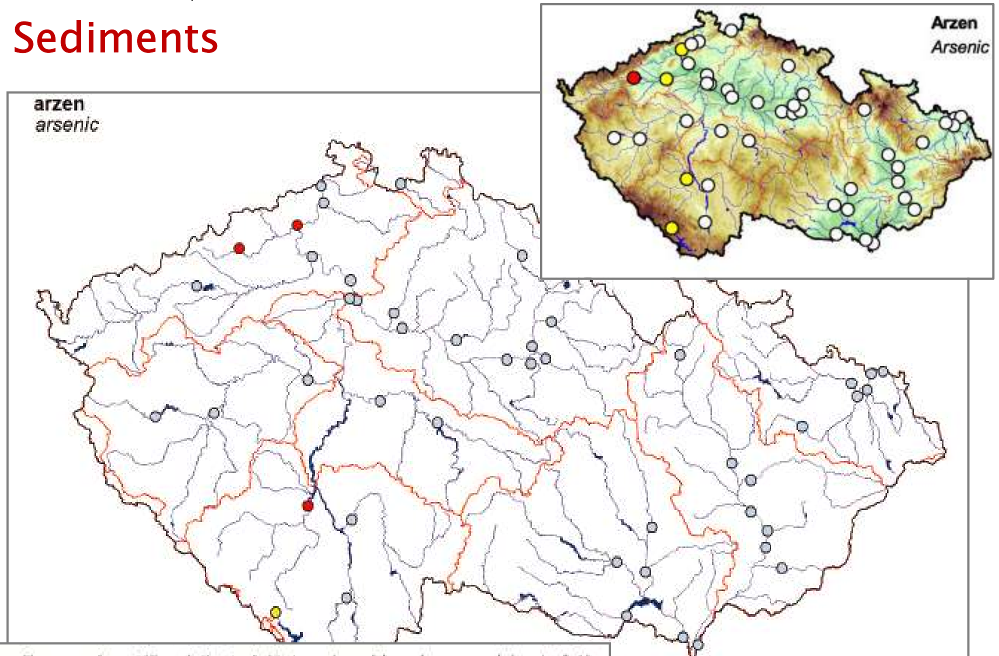
Suspended matter



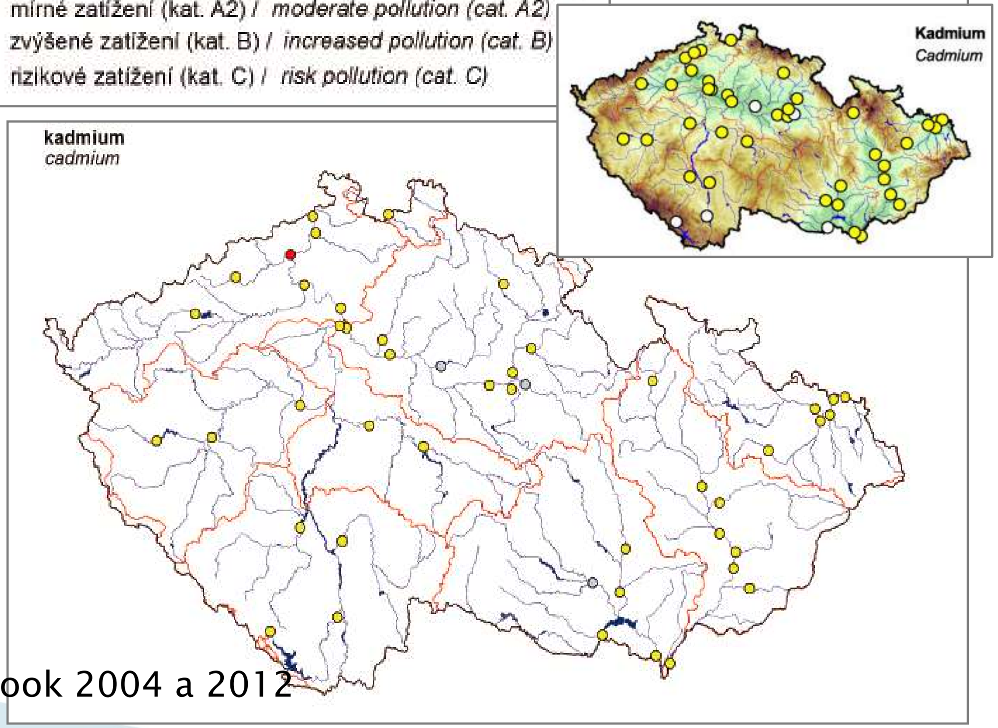
	A1
As (mg.kg⁻¹)	30
Cd (mg.kg⁻¹)	0,5



Sediments



- přirozené zatížení (kat. A1) / *natural background (cat. A1)*
- mírné zatížení (kat. A2) / *moderate pollution (cat. A2)*
- zvýšené zatížení (kat. B) / *increased pollution (cat. B)*
- rizikové zatížení (kat. C) / *risk pollution (cat. C)*

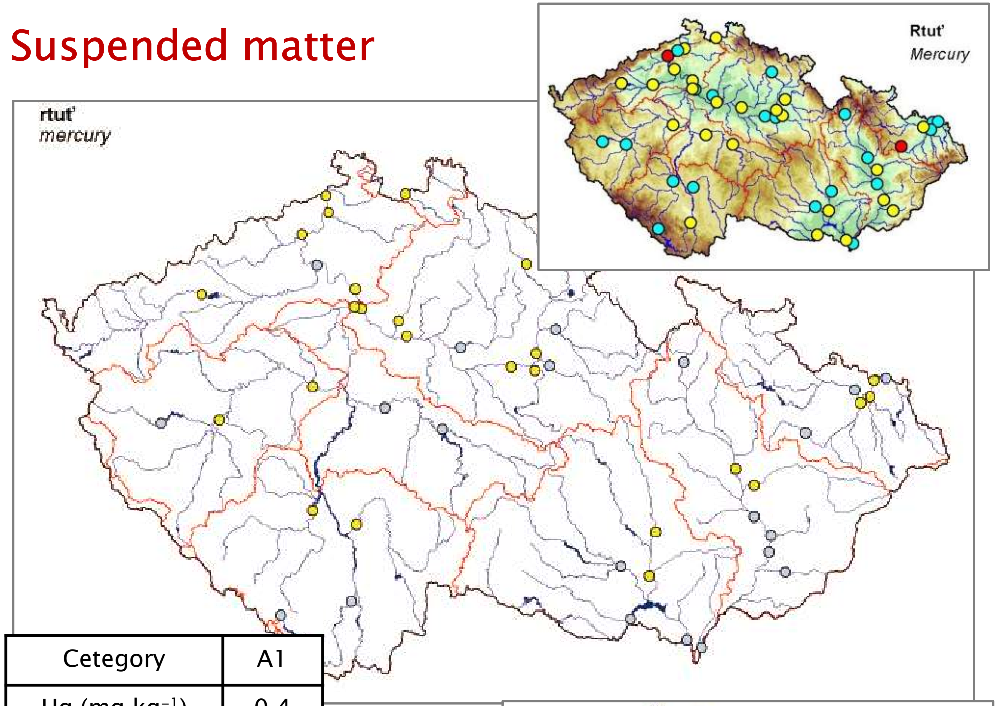


Hydrological yearbook 2004 a 2012

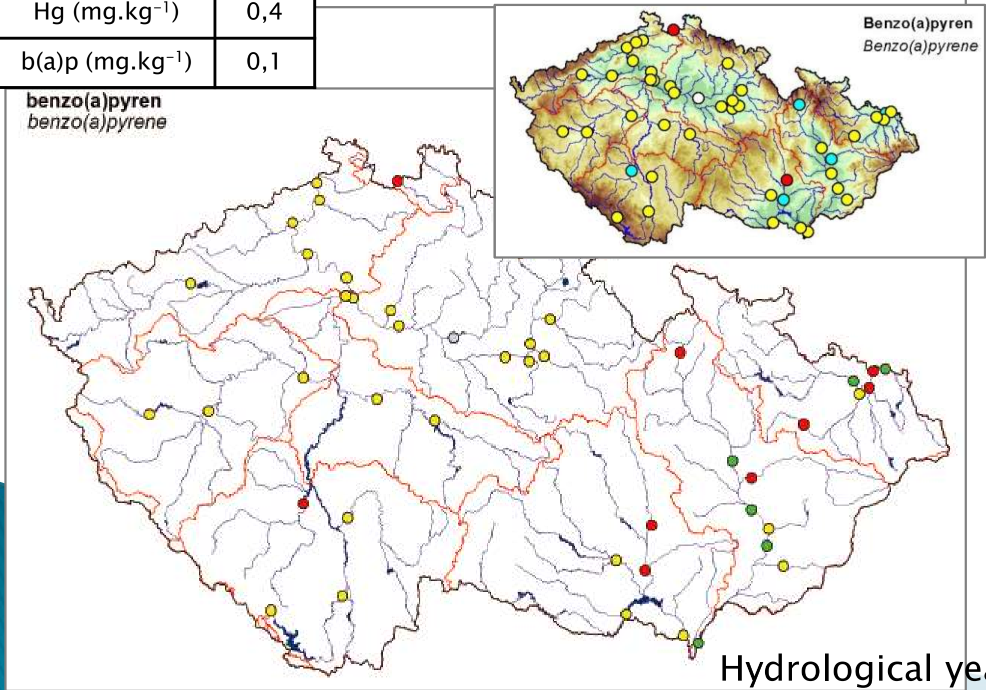
Suspended matter and sediment pollution

assessment according to the methodological instruction sof the Ministry of Environment of the Czech Republic „Kritéria znečištění zemin a podzemních vod“ 1996 in the meaning of „Analýza rizik kontaminovaného území Nr.. 9/2005

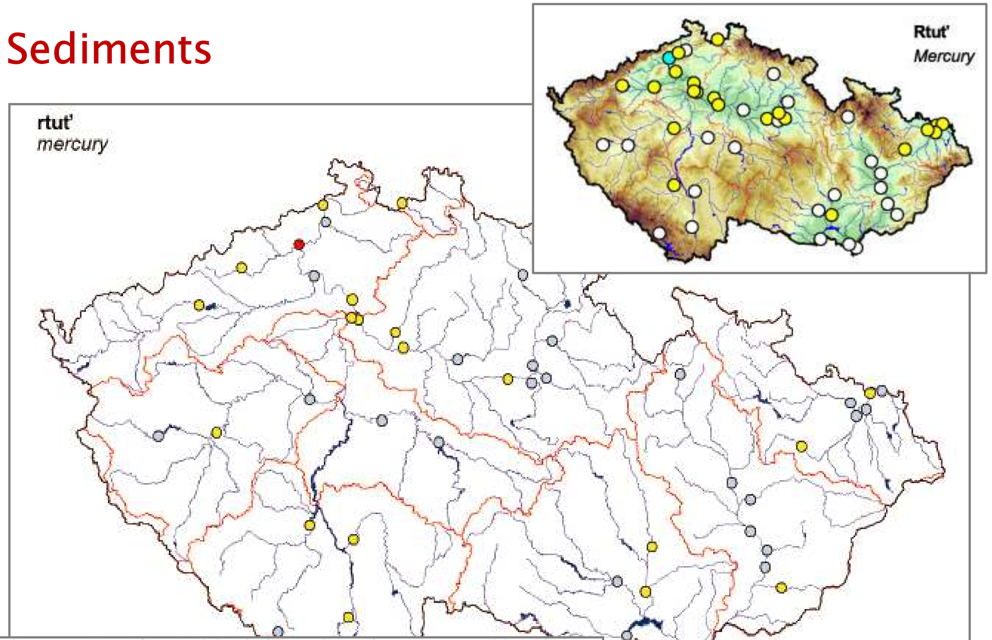
Suspended matter



Cetegory	A1
Hg (mg.kg⁻¹)	0,4
b(a)p (mg.kg⁻¹)	0,1



Sediments



- přirozené zatížení (kat. A1) / *natural background (cat. A1)*
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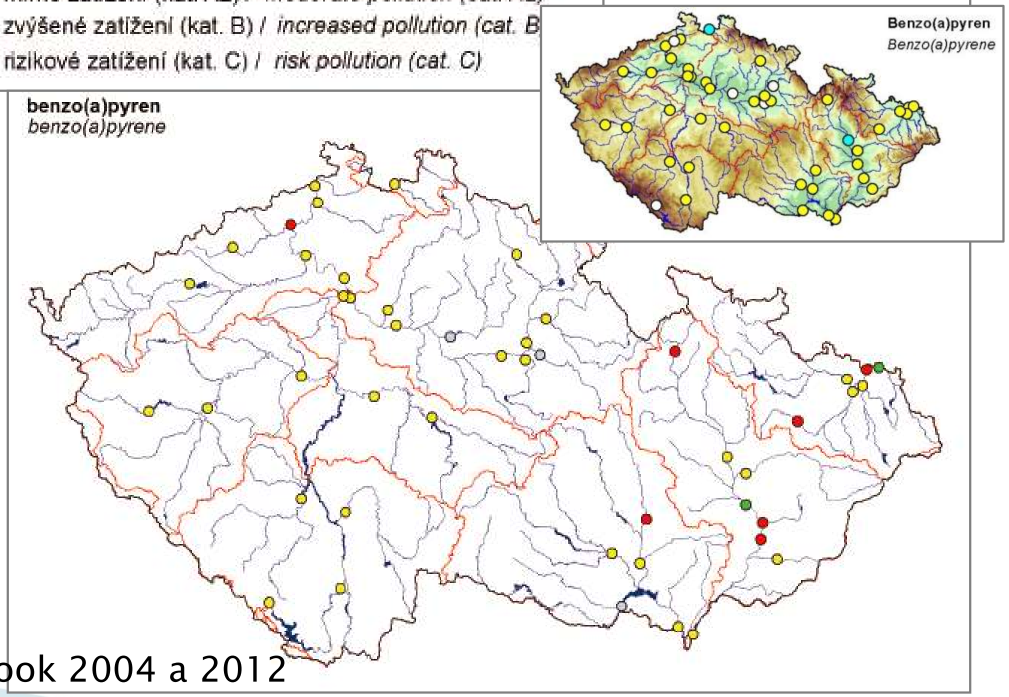

Hydrological yearbook 2004 a 2012

Suspended matter and sediment pollution

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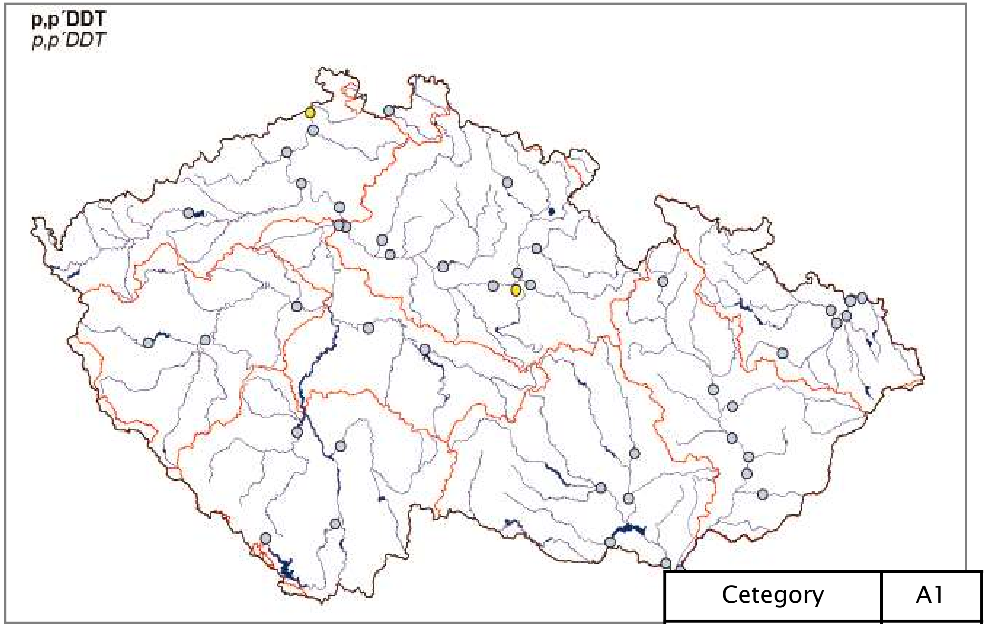
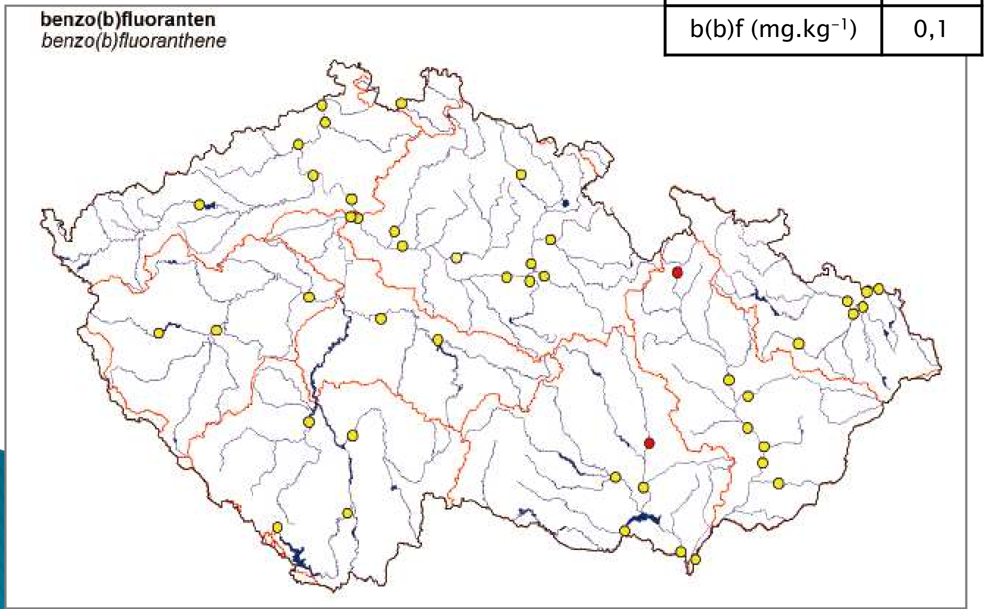
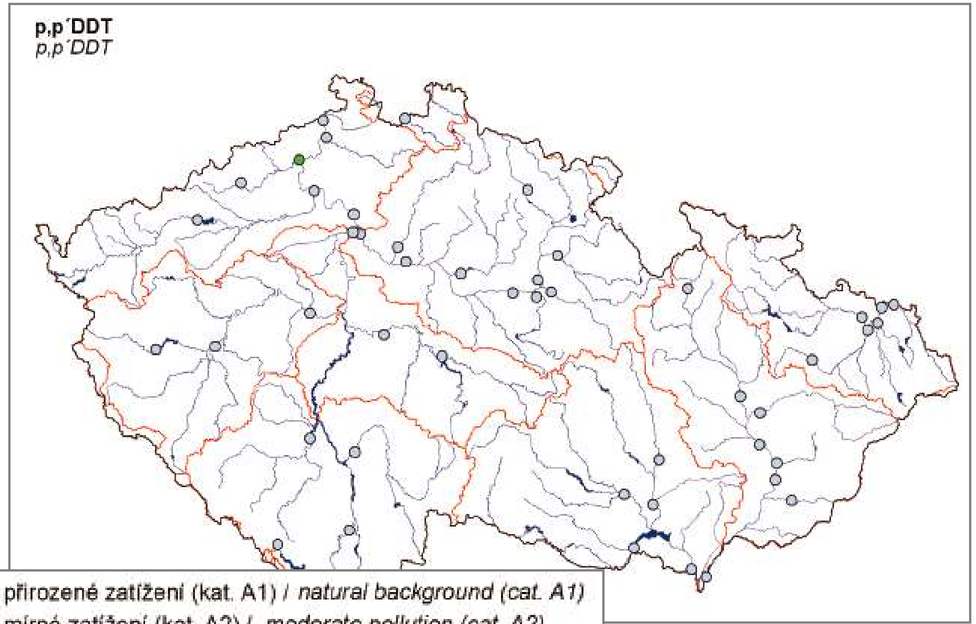
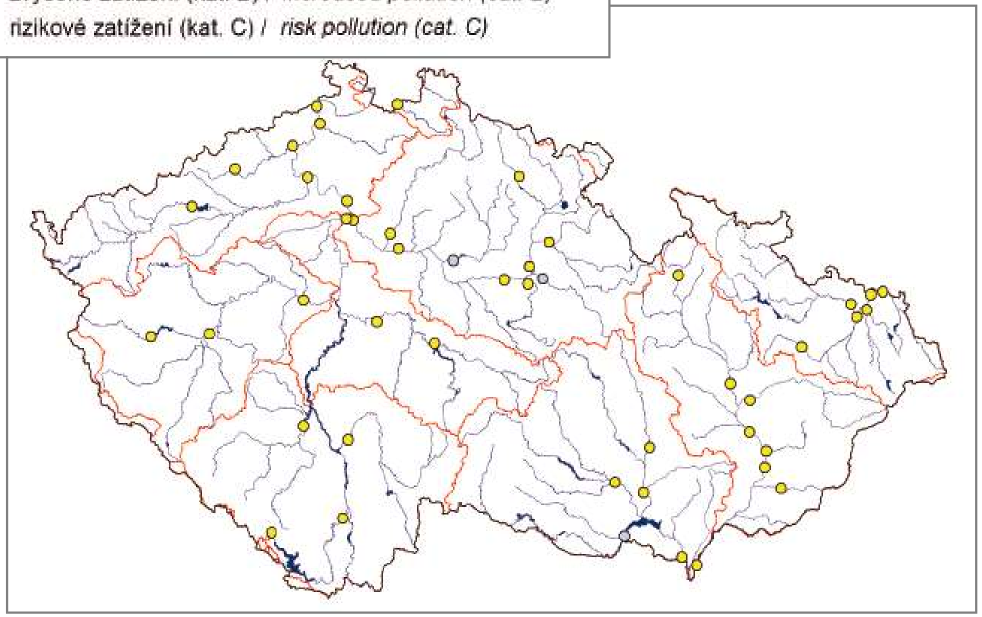
Suspended matter





Sediments





Cetegory	A1
DDT (mg.kg^{-1})	0,05
b(b)f (mg.kg^{-1})	0,1

- přirozené zatížení (kat. A1) / *natural background (cat. A1)*
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- zvýšené zatížení (kat. B) / *increased pollution (cat. B)*
- rizikové zatížení (kat. C) / *risk pollution (cat. C)*

Water, suspended matter, sediment and biota quality database

Arrow (CHMI) - surface water + ground water quality http://hydro.chmi.cz/isarrow/index.php

data chice: district, region, year, catchment, water body, matrix (water, sediment, suspended matter, biota) etc...

Sediment pollution risks – old loads (deep sediments) case studies the Elbe River

- ## Sediment sampling of deeper (older) layers

highest contamination of the Elbe River in the 2nd half of the 20th century
anthropogenic pollution indicators:

- *heavy metals, As, specific organic compounds = bound on suspended matter → settling down at lower flow velocities layers of contaminated sediments*

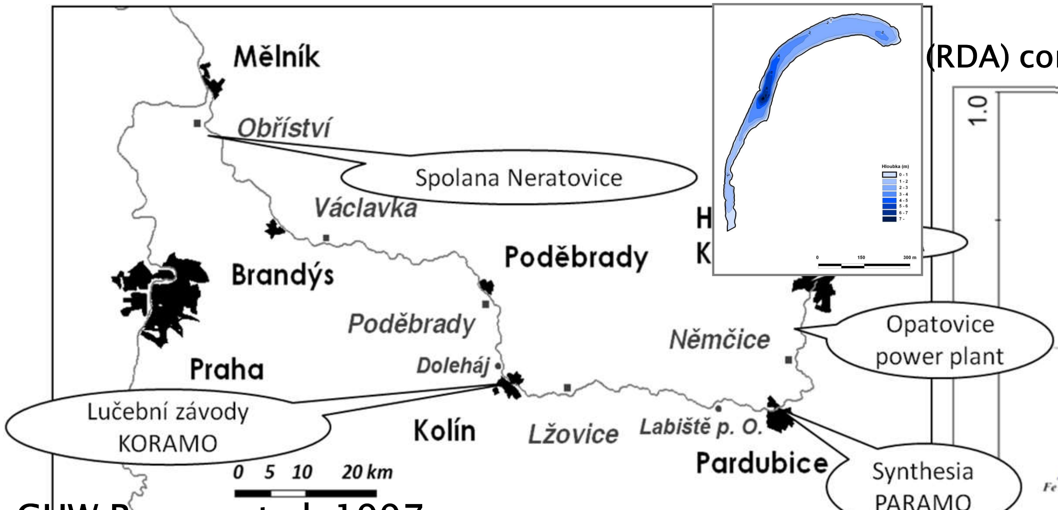
Where? = old meanders (artificially of naturally cut oxbow lakes) and floodplain
How large is the spread of pollution?
How far from the source of contamination?
Influence of the hydrological connectivity with the river?
Level of contamination?
Change of concentration with the depth of sediment, respectively historical changes of pollution in the river?

ENVIRONMENTAL RISK
- Remobilization risk during floods
- Release of toxic substances from sediments
(change of pH, redox potencial, presence of other substances e.g. solvents, salts…)

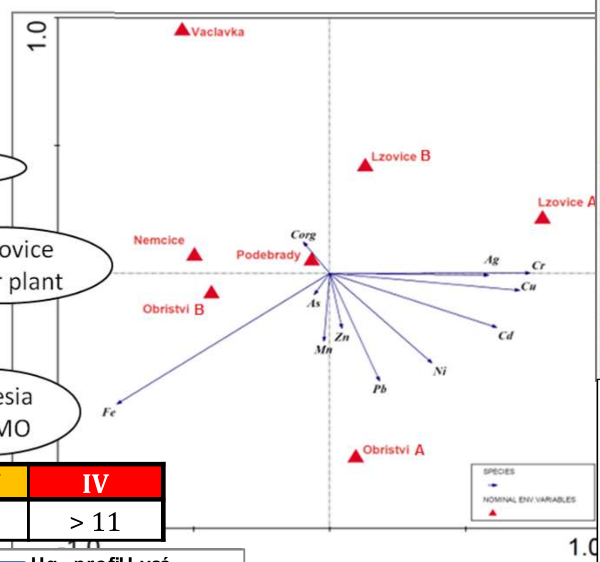
Suspended matter and sediment pollution risks – case studies

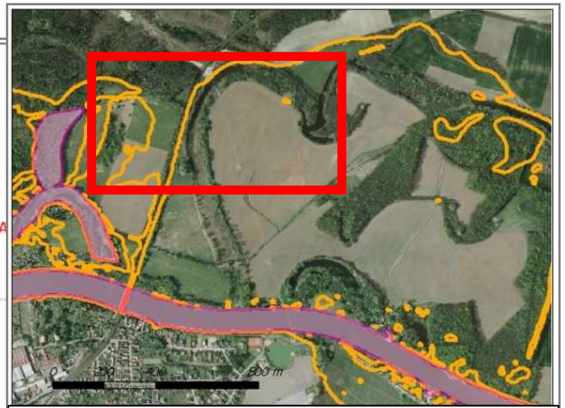
Research of oxbow lake sediments in the central part of the Czech Elbe River floodplain (since 2002)

Selected oxbow lakes differ in:
Age – separation from the main riverbed (historical maps)
Hydrological connectivity with the river – oxbow lakes connected by surface or only underground
Sources of polluition – industrial, municipal, agricultural



(RDA) concentration vs. sampling point:

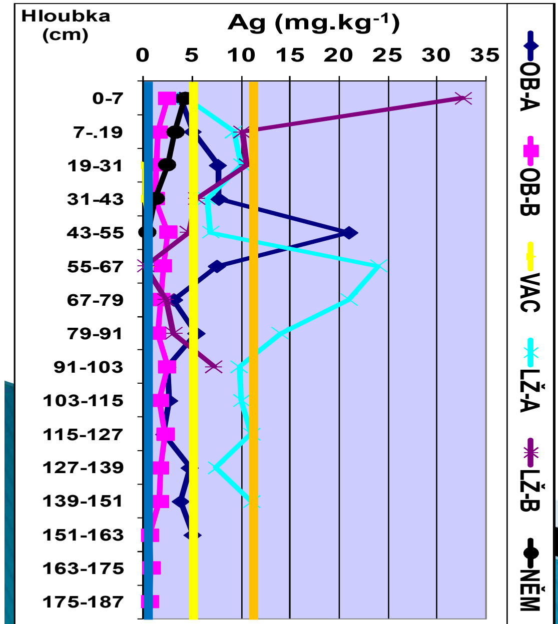


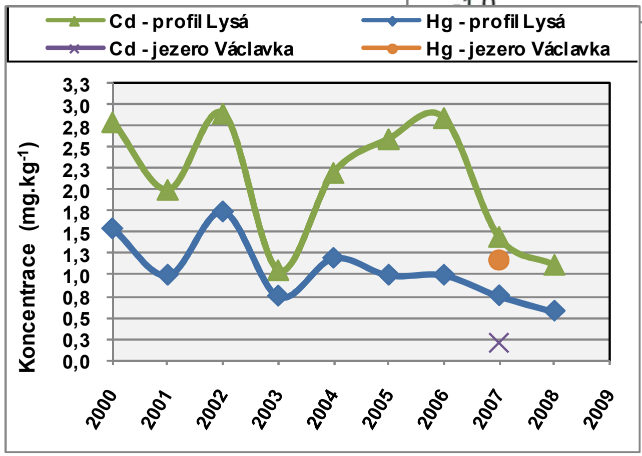


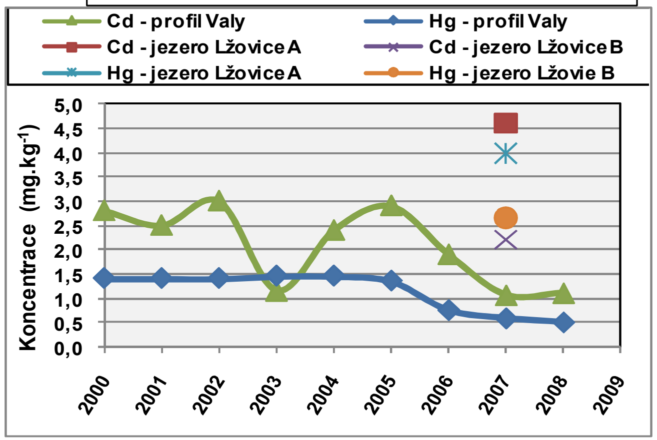
Flooding areas – Václavka
(sources: www.dibavod.cz; geoportal.cenia.cz)
20-year flood
5-year flood

GHW Prange et al. 1997

(mg.kg-1)	I	I - II	II	II - III	III	III - IV	IV
Ag	0,3	≤ 0,5	≤ 1	≤ 3	≤ 5	≤ 11	> 11





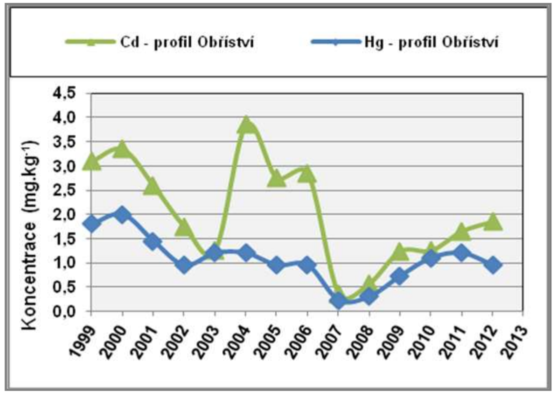


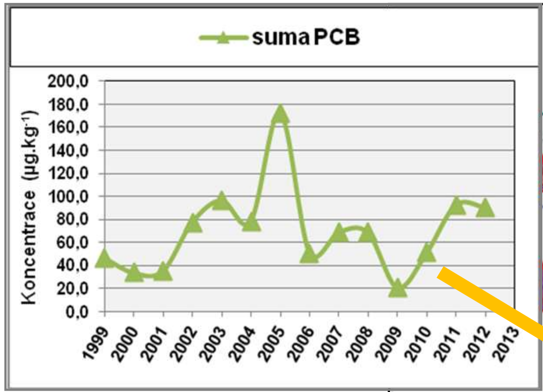
Summary

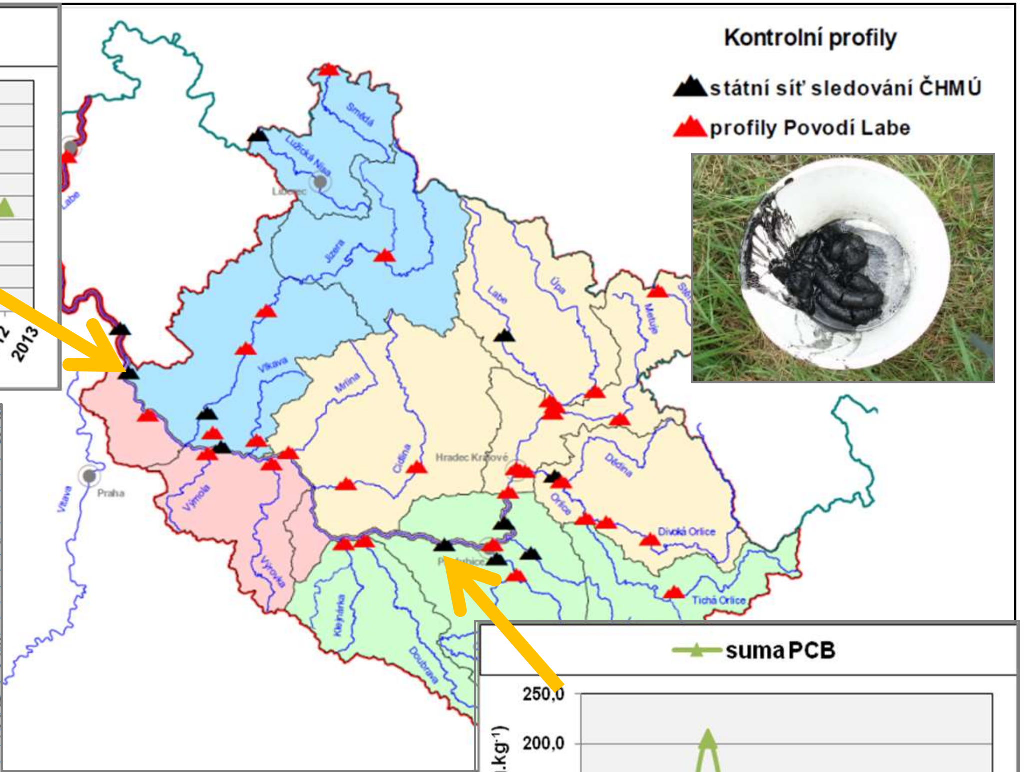
- the lowest concentrations in lakes with restricted hydrological connectivity with the river
- different distribution of concentrations within one lake
- sediments contaminated with Ag, Cd, Hg (Pb, Zn, Cu)
- higher concentrations in lakes than in the Elbe surface sediments = OLD POLLUTION

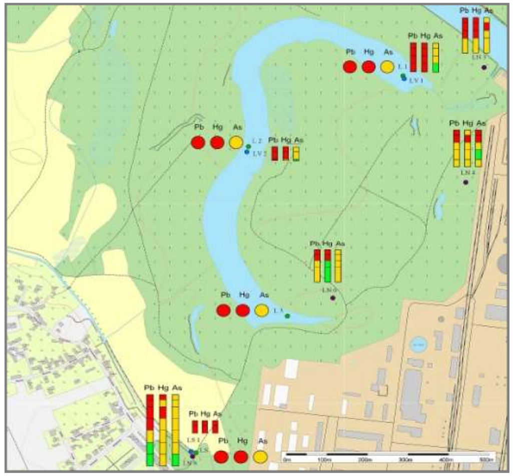
Suspended matter and sediment pollution risks – case studies

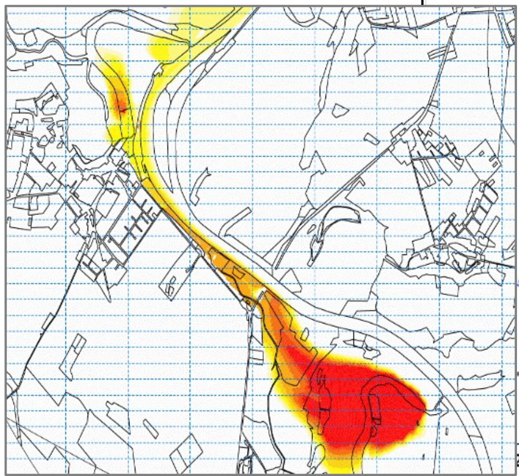
Development of sediment contamination in the Elbe River

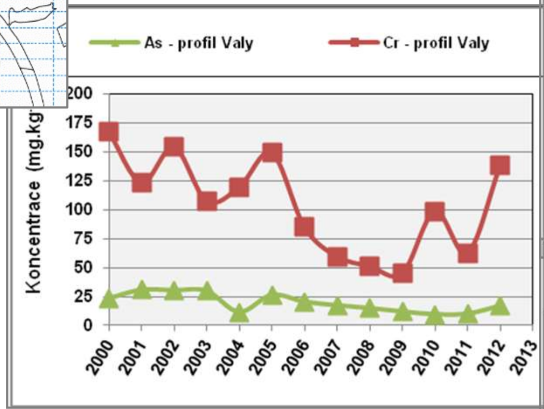


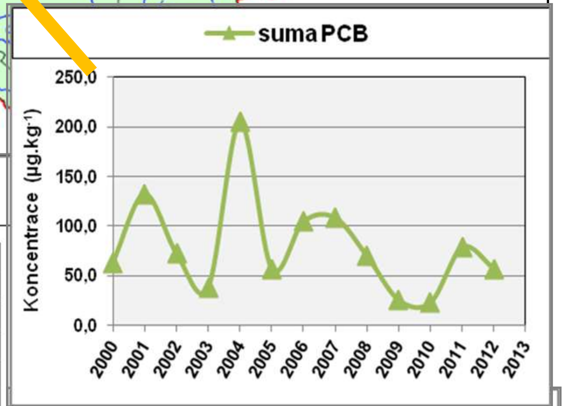


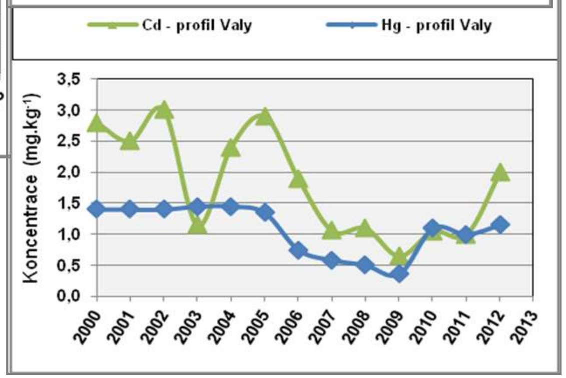












Projects:

ELSA Schadstoffsanierung Elbsedimente

Hamburg city + Hamburg port

-risk of remobilization of pollution from old loads

-sediment pollution assessment according to ICPER 2014

- Hydroteam Faculyt of Science,

- Povodí Labe (the Elbe River Authority) + DHI + Geomin

SedBiLa = The importance of the Bílina River as a historical and current source of pollution for the management of sediments in the Elbe basin

SedLa = The importance of old sediments in the Elbe and its side structures in the section from Pardubice to the confluence with Vltava