Hot Topics in Physical Geography
Winter term 1/1 Ex + C, 8 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–accumulation 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 km³, 1990 – 21 km³)
  - use of underground resources
- after 1989 – water quality improvement in connection with political changes → decrease of 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 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:

<table>
<thead>
<tr>
<th>Sea</th>
<th>Catchment</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>North sea</td>
<td>Labe</td>
<td>66.2%</td>
</tr>
<tr>
<td>Black sea</td>
<td>Dunaj</td>
<td>24.0%</td>
</tr>
<tr>
<td>Baltic sea</td>
<td>Odra</td>
<td>9.8%</td>
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</table>

Total length of streams in Czechia: 76,000 km
- basic net of streams (over 5 km²): 36,865 km
- Modified streams – 25% of total length: 18,784 km
- Length of artificial canals: 578 km
- Length 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

Length 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$^3$
- Nechanice – 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

Sources of increased concentrations

- 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

What influences water, suspended load and sediment quality

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

**soil character**: proportion 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

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
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
- point sources of pollution:
  - localized outflow of raw or wastewaters
  - industrial plants, water treatment plants
  - easier to solve (new technologies…)
- diffuse 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

Images:
- Arable land washout and erosion
- Outflow from Synthesia chemical plant
- Prague orbital motorway
- Seepage of mining waters – Oloví, the Ore Mountains
Water, suspended matter and sediment quality parameters

- **Physical parameters**
  
  **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
  \[ \text{pH} = -\log [H^+] \]
  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

  **Anthropogenic acidification**
  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=Ω$^{-1}$):** 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,
  \[ 1°N = 10\text{mg CaO in 1 liter}, \text{resp.} 7.2 \text{mg MgO in 1 litre} \]
  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
color 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 hexamethylenetetramine 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

Chemical parameters

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 etc.
in lower river courses enhanced values due to planktonic photosynthesis (lakes)
measurements in situ – oximeters: dissolved oxygen (mg.L⁻¹) or saturation (%)

Decrease: higher temperature and salinity (inorganic pollution)
bacterial decomposition of organic material (industrial, agricultural and municipal pollution)
oxidation of organic substance
oxidation of nitrite (N–NO₂⁻) and ammonium nitrogen (N–NH₄⁺) into nitrate nitrogen (N–NO₃⁻)
(nitrate fertilizers, ammonium – chemical industry)
respiration
oxidation of upper sediment layers and products of anaerobic decomposition
oxidation of pollutants!!! – decreases saturation significantly!!!

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Concentration (mg.L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 °C</td>
<td>14,621</td>
</tr>
<tr>
<td>10 °C</td>
<td>11,288</td>
</tr>
<tr>
<td>20 °C</td>
<td>9,092</td>
</tr>
<tr>
<td>30 °C</td>
<td>7,559</td>
</tr>
</tbody>
</table>
Water, suspended matter and sediment quality parameters

Main nutrients – N + P

Nitrogen compounds: atmospheric – N₂, organic – N₉(org)(sewage, slurry), ammonium N–NH₄, nitrite N–NO₂, nitrate N–NO₃, cyanides CN⁻

Biochemical transformations – N cycle in aquatic systems:

ammonium nitrogen – fast oxidation
produced by microorganisms – decomposition processes
indicates fecal 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 drinking water
E.g. maximum concentration in outflow in 1998: Water treatment plant Děčín  363 mg.L⁻¹

nitrate 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–NO₃ 39 mg.L⁻¹ N–NH₄ 0,1 mg.L⁻¹ Sewer : N–NO₃ 4 mg.L⁻¹ N–NH₄ >20 mg.L⁻¹

cyanides – highly toxic, industrial pollution, energetics

Phosphorus compounds:
organic P (1,5g per capita/day), inorganic P–PO₄
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:
FePO₄(Fe³⁺) dissolution after Fe reduction PO₄³⁻(Fe²⁺)
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

**Halogen**s—low concentration, elevated values = anthropogenic pollution

**Chlorine**—sources: municipal waste waters, animal production, chemical industry and traffic (winter spreading material)

- 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!!!

- 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$^{-1}$
Organic compounds

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

hundreds of substances 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 production, less commonly industrial pollution – e.g. Food production, paper mills etc.

\[ C_t = C_0 \cdot e^{-K_1 t} \]

\( C_t \) - concentration after 5 days
\( C_0 \) - concentration day 0
\( K_1 \) - 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

**Comparison of organic pollution in Czech watersheds in 2015**

<table>
<thead>
<tr>
<th>Waste water source</th>
<th><strong>BOD</strong>(_5) (mg.L(^{-1}))</th>
<th><strong>COD</strong> (mg.L(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper mills</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Breweries and malting plants</td>
<td>850</td>
<td>1700</td>
</tr>
<tr>
<td>Tanning industry</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>Sugar refinery</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>Yeast factory</td>
<td>2200</td>
<td>3500</td>
</tr>
<tr>
<td>Fluid pig excrements</td>
<td>20000</td>
<td>40000</td>
</tr>
</tbody>
</table>

Langhammer, 2006: Water quality course, FaSci, UC

**TOC (C\(_{org}\))** – oxidation of all organic substances and production of CO\(_2\) and H\(_2\)O

A. Wet combustion – strong oxidizing agent

B. Thermic combustion
determination of produced CO\(_2\)

**BOD**\(_5\) ≤ **COD**\(_{Mn}\) ≤ **COD**\(_{Cr}\) ≤ **TOC**

unpolluted surface water **TOC** < 7,0 mg.L\(^{-1}\)
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) unpollluted surface water HCH < 3,0 ng.L⁻¹
In Czechoslovakia forbidden in 1975
Lindan (HCH – Y hexachlorocyclohexane) – persistent insecticide, forbidden
HCB (Hexachlorobenzene) – persistent fungicide, volatile, forbidden

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

unpollluted 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 determining 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

**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, teratogenicity

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

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
**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 and the atmosphere, self-cleaning processes, foam

**Petroleum substances** – accidents (tankers), traffic, layer on water surface prevents gas exchange (50 L of oil = 1km²), 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…)

Measurements: α, β, γ activities, uranium concentration (µg.L⁻¹)
### Relative Abundance of the Natural Isotopes

<table>
<thead>
<tr>
<th>Isotope</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>Isotope</th>
<th>%</th>
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<td>Ni</td>
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<td>0.105</td>
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<td>Fe</td>
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</tbody>
</table>

Microbiological and biological parameters

**abundance of thermotolerant coliform bacteria (number of bacteria/volume)**
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 faecal pollution

**drinking water = zero in 100ml**

**abundance of enterococci (number of bacteria/volume)**
E. faecalis (90–95%) a E. faecium (5–10%) commonly in intestines indicates faecal pollution bacterial diseases

**chlorophyll a (µg.L\(^{-1}\))**
- photosynthetic pigment, green colour, reflects the amount of photosynthetically active organisms in water (plants, cyanobacteria and some algae)

**saprobity** – water quality evaluation based on presence of certain species (macrozoobenthos) indicating certain level of water pollution
saprobasic system comprises a wide range of organisms (indicators) – wide applications presence of the indicator species corresponds to the level of organic pollution (BOD\(_5\) values), oxygen concentrations, abundance of bacteria and prevailing processes (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

**trophity** – evaluation based on nutrient supply available for plant growth trophic levels correspond to certain contents of P (P total), N (N total), chlorophyll a, oxygen saturation and water transparency (N) + P limiting factors – eutrophication rough estimations of biological condition of a water body various systems

<table>
<thead>
<tr>
<th>Chl a (µg.L(^{-1}))</th>
<th>P (tot) (mg.L(^{-1}))</th>
<th>Secchi disk depth (m)</th>
<th>Trophic Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2.6</td>
<td>0–12</td>
<td>&gt; 8–4</td>
<td>Oligotrophic</td>
</tr>
<tr>
<td>2.6–20</td>
<td>12–24</td>
<td>4–2</td>
<td>Mesotrophic</td>
</tr>
<tr>
<td>20–56</td>
<td>24–96</td>
<td>2–0.5</td>
<td>Eutrophic</td>
</tr>
<tr>
<td>56–155+</td>
<td>96–384+</td>
<td>0.5— &lt; 0.25</td>
<td>Hypereutrophic</td>
</tr>
</tbody>
</table>

(Carlson, 1996)
Water, suspended matter and sediment monitoring

- **State monitoring networks** – state institutions
  
  **Czech Hydrometeorological Institute** [http://portal.chmi.cz/](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](http://www.pla.cz) (Hradec Králové) 14 976 km²
  - the Morava River Authority – [http://www.pmo.cz](http://www.pmo.cz) (Brno) 21 133 km²
  - the Vltava River Authority [http://www.pvl.cz](http://www.pvl.cz) (Praha) 27 580 km²
  - the Ohře River Authority – [http://www.poh.cz](http://www.poh.cz) (Chomutov) 10 098 km²
  - the Odra River Authority – [http://www-pod.cz](http://www-pod.cz) (Ostrava) 7 246 km²

- **Forests of the Czech Republic** – [http://www.lesycr.cz](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 Institute for Soil and Water Conservation ASCI CR
  - Czech Geological Survey, universities,
  - environmental institutions, private environmental companies,
  - restoration companies
  - nongovernmental organisations etc...

- **International monitoring programmes**
  - *e.g. International Commission for the Protection of the Elbe River*
  - international sampling stations on the Elbe River (since 1993)
Water, suspended matter and sediment monitoring

- **Details of monitoring** – hydrological balance of water quantity and quality assessment
  - **water quantity** – cca 430 gauging stations
  - water level (m a.s.l.)
  - discharge Q (m$^3$ s$^{-1}$)
  - precipitation, snow, temperature measurements each 10 minutes

- **Surface water quality sampling**
  - since 1963, 12× or 24× year, cca 200 sampling stations,
  - cca 80 parameters
  - e.g. in 2015 results available from 1673 sampling points
  - historically over 350 parameters

- **Underground water quality sampling**
  - 175 springs
  - 221 shallow underground water (Holocene)
  - 267 deep hydrogeological wells

[www.chmi.cz](http://www.chmi.cz) – Czech Hydrometeorological Institute
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

- **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

- **biota**
  
  22 sampling stations, 1 × year
  
  Dreissena polymorpha, biofilm, fish, juvenile fish, benthos– 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**

<table>
<thead>
<tr>
<th>PARAMETER_DETAIL</th>
<th>SOP</th>
<th>SOP-POPIS</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>zinc</td>
<td>AK12B</td>
<td>Determination of metals and phosphorus ICP/OES - DIN 38406 - E22</td>
<td>mg/kg</td>
</tr>
<tr>
<td>nickel</td>
<td>AK12B</td>
<td>Determination of metals and phosphorus ICP/OES - DIN 38406 - E22</td>
<td>mg/kg</td>
</tr>
<tr>
<td>lead</td>
<td>AK12B</td>
<td>Determination of metals and phosphorus ICP/OES - DIN 38406 - E22</td>
<td>mg/kg</td>
</tr>
<tr>
<td>arsen</td>
<td>AK10B</td>
<td>Determination of metals AAS/ETA - ČSN EN ISO 15586</td>
<td>mg/kg</td>
</tr>
<tr>
<td>copper</td>
<td>AK12B</td>
<td>Determination of metals and phosphorus ICP/OES - DIN 38406 - E22</td>
<td>mg/kg</td>
</tr>
<tr>
<td>mercury</td>
<td>AK05B</td>
<td>Determination of mercury - ČSN 757440</td>
<td>mg/kg</td>
</tr>
<tr>
<td>cadmium</td>
<td>AK10B</td>
<td>Determination of metals and phosphorus ICP/OES - DIN 38406 - E22</td>
<td>mg/kg</td>
</tr>
<tr>
<td>chromium</td>
<td>AK12B</td>
<td>Determination of metals and phosphorus ICP/OES - DIN 38406 - E22</td>
<td>mg/kg</td>
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<tr>
<td>PCB congener 28</td>
<td>AO18B</td>
<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
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<tr>
<td>PCB congener 52</td>
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<td>µg/kg</td>
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<tr>
<td>PCB congener 101</td>
<td>AO18B</td>
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<td>µg/kg</td>
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<tr>
<td>PCB congener 138</td>
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<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
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<tr>
<td>PCB congener 153</td>
<td>AO18B</td>
<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
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<tr>
<td>PCB congener 180</td>
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<td>µg/kg</td>
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<tr>
<td>alfa-hexachlorcyclohexane</td>
<td>AO18B</td>
<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
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<tr>
<td>hexachlorobenzene</td>
<td>AO18B</td>
<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
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<tr>
<td>pentachlorobenzene</td>
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<td>µg/kg</td>
</tr>
<tr>
<td>beta-hexachlorecyclohexane</td>
<td>AO18B</td>
<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
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<tr>
<td>gama-hexachlorecyclohexane</td>
<td>AO18B</td>
<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
</tr>
<tr>
<td>p,p-DDE</td>
<td>AO18B</td>
<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
</tr>
<tr>
<td>p,p-DDD</td>
<td>AO18B</td>
<td>Determination of PCB, OCP, PBDE, DEHP, mos., pyrethr., ch. alk. C10-13, C14-17-GC/MS/MS-ISO18856, 22032</td>
<td>µg/kg</td>
</tr>
<tr>
<td>suma 6 cong. PAU</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>suma 5 cong. PAU</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>fenanthrene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>anthracene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>fluoranthene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>pyrene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
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<tr>
<td>benzo(a)anthracene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>chrysene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>benzo(b)fluoranthene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>benzo(k)fluoranthene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>benzo(a)pyrene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>benzo(g,h,i)pyrene</td>
<td>AO05B</td>
<td>Determination of PAU HPLC/FD - TNV 758055, EPA 8310</td>
<td>µg/kg</td>
</tr>
<tr>
<td>hydrocarbons C10-C40</td>
<td>AO14B</td>
<td>Determination of hydrocarbons C10-C40 GC/FID - ČSN EN 14039, ČSN EN ISO 16703</td>
<td>mg/kg</td>
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<tr>
<td>tributyltin</td>
<td>AO19B</td>
<td>Bestimmung von Organo-Zinn Stoffe GC/MSD - ČSN EN ISO 23161</td>
<td>µg/kg</td>
</tr>
</tbody>
</table>
Water quality development in the Czech Republic

- **BOD$_5$**
  - pollution assessment according to Czech State Norm 75 7221

<table>
<thead>
<tr>
<th>Class of pollution</th>
<th>1980</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean water</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;4</td>
<td>&lt;4</td>
</tr>
<tr>
<td>Slightly polluted</td>
<td>&lt;4</td>
<td>&lt;4</td>
<td>&lt;8</td>
<td>&lt;8</td>
</tr>
<tr>
<td>Water</td>
<td>&lt;8</td>
<td>&lt;8</td>
<td>&lt;15</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Polluted water</td>
<td>&lt;15</td>
<td>&lt;15</td>
<td>≥15</td>
<td>≥15</td>
</tr>
<tr>
<td>Strongly polluted</td>
<td>≥15</td>
<td>≥15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavily polluted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Czech Hydrometeorological Institute
Water quality development in the Czech Republic

- **Total Phosphorus**
  - pollution assessment according to Czech State Norm 75 7221

<table>
<thead>
<tr>
<th>Year</th>
<th>Class of pollution</th>
<th>1980</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clean water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slightly polluted water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polluted water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strongly polluted water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavily polluted water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class of pollution</th>
<th>1990</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean water</td>
<td>&lt;0,05</td>
<td>&lt;0,05</td>
</tr>
<tr>
<td>Slightly polluted water</td>
<td>&lt;0,15</td>
<td>&lt;0,15</td>
</tr>
<tr>
<td>Polluted water</td>
<td>&lt;0,4</td>
<td>&lt;0,4</td>
</tr>
<tr>
<td>Strongly polluted water</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Heavily polluted water</td>
<td>≥1</td>
<td>≥1</td>
</tr>
</tbody>
</table>

Source: Czech Hydrometeorological Institute
Water quality development in the Czech Republic

- N-NO₃ pollution assessment according to CZECH STATE NORM 75 7221

<table>
<thead>
<tr>
<th>Class of pollution</th>
<th>Clean water</th>
<th>Slightly polluted water</th>
<th>Polluted water</th>
<th>Strongly polluted water</th>
<th>Heavily polluted water</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-NO₃ (mg.L⁻¹)</td>
<td>&lt;3</td>
<td>&lt;6</td>
<td>&lt;10</td>
<td>&lt;13</td>
<td>≥13</td>
</tr>
</tbody>
</table>

Source: Czech Hydrometeorological Institute
Suspended matter and sediment pollution
assessment according to the methodological instruction of 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

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>As (mg·kg⁻¹)</td>
<td>30</td>
</tr>
<tr>
<td>Cd (mg·kg⁻¹)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### Sediments

- **Natural background** (cat. A1)
- **Moderate pollution** (cat. A2)
- **Increased pollution** (cat. B)
- **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**

<table>
<thead>
<tr>
<th>Category</th>
<th>(0.4) mg.kg(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg</td>
<td>0.4</td>
</tr>
<tr>
<td>(b(a)p)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Sediments**

- \(\text{Hg} (\text{mg.kg}^{-1})\) \(0.4\)
- \(\text{b(a)p} (\text{mg.kg}^{-1})\) \(0.1\)

Hydrological yearbook 2004 a 2012
Suspended matter and sediment pollution

assessment according to the methodological instruction of 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

<table>
<thead>
<tr>
<th>Category</th>
<th>A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT (mg.kg⁻¹)</td>
<td>0.05</td>
</tr>
<tr>
<td>b(b)f (mg.kg⁻¹)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Benzo[a]fluoranthene

Sediments

- p.p. DDT
- p.p. DDT

- DDT (mg.kg⁻¹) / natural background (cat. A1)
- m.m. 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 2012
Water, suspended matter, sediment and biota quality database


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 potential, 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 pollution** – industrial, municipal, agricultural

Flooding areas – Václavka
(sources: www.dibavod.cz; geoportal.cenia.cz)

20-year flood
5-year flood

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 Faculty 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