Transboundary riverine transport of suspended sediment and chemicals from Czech Republic

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River Basins, 19-20.6.2017

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Outlines

- Suspended sediment
  - What is it, where it comes from, where it goes
- Chemicals
  - What chemical are monitored (and evaluated)
- How we acquire data
  - Daily suspended sediment sampling – amount
  - Quarterly suspended sediment sampling – chemistry
- Data and data processing
  - Evaluated locations
  - Data handling - cleaning
  - Computation of suspended sediment runoff
  - Computation of chemicals runoff
- Results
  - Q, C
  - Year load
  - Chemical load
- Summary

Suspended sediment

Sediment that is carried in suspension by the turbulent components of water. – U.S. Forest Service Glossary

That sediment transported by a fluid that it is fine enough for turbulent eddies to outweigh settling of the particles through the fluid – Parsons A.J., Earth Surface Processess and Landforms, v.40, i.10, Aug 2015, pp. 1417-1420

Sediment picked up and suspended by fast-moving water – U.S.G.S website

Suspended sediment is generally transported within and at the same velocity as the surrounding fluid. – Vanacker V., Encyclopedia of Snow, Ice and Glaciers, Aug 2014, pp.1125-1126

Very fine soil particles which remain in suspension in water for a considerable period of time without contact with the bottom. Such material remains in suspension due to the upward components of turbulence and currents and/or by Colloidal Suspension. – Ecology dictionary

Droppo I.G., A new definition of suspended sediment: implications for the measurement and prediction of sediment transport, Erosion and Sediment Transport Measurement in Rivers, IAHS Publ. 283, 2003

Suspended sediment

Fine, mostly flocculated organic and anorganic sediment particles held for considerable time in water suspension by turbulent components of water.

Two main sources:

- surface runoff

Suspended sediment

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Two main sources:

- surface runoff

- re-suspended material from river beds

Suspended sediment

Minor sources:

- leaves, submersed parts of plants
- air deposition
- WTPs

Where it goes?

Low flow velocity -> sedimentation

- weirs, dams, dead ends and bays
- (re)deposition in alluvial plains after floods

How do we acquire data
amount of suspended sediment

ISCO sampler
+ reliable (regular sampling)
+ programmable
+ don’t need management
- needs electricity
- needs station
- only 24 bottles
- Immobile
- clogging

Monitoring programme – **2x a day, extra samples**

How do we acquire data
amount of suspended sediment

Hand-held device
+ cheap
+ easy to operate
+ lots of samples
- needs operator
- can't be programmed
- mistakes

Monitoring programme – **1x a day, extra samples**

How do we acquire data
for chemical analysis

Suspended sediment sampled by centrifugation
+ exact amount of water
+ big sample (tens of m^3)
+ mobility
- time consuming
- expensive
- needs two persons

Monitoring programme – **4x per year**

How do we acquire data
lab work

Pressure filtration for amount measurement

Analyses: **Hg – AMA-254, heavy metals – IPC-MS, organic compounds – GC-ECD**

- contract with river management authority

Chemicals

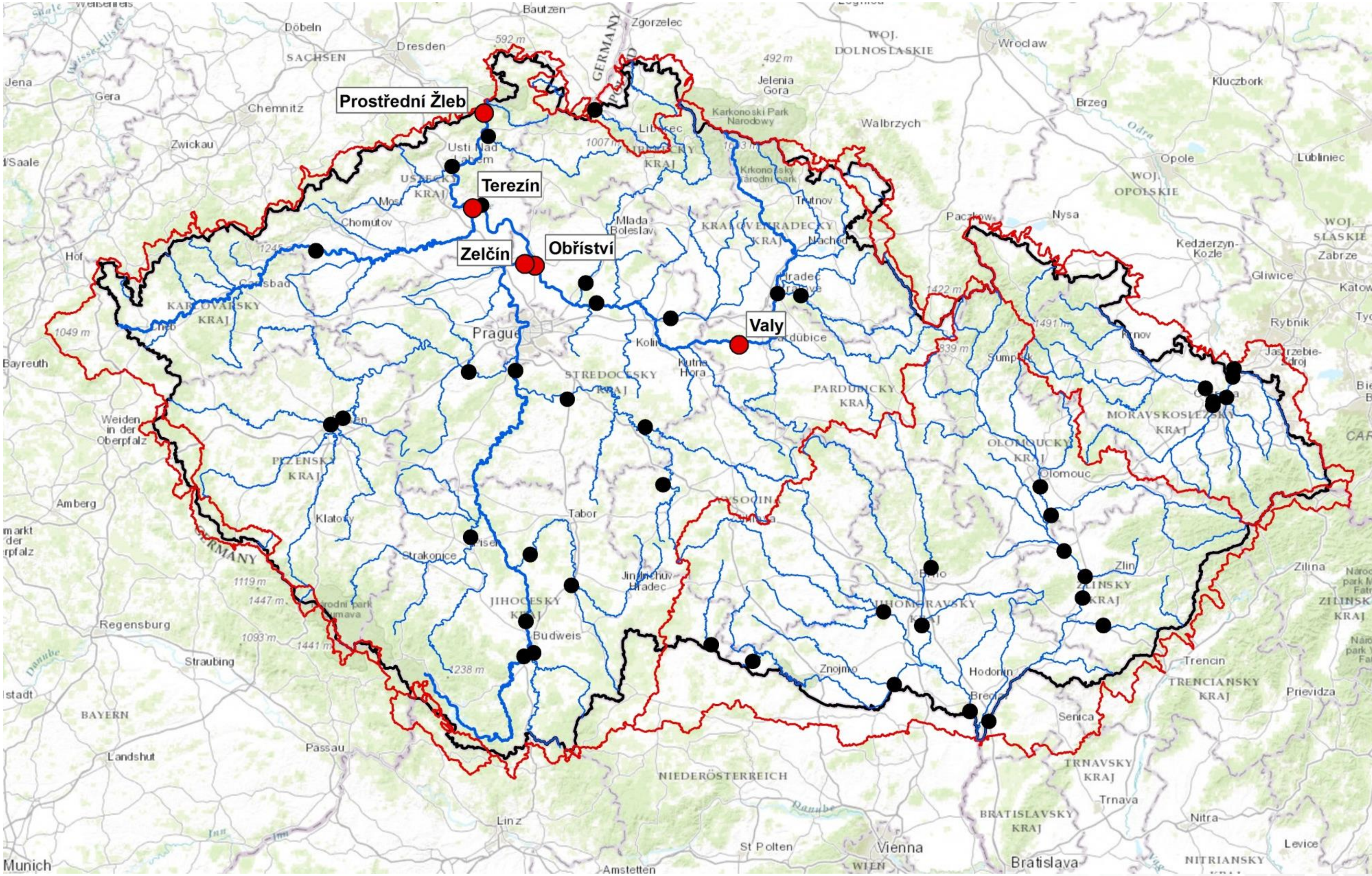
Monitored chemicals:

- 82 compounds: heavy metals, PAHs, chlorbenzens, (chlorinated)pesticides, PCB, phenols, phtalates, support parameters – TOC, turbidity
- One third of them under LoD, lot of others have low concentrations
- Parameters mostly over LoD (44):

Aluminium	Anthracene	Tonalide
Antimony	Benz(a)anthracene	Triclosan
Arsenic	Benzo(a)pyrene	DDT o,p'
Beryllium	Benzo(b)fluoranthene	DDT p,p'
Cadmium	Benzo(ghi)perylene	DDE o,p'
Copper	Benzo(k)fluoranthen	DDE p,p'
Chromium total	Dibenz(a,h)antracen	DDD o,p'
Lead	Fluoranthene	DDD p,p'
Mercury	Fluorene	PCB 28
Nickel	Chrysene	PCB 52
Zinc	Indeno(1,2,3-cd)pyrene	PCB 101
Bisphenol A	Naphthalene	PCB 118
Hexachlorobutadiene	Phenanthrene	PCB 138
Hexachlorbenzene	Pyrene	PCB 153
	Galaxolide	PCB 180

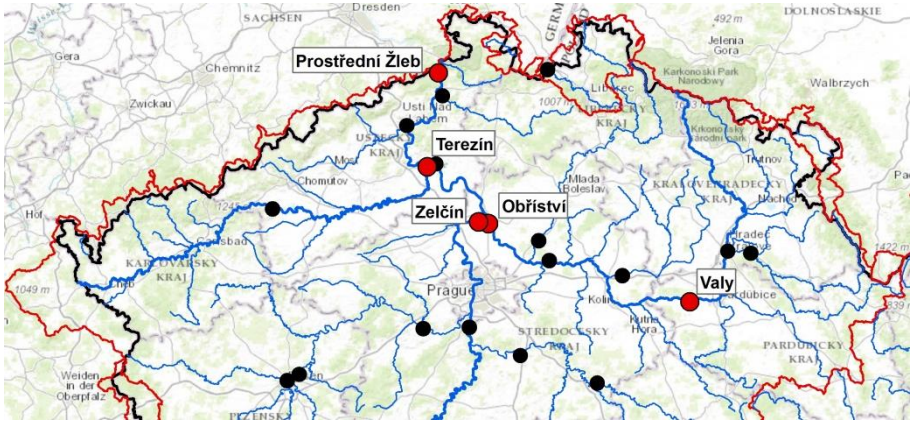
For evaluation were selected – Cd, Hg, As, Pb, HCB, DDX, PCBs (28, 52, 101, 118, 138, 153, 180), 6 PAHs (Flo, BaP, BbF, BkF, BghiP, I123cdP)

Localities



Localities

Station	River	Altitude	Km	Lon	Lat	Q_a
Valy	Labe	208.9	954.7	15.6195	50.0333	59
Obristvi	Labe	157.6	842.1	14.4961	50.3114	104
Prostredni Zleb	Labe	121.0	731.9	12.5505	50.2459	311
Zelcin / Vranany	Vltava	160	837.4	14.4422	50.3186	150
Terezin	Ohre	147.8	764.2	14.1527	50.5154	38



Time span for evaluation: **2013 – 2015**

Localities

Prostredni Zleb – Labe
(German borders)

Zelcin – Vltava

Zelcin,
suction line
in dry period

Data processing – data processing

Raw data were adjusted for analysis

- Detection of outliers – check of data
  - X±3*SD

- Missing data replacement
  - Adjacent values
  - Averaging of multiple points
  - Estimation from flow by weighted average and splines

- Handling of data under limit of quantification
  - Half of limit used
  - In sums (DDX, PCBs):
    - ½ LoD as value
    - Sum se as ½ LoD

Data processing – computations

Suspended sediment runoff

- Daily concentration [mg/l] = C_d
- Daily average discharge [m^3/s] = Q_d

  - $F_i[t]=Q_d*C_d*0.086400$ -> daily load (tons per day)
    - Q_d = 304 m^3/s; C_d = 16 mg/l -> 4 864g/s -> 17 510.4 kg/hour -> 420.25 tons per day

Chemical runoff (load) per year

- Daily load [t] = F_i
- Concentration of chemical in corresponding time window‡ [mg/kg or µg/kg] = $C_{sample,k}$

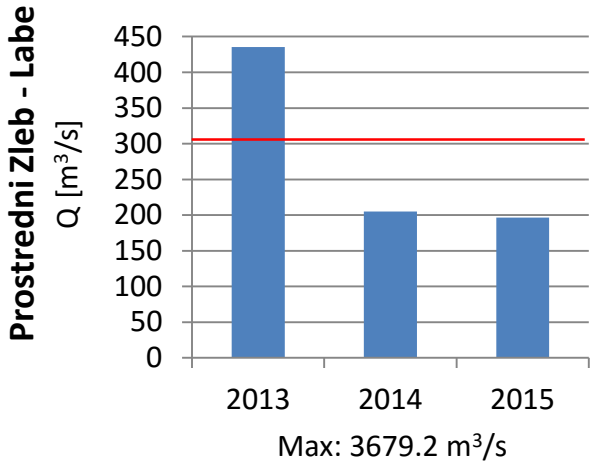
  - $F_j = C_{sample,k} * F_i$

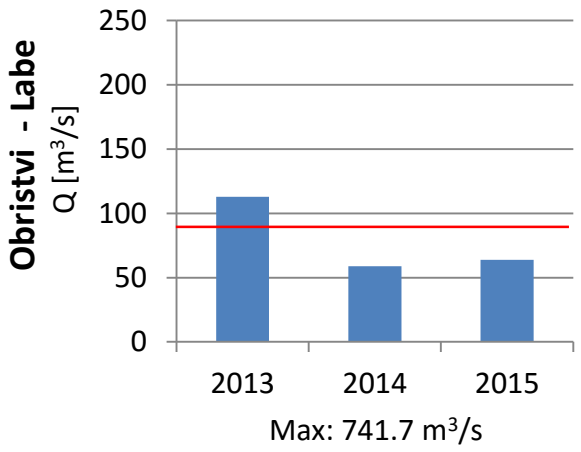
  ‡ Borders of time window are in the middle date of two consecutive samples i.e. when samples are taken 1.5., 1.9. and 1.12., the borders are 1.7. and 15.10

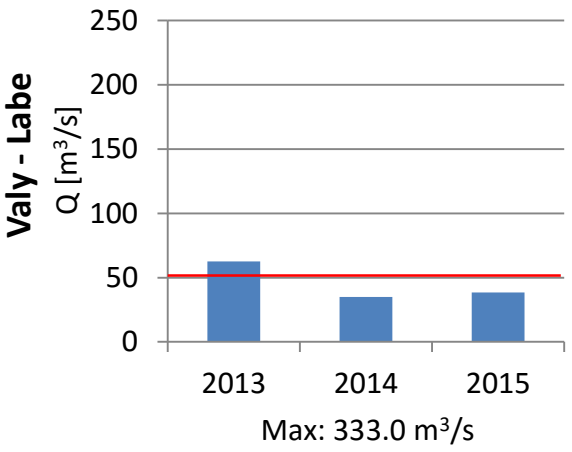
- Finally year load is summed up

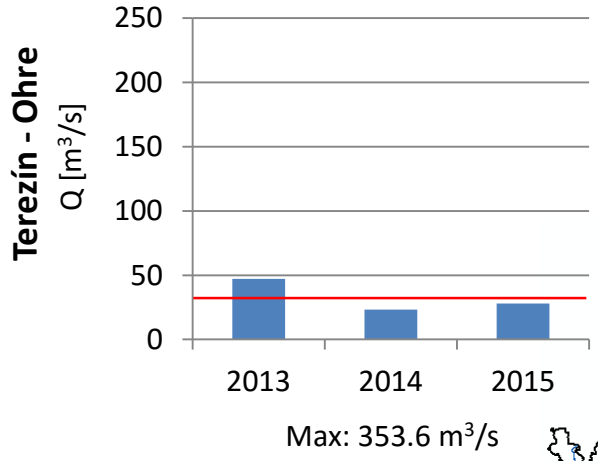
Adopted from: International commission for the protection of the Elbe river, Magdeburg 2014

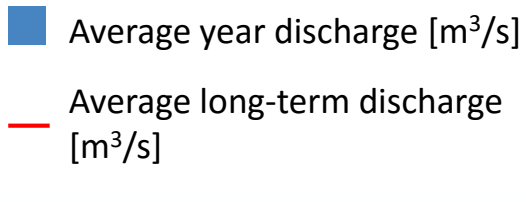
Results – discharge

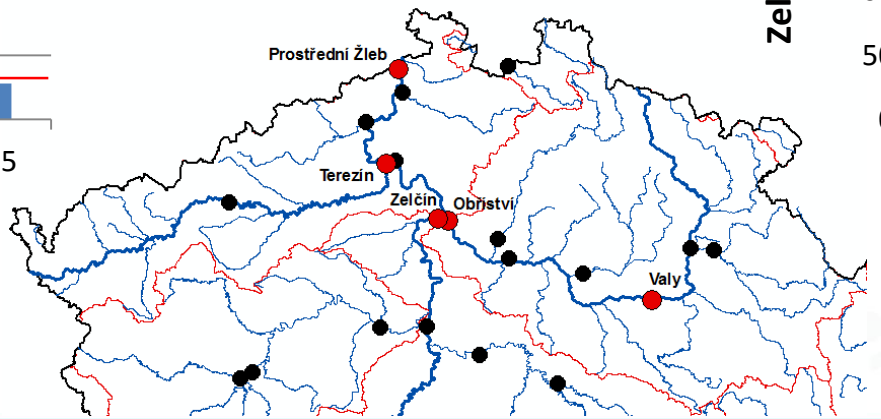


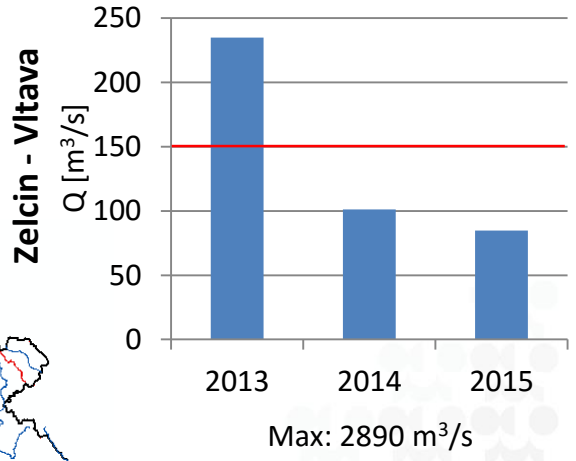




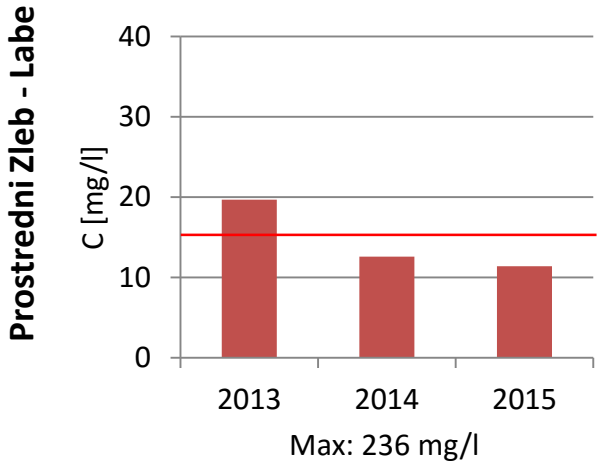


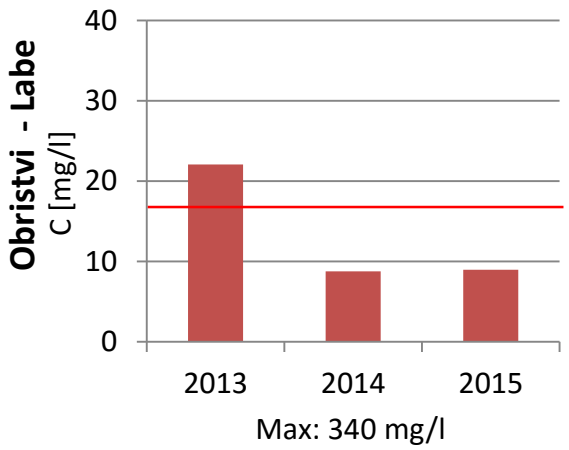


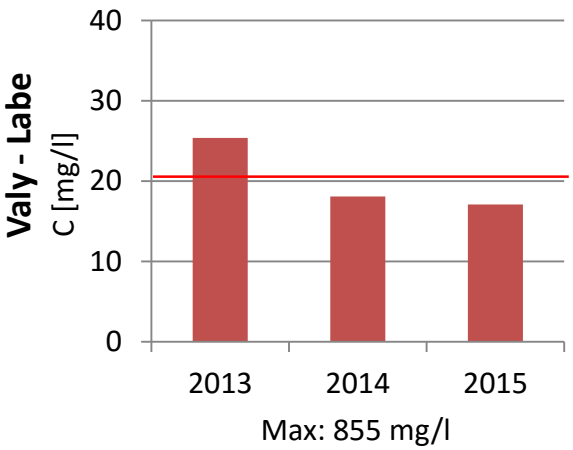


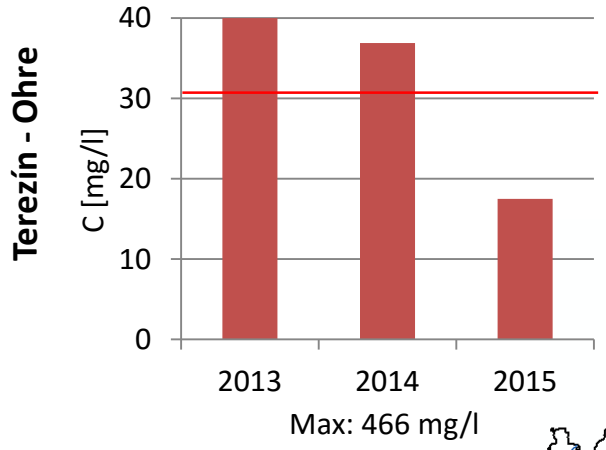


Results – suspended solids



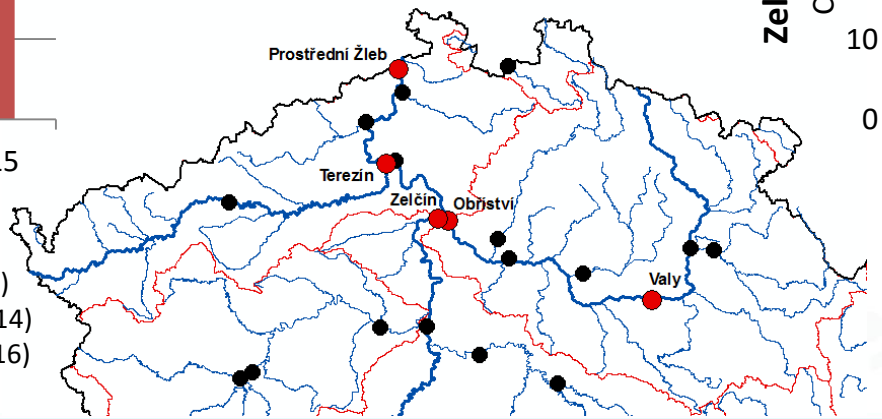


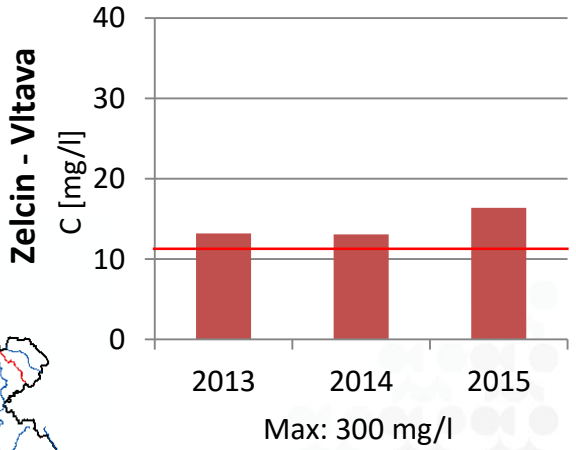




Average year concentration [mg/l]

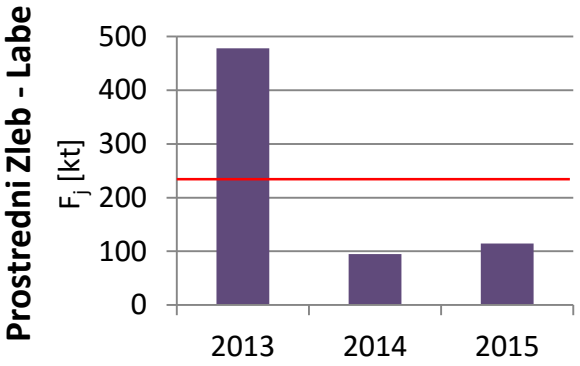
Average long-term concentration [mg/l]

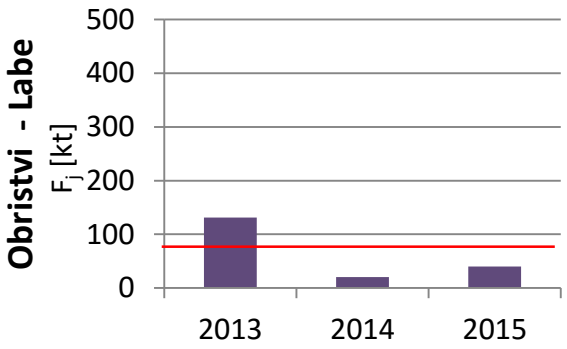


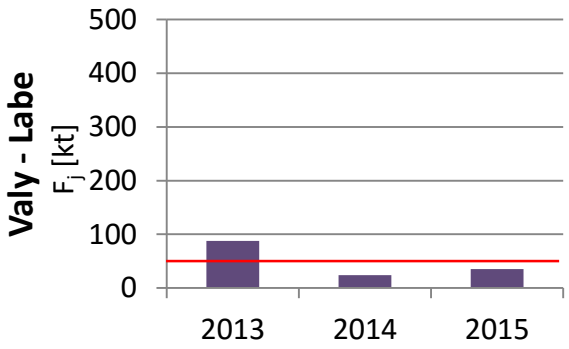


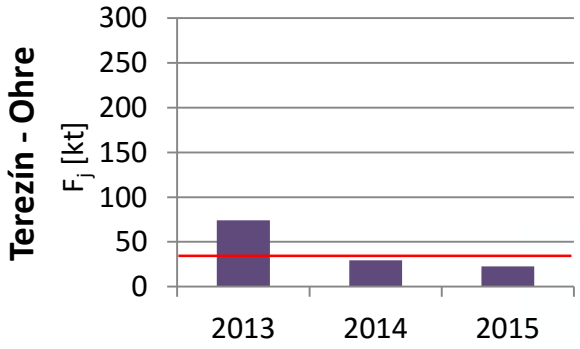
13 mg/l median, Ebro – Spain (Negrel, 2007)
10 mg/l – 1400 mg/l Kamchatka (Mouri, 2014)
820 – 1275 mg/l in floods, Algeria (Allili, 2016)
30.5 mg/l, Japan (Sadeghi, 2008)

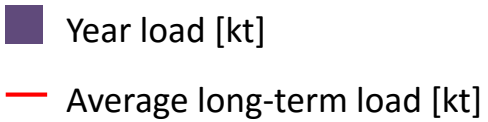
Results – year loads

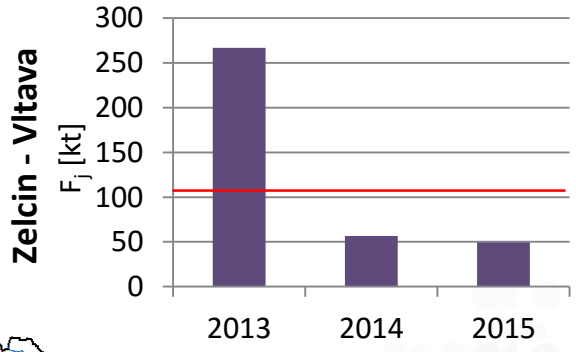


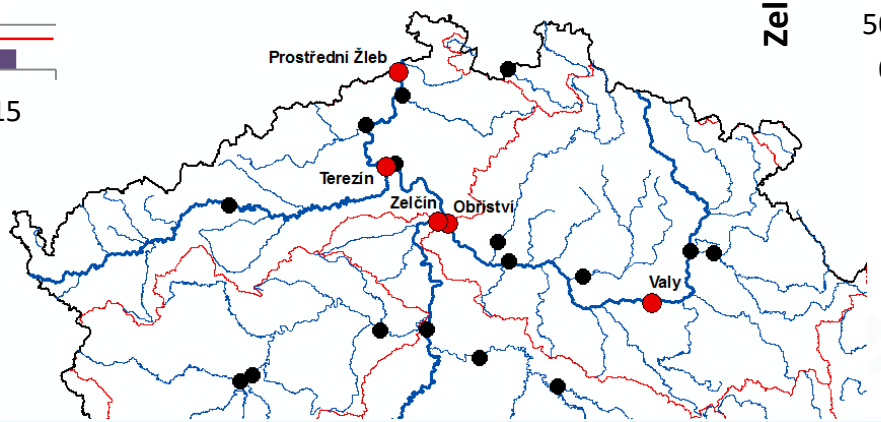




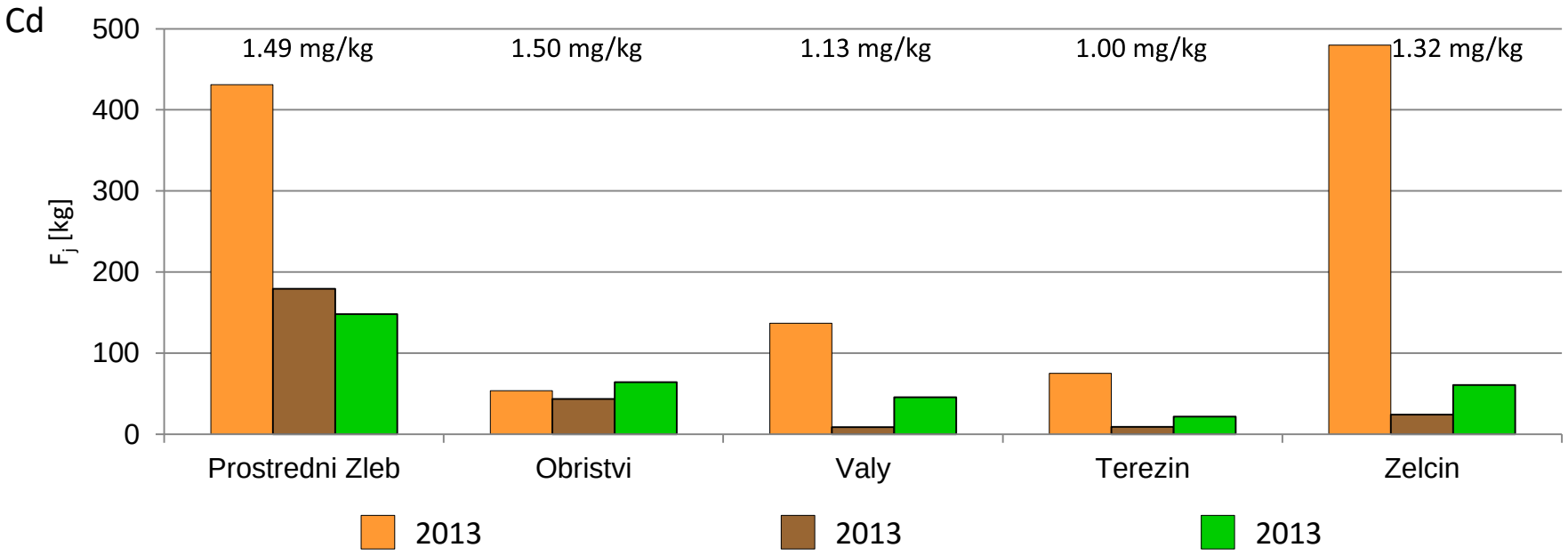


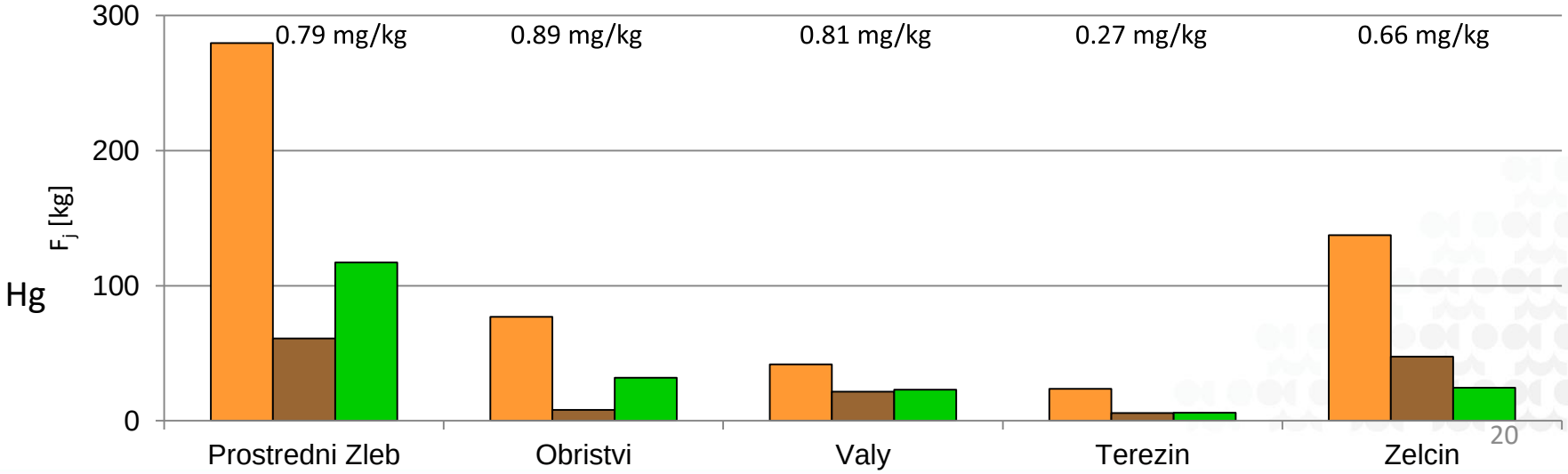






Results – heavy metals





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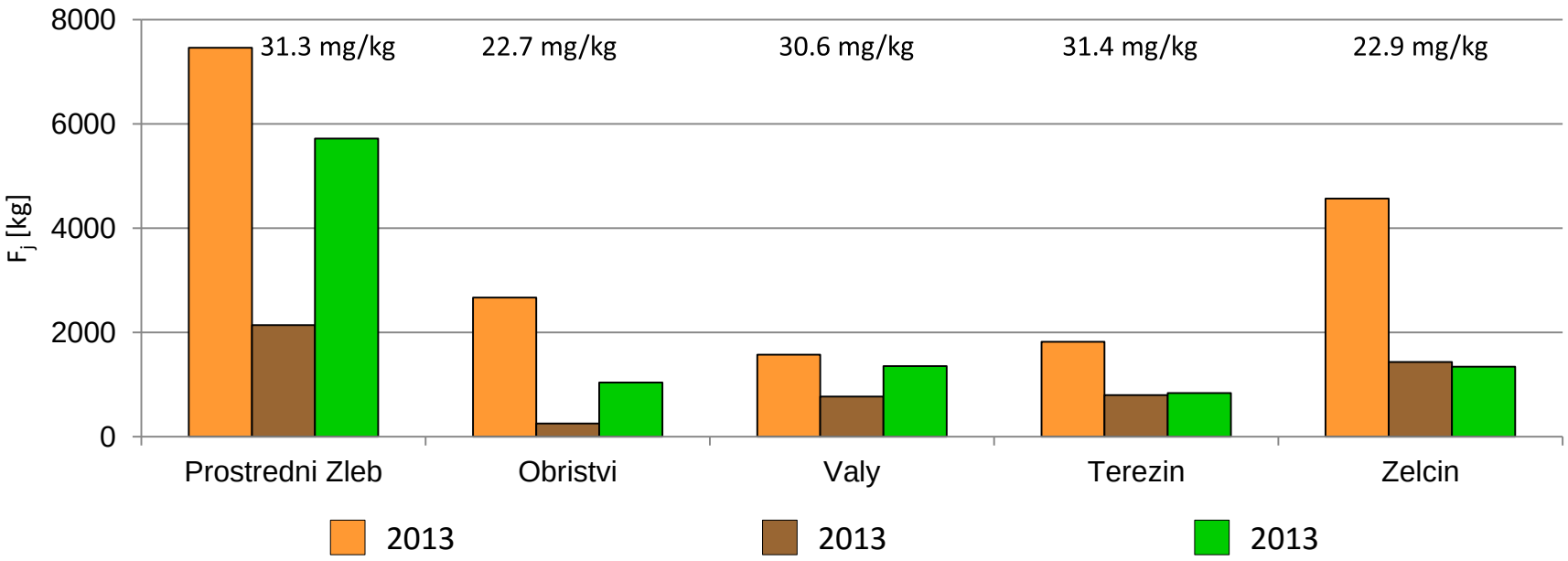
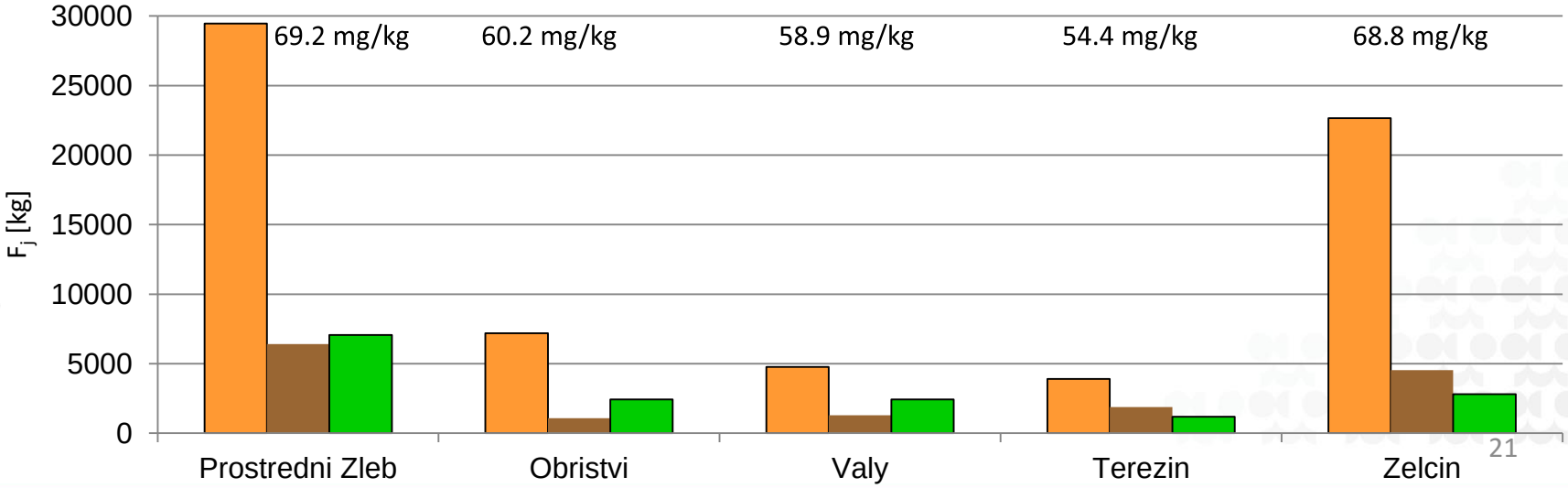
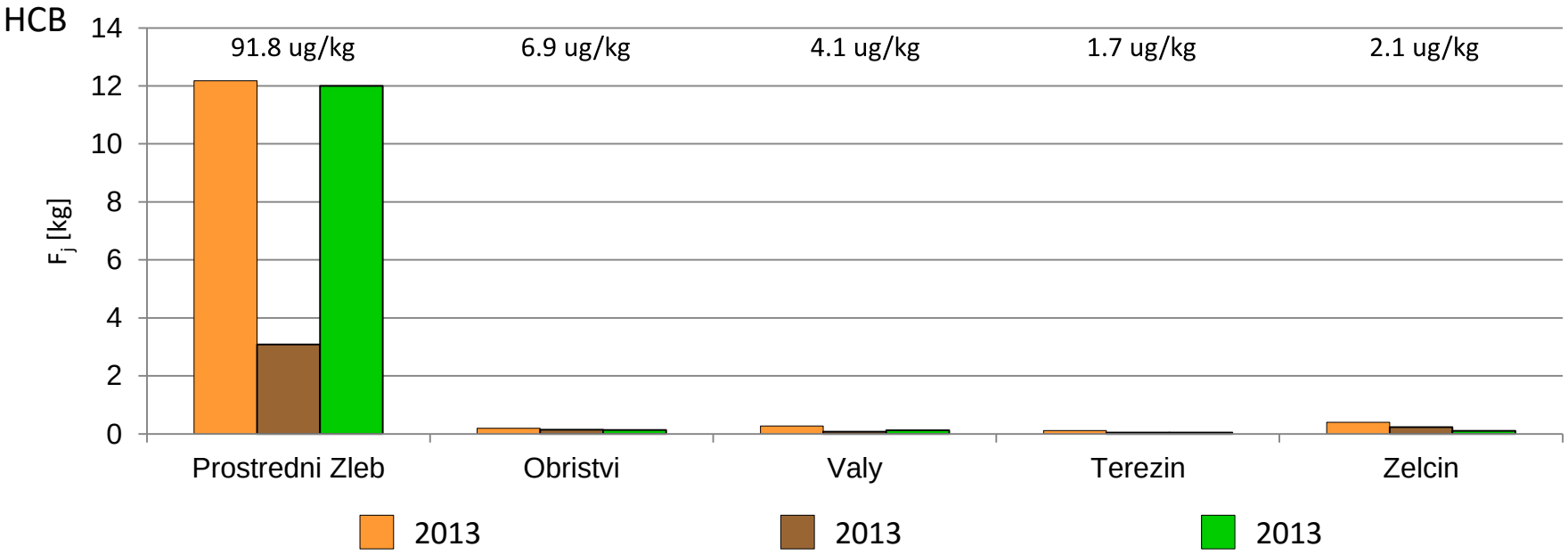
As

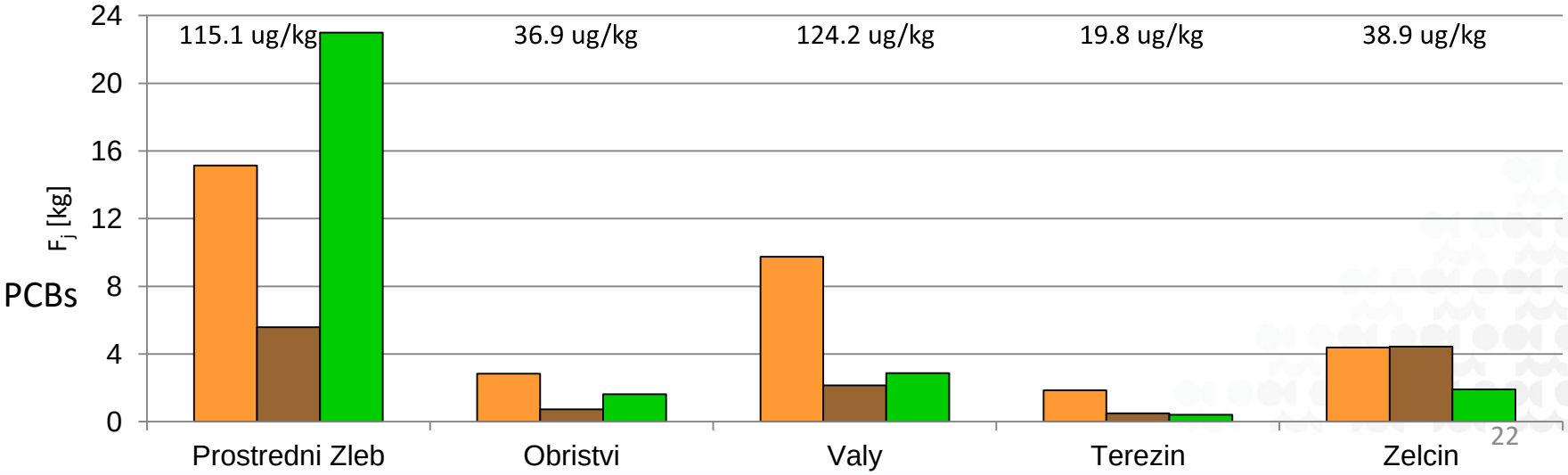


Pb



Results – organic compounds





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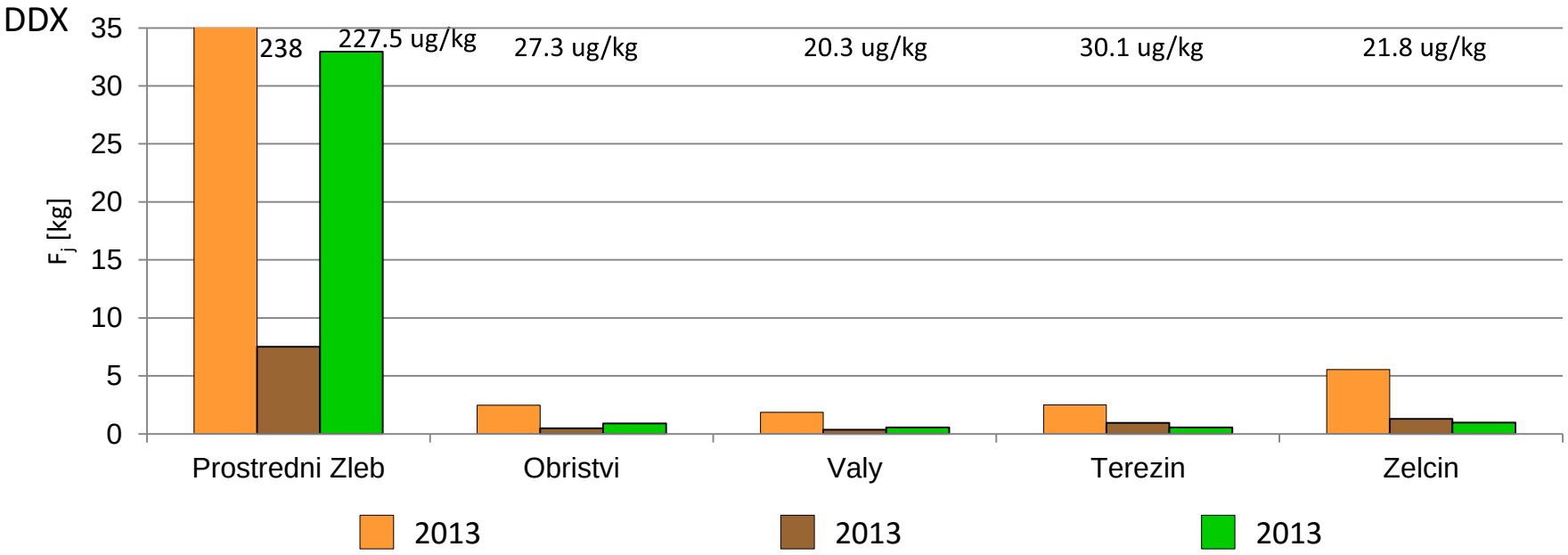

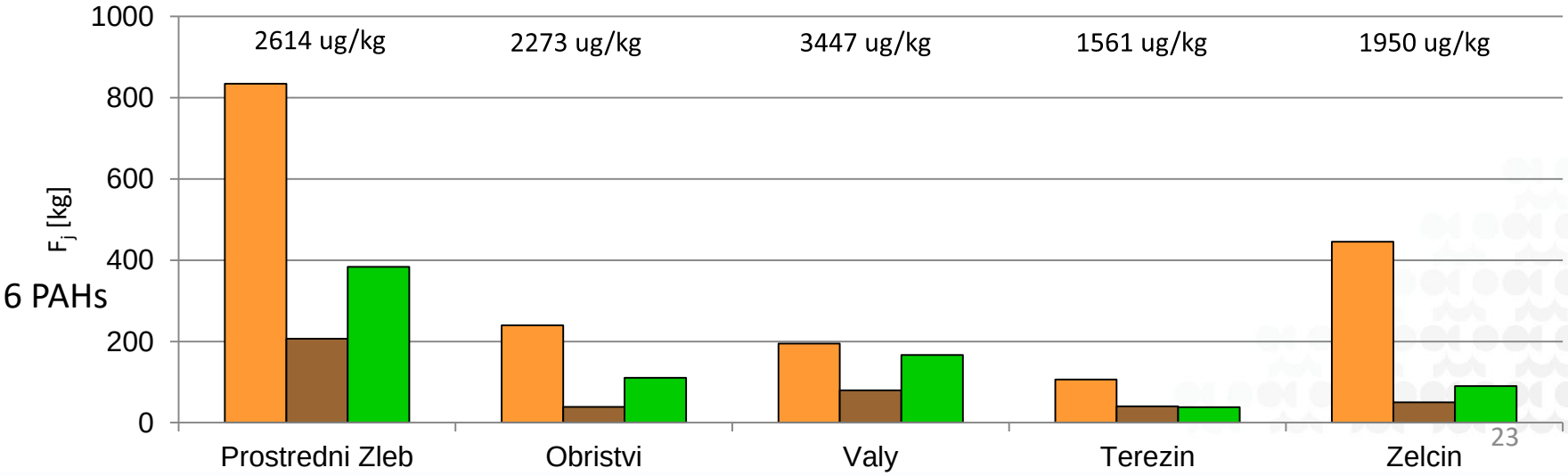

Results

Where the chemical loads in Prostredni Zleb came from?

Results

Where the chemical loads in Prostredni Zleb came from?

- Bilina: Q_a = 6.5 m^3/s, basin 1071 km^2 vs. Labe: Q_a = 311 m^3/s, basin 49 933 km^2
  - Strong pollution from chemical industry, mining and old burdens
  - Heavy metals are present in other rivers as well
    - Cd 2 to 5 times higher
  - Some organics have much higher concentrations in Bilina
    - HCB 60 to 200 times higher average concentration
    - DDX 10 to 300 times higher average concentration

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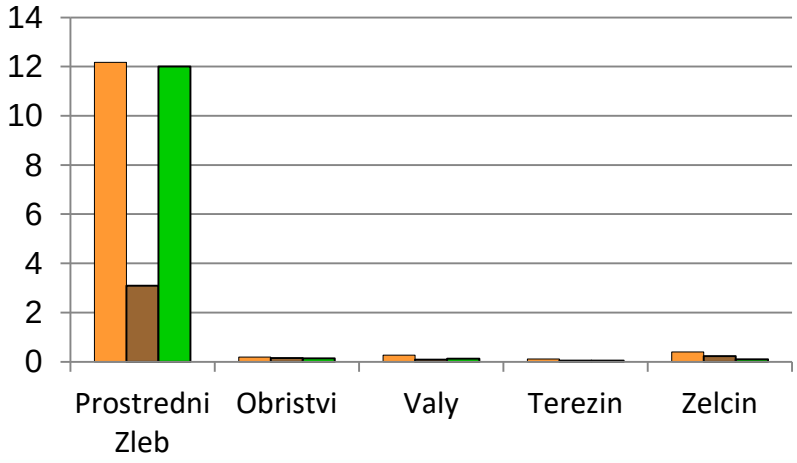

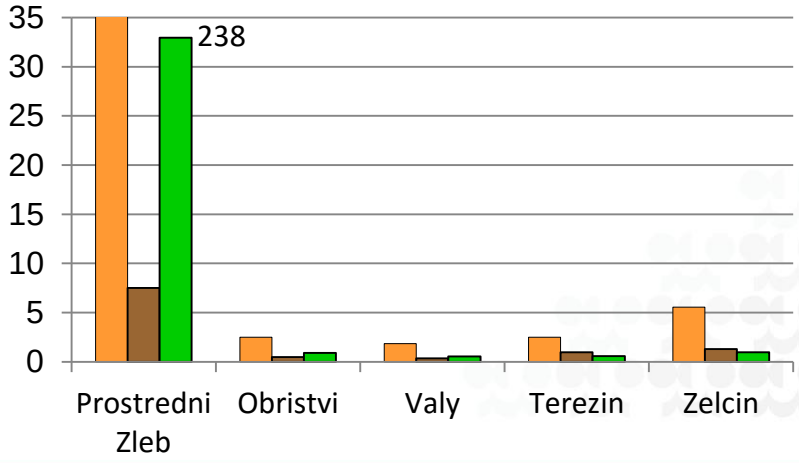

Summary

- Monitoring automated or manual – none is perfect
- Load measured daily, concentrations 4 times a year
- Biggest part of material is transported during high flow regime
  - $F_i[t]=Q_d*C_d*0.086400$
- Suspended sediment concentrations are comparable to other published data
- One bigger flood or more moist year can double (or triple) transported amounts
- Overall yield reaches hundreds of thousands of tons (e.g. 100 – 500kt on Labe)
- One small but solidly polluted stream can have big impact in much larger river

Thank you for attention!

ČHMÚ

Lukáš Kohút

River Basins, 19-20.6.2017

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