MENV PRO

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The Environmental Science Education for Sustainable Human Health

in commemoration of Professor Armen Saghatelyan

6 – 13 September 2021

UNIVERSITÀ DEGLI STUDI DELLA TUSCIA

GIRAF PM

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Accumulation index

↑

Distribution coefficient

↓

Dispersion index

Geochemical background

Geochemical background is the average content of analyte in various environmental compartments according to the results of the study of their natural variation (statistical parameters of distribution) within the boundary of geologically and/or landscape-geochemically homogeneous units[1].

The geochemical background is a relative measure to distinguish between natural element or compound concentrations and anthropogenically-influenced concentrations in real sample collectives[2].

[1]*Saet Y.E., Revich B.A., Yanin E.P., (1990) Environmental Geochemistry. Nedra, p. 335*
[2]*Matschullat J., Ottenstein R., Reimann C. (2000) Geochemical background – can we calculate it? Environmental Geology 39(9), 990-1000.*

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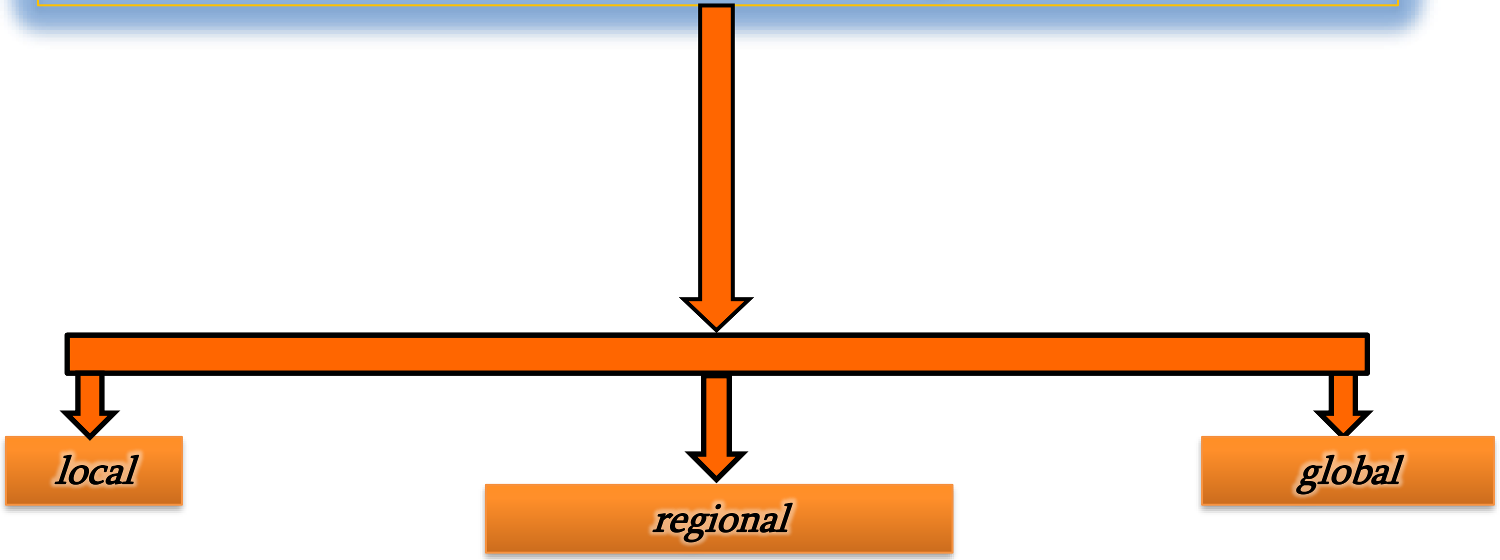
Geochemical background



Where?

- parent rocks
- soil
- plant
- animals

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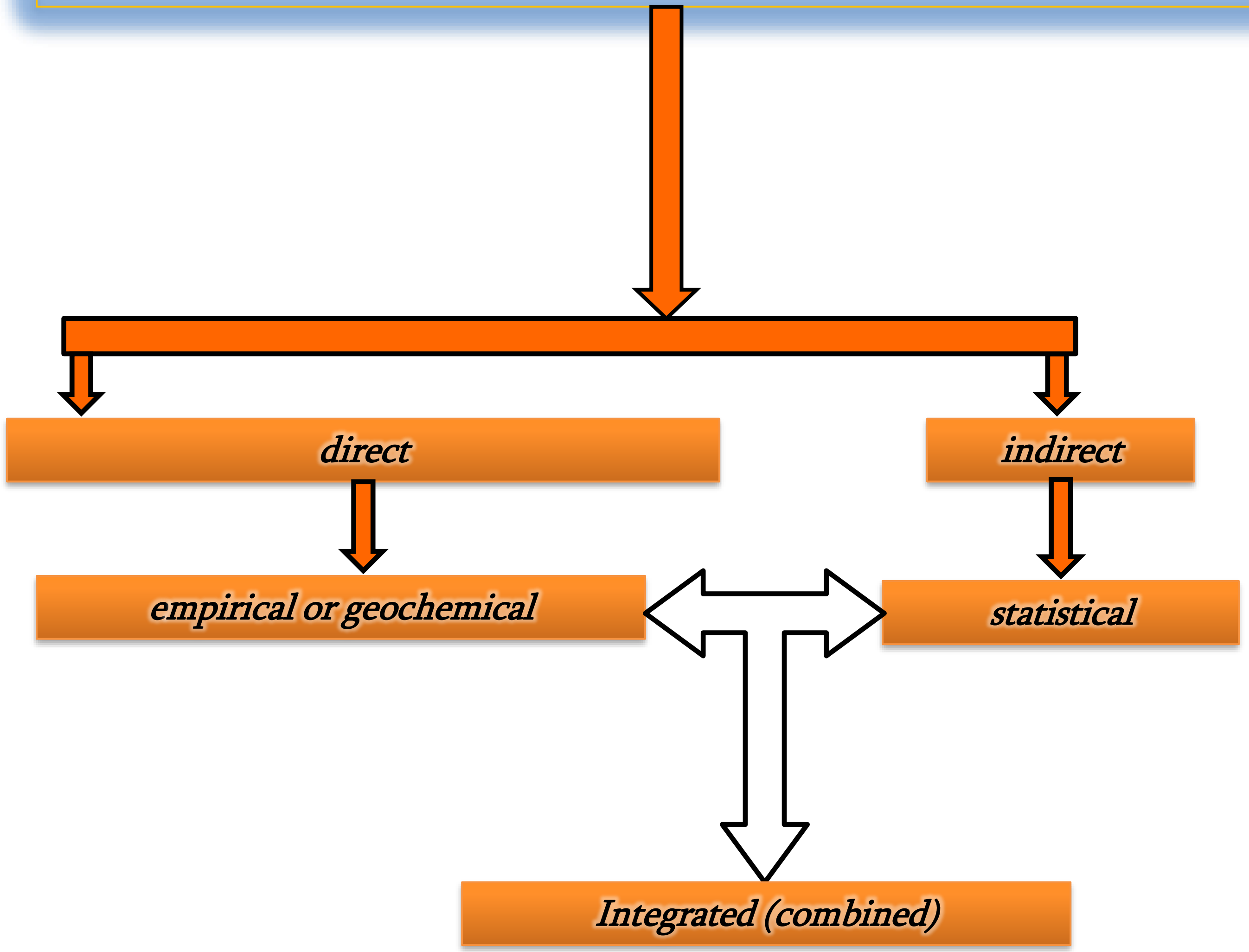
Methods of determination



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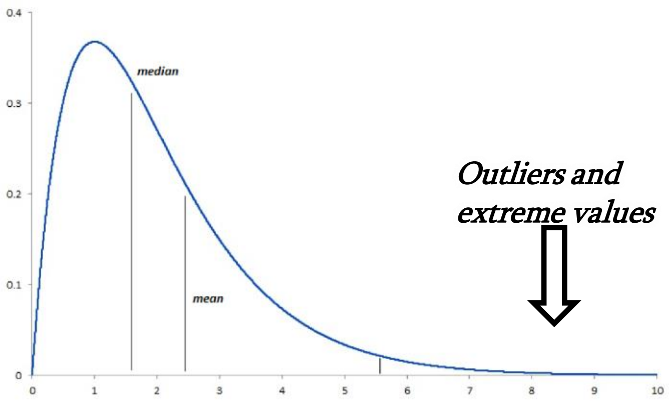
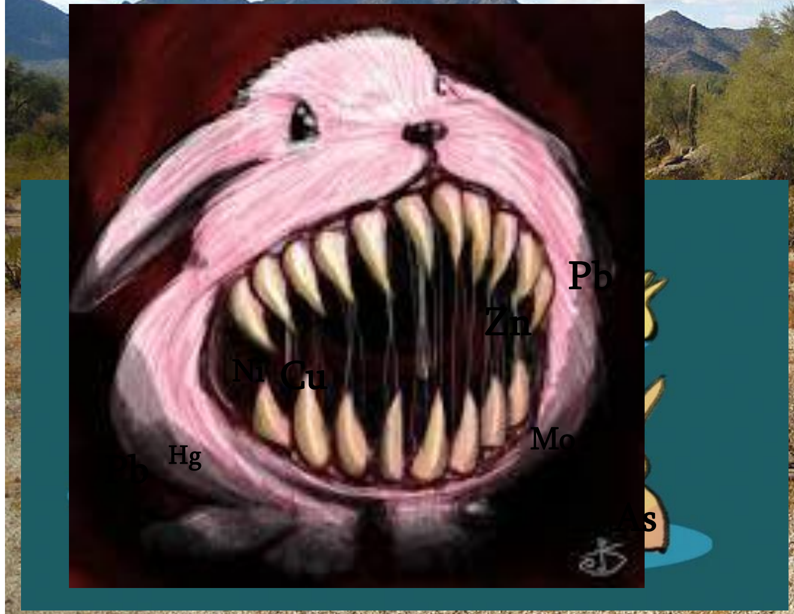
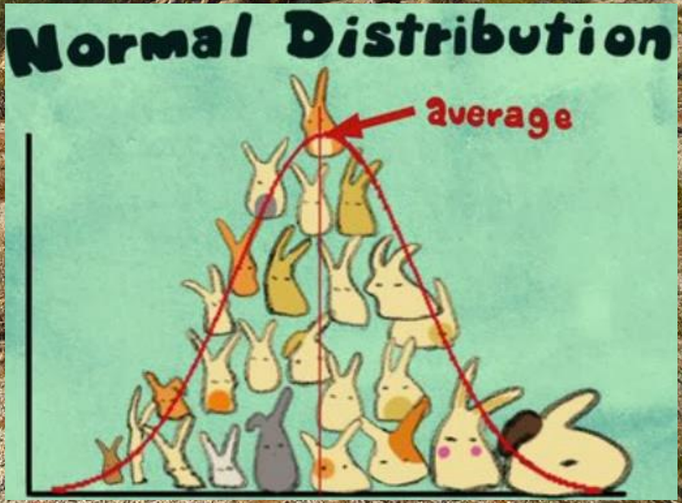
Integrated method

Methods: Outliers and extreme values

- *2σ, 3σ, 4σ*
- *Box and whisker plots*
- *ECDF- or CP-plot etc.*







Integrated method

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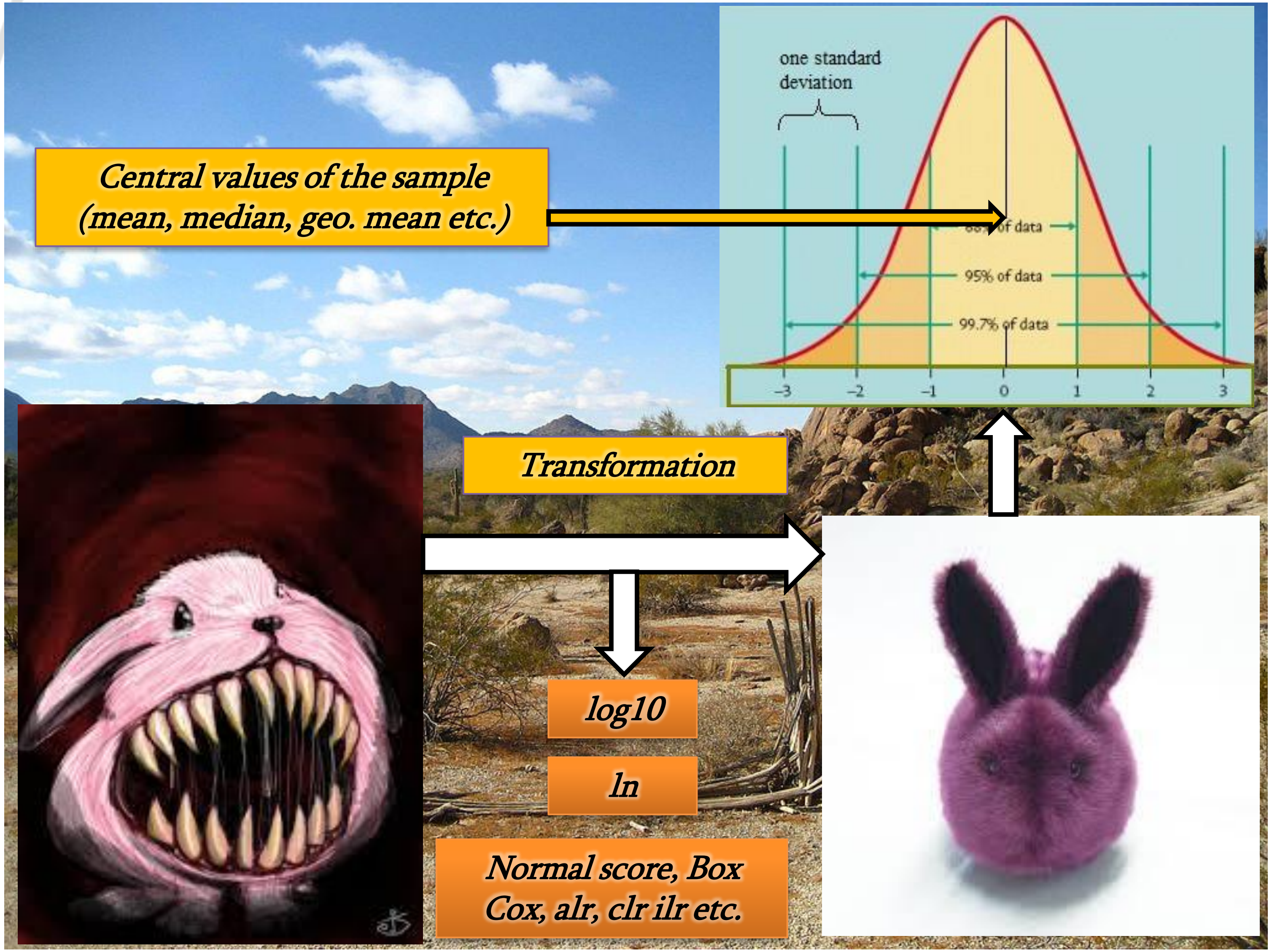

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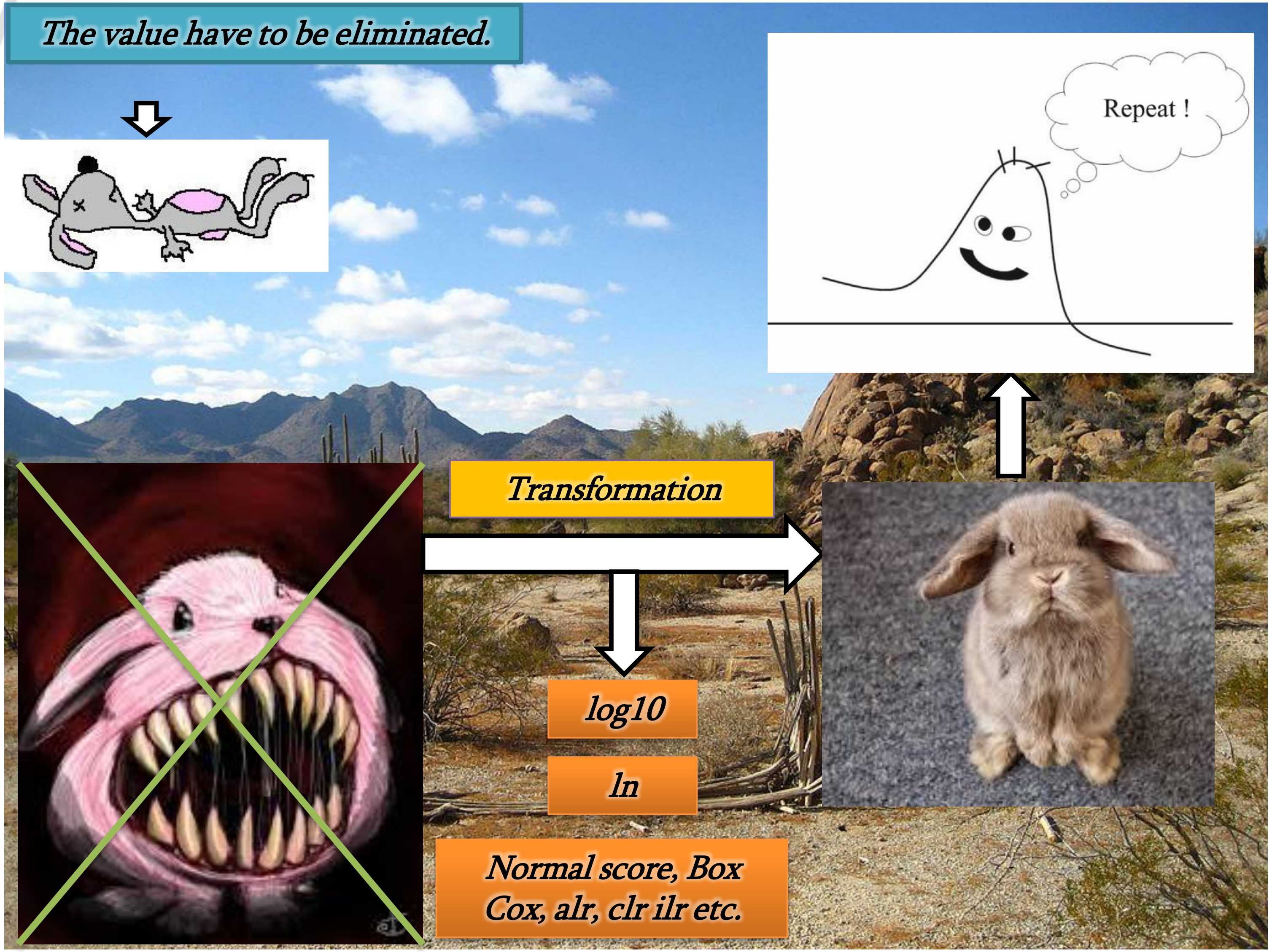
Integrated method



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Geochemical background

Mono-elemental pollution → *Enrichment Factor (EF)*; *Geo-accumulation index (Igeo)*

Multi-elemental pollution → *Nemerow Pollution Index (PI)*; *Summary pollution index (Zc)*

Ecological risk → *Potential ecological risk index (PERI)*

Human health risk → *US EPA Human health risk assessment guideline (HQ, HI)*

Spatial distribution mapping → *Inverse distance weighting (IDW)*; *Kriging*

Polluted and risky sites delineation

↓

Pollution sources identification

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Enrichment factor (EF)[3]:

$$EF = (C_i/C_T)/ (B_i/B_T),$$

where:

C_i is the concentration of an ith element in sample,
C_T is the concentration of proxy-element in the same sample,
B_i and B_T are **background values** of ith element and proxy-element, respectively.

EF levels classification.

EF<2 - deficiency to minimal enrichment,
2<EF<5 - moderate enrichment,
5<EF<20 - significant enrichment,
20<EF<40 - very high enrichment,
EF<40 - extremely high enrichment.

Geoaccumulation index (Igeo)[4]

$$I_{geo} = \log_2\left(\frac{C_n}{1{,}5B_n}\right),$$

where:

C_n is the concentration of n-element in sample,
1,5 is used as a factor for minimizing a probable geogenic effects-caused variation of the **background value**,
B_n – a background value of n-element.

Igeo levels classification.

Igeo ≤ 0 – non contamination,
0<Igeo ≤ 1 - light to moderate,
1<Igeo ≤ 2 - moderate,
2<Igeo ≤ 3 - moderate to strong,
3<Igeo ≤ 4 - strong,
4<Igeo ≤ 5 - strong to extremely serious,
5<Igeo ≤ 10 - extremely serious

[3] *Johnson, C.C., Demetriades, A., Locutura, J., Ottesen, R.T., (2011) Mapping the Chemical Environment of Urban Areas, p. 616*
[4] *Muller, G. (1969) Index of geoaccumulation in sediments of the Rhine River. Geol. J., 2, 108–118*

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Summary pollution index (Zc)[1]

$$K_c = \frac{C_i}{C_f}, \quad (3)$$

$$Z_c = \sum_{i=1}^{n} K_c - (n-1), \qquad (4)$$

where:
Kc is the concentration coefficient,
C_i is the content of the i[th] element,
C_f is the **geochemical background** of the same element,
n is the number of elements in the same sample with $K_c > 1$.

Zc level classification:
Z_c<16 –low level,
16<Z_c<32 –moderately hazardous level,
32<Z_c<128 –hazardous level,
Z_c>128 – extremely hazardous level.

Summary concentration index (SCI)[5]

$$K_{MAC} = \frac{C_i}{C_{MAC}}, \qquad (5)$$

$$SCI = \sum K_{MAC}. \qquad (6)$$

where:
K_{MAC} is the concentration coefficient,
C_i is the content of the i[th] element,
C_f is the Maximum acceptable concentration of the same element.

SCI level classification:
SCI<8 - allowable
8<Z_c<16 - low,
16<Z_c<32 - medium,
32<Z_c<128 - high,
SCI>128 - extremely high.

[1]*Saet Y.E., Revich B.A., Yanin E.P., (1990) Environmental Geochemistry. Nedra, p. 335*
[5]*RA Government, (2005) Decree About the order of evaluation of economical activities – caused impact on soil resources, Decis. N-92-N. URL http://www.arlis.am/DocumentView.aspx?DocID=13401*

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Potential ecological risk index (PERI)[6]

$$C_i = \frac{C_n}{C_f},$$

$$E_r = T_r \times C_i,$$

$$PERI = \sum_{i=1}^{n} E_r^i.$$

where:

E_r is the potential risk factor for each element;
T_r – the toxicity exposure ratio (TER) of the element,
C_f – a **background value** of the element in sample,
C_n – the content of the element in the sample.

E_r and PERI classification:

E_r <40 - low,
40 < E_r <80 - moderate,
80 < E_r <160 - considerable,
160 < E_r <320 – high,
E_r > 320 - very high.

PERI <150 - low,
150 <PERI <300 - moderate,
300 <PERI <600 - considerable,
PERI > 600 – very high.

[6] *Håkanson, L., 1980. An ecological risk index for aquatic pollution control. A sedimentological approach. Water Res. 14, 975–1001. doi:10.1016/0043-1354(80)90143-8*

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Non-carcinogenic risk assessment[7]

$$CDI_{children/adults} = (C \times EF \times ED \times IRS \times CF)/(AT \times BW),$$

$$HQ^i = CDI^i/RfD^i,$$

$$HI = \sum_{i=1}^{n} HQ^i.$$

where:

CDI is the chronic daily intake of metal;
C is the element concentration in soil (mg/kg),
EF - exposure frequency;
ED-exposure duration;
IRS id the ingestion rate;
AT (average time) (AT=365×ED),
BW (average body weight, kg).

Non-carcinogenic risk classification:

HQ/HI<0.01 – no shading,
0.01<HQ/HI<1 – purple,
HQ/HI>1 – blue.

Carcinogenic risk[7]

$$CDI_{canc} = (C \times IFS \times CF)/(AT \times LT),$$

$$CR^i = CDI^i/SF^i,$$

where:

IFS is the ingestion rate-age adjusted; CF is the Conversion factor: 10^{-6} kg/mg.
LT is the lifetime duration: 70 years.

Carcinogenic risk classification:

No shading - $<10^{-6}$,
yellow - 10^{-6}-10^{-4},
red - 10^{-4}-10^{-2},
black - $>10^{-2}$,

[7] *RAIS, 20217. Risk Exposure Models for Chemicals User's Guide Elec. document. Risk Assess. Inf. Syst. URL https://rais.ornl.gov/tools/rais_chemical_risk_guide.html (accessed 04.09.2021).*

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SOME INTERESTING CASES

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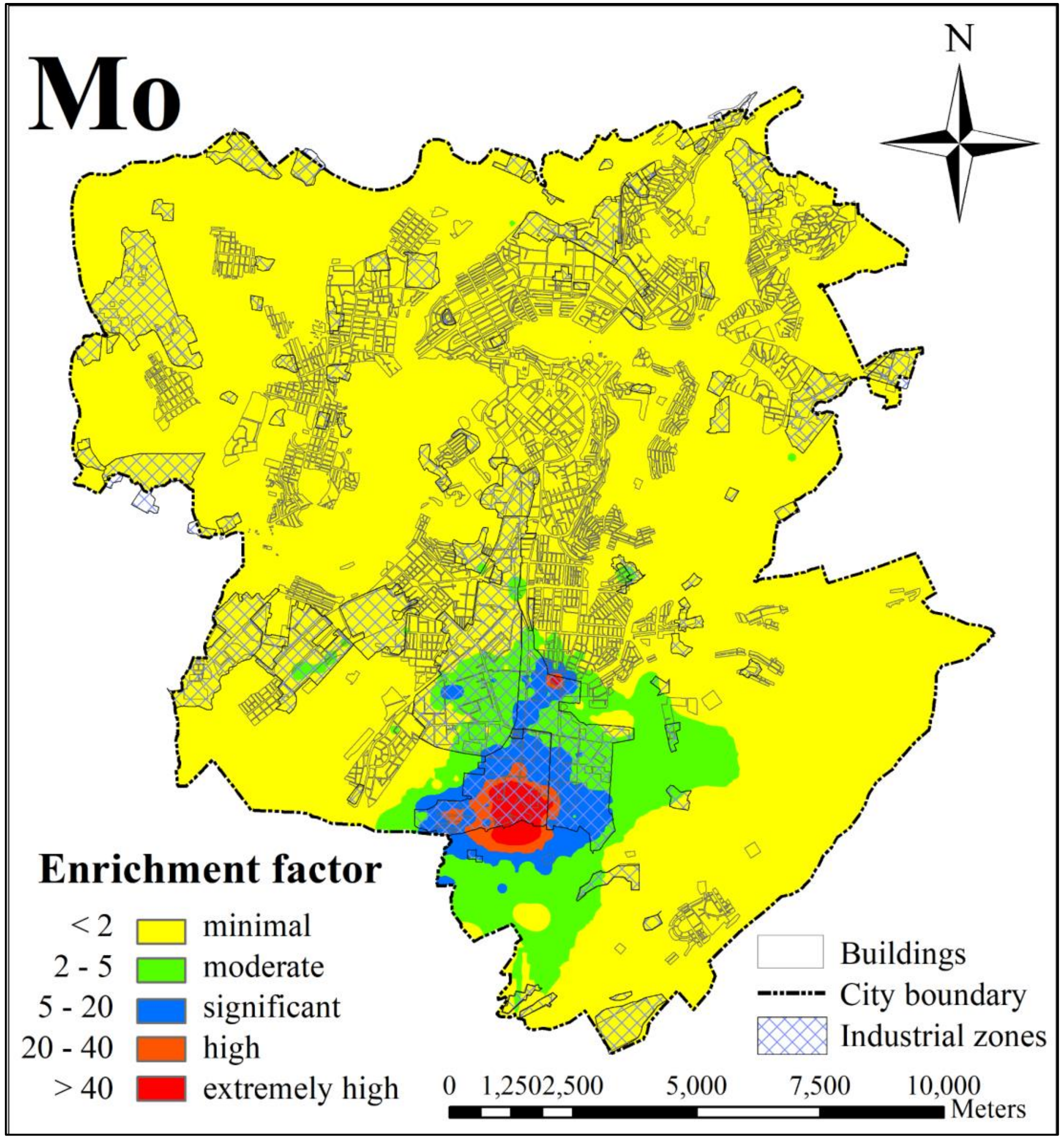
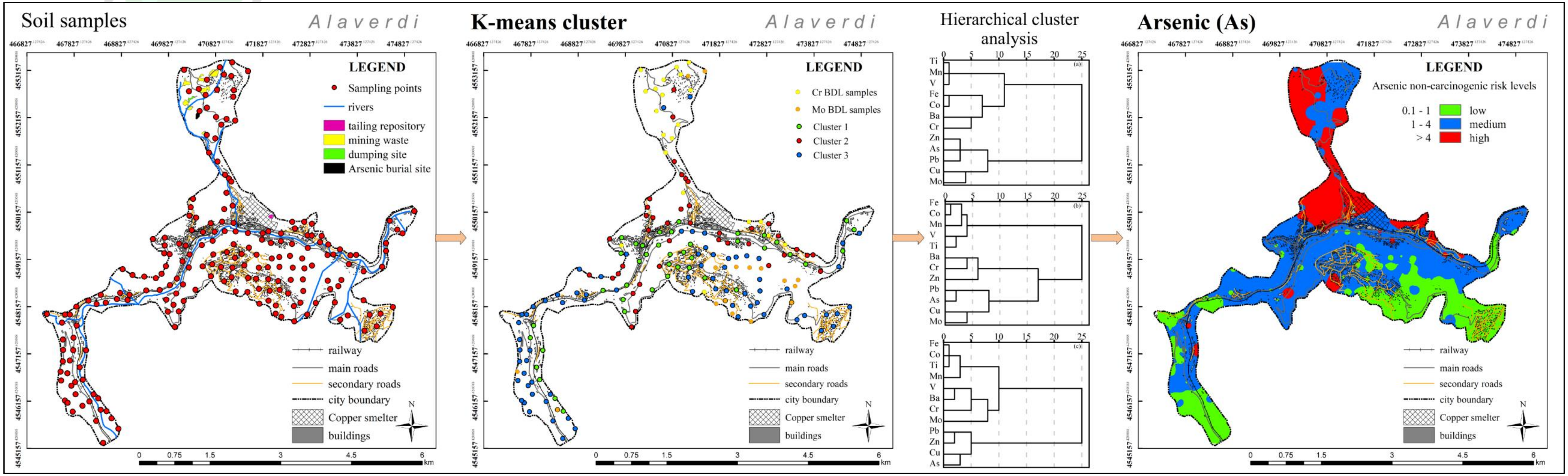
Mo pollution levels distribution in Yerevan[8]



[8]*Tepanosyan, G., Sahakyan, L., Belyaeva, O., Maghakyan, N., Saghatelyan, A., 2017. Human health risk assessment and riskiest heavy metal origin identification in urban soils of Yerevan, Armenia. Chemosphere 184, 1230–1240. https://doi.org/10.1016/j.chemosphere.2017.06.108*

Environmental geochemistry workflow[9]



[9]*Tepanosyan, G., Sahakyan, L., Maghakyan, N., & Saghatelyan, A. (2020). Combination of compositional data analysis and machine learning approaches to identify sources and geochemical associations of potentially toxic elements in soil and assess the associated human health risk in a mining city. Environmental Pollution, 261. https://doi.org/10.1016/j.envpol.2020.114210*

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Thank you for your kind attention!

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