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## POLLUTION INDEXES FOR SOIL QUALITY ASSESMENT

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### **Introduction**

Soil and sediment contamination with metals is an important concern because of their toxicity, persistence and bioaccumulation in the environment. In order to assess the degree of soil contamination pollution indexes are calculated. The most common indexes for soil contamination are enrichment factor and geoaccumulation index. Geoaccumulation index was used since 1970, first for sediment contamination at the moment being used as well as to assess soil contamination.

### **Materials and methods**

The pollution indexes for soil assessment are: *Contamination factor (C<sub>f</sub>)*, *Modified degree of contamination index (mCd)*, *Geoaccumulation index (I<sub>geo</sub>)*, *Enrichment Factor (EF)*.

### **Results and conclusions**

*Contamination factor (C<sub>f</sub>)* is the ratio of average metal concentration in the soil samples reported to the baseline reference concentration in the earth crust, as summarised in the following formula:  $C_f = \frac{C_i}{C_e}$  (1)

where, C<sub>i</sub> represent the mean concentration of the metal in the examined samples, respectively C<sub>e</sub> - the normal value of the metal in the earth crust.

Higher value indicate lower retention time of the element in the soil and thus a higher risk to the environment.

The degree of contamination, C<sub>d</sub>, which is an overall indicator of contamination, is estimated by summing the contamination factors (CF) of each pollutant, according to the formula:

$$C_d = \sum_{i=1}^n C_f \quad (2)$$

where *n* is the number of analyzed elements, *i* represents the pollutant, while C<sub>f</sub> signifies the contamination factor.

C<sub>d</sub> is determined as the ratio of metal concentration in soil to the metal's background values.

The modified degree of contamination (mCd) is calculated as the sum of all the contamination factors divided by the number of analyzed pollutants. This index

averages the contamination of all elements at a particular site through a single value and is determined using the following formula:  $mC_d = \frac{\sum_{i=1}^n Cf}{n}$  (3)  
The assessment of soil quality regarding  $mC_d$  is presented in Table 1.

**Table 1.** Modified degree of contamination and its effects

<b>mC<sub>d</sub> levels</b>	<b>Contamination status</b>
$mC_d < 1.5$	Very low degree of contamination
$1.5 \leq mC_d < 2$	Low degree of contamination
$2 \leq mC_d < 4$	Moderate degree of contamination
$4 \leq mC_d < 8$	High degree of contamination
$8 \leq mC_d < 16$	Very high degree of contamination
$16 \leq mC_d < 32$	Extremely high degree of contamination
$mC_d \geq 32$	Ultra-high degree of contamination

*Geoaccumulation index* ( $I_{geo}$ ) compares the current concentration in the soil with the pre-industrial pollution, being defined by the mathematical relation:

$$I_{geo} = \log_2(C_n / 1.5B_n) \quad (4)$$

where  $C_n$  is the metal concentration, while  $B_n$  represents the background of the element. Taking into account  $I_{geo}$ , the contamination classes are presented in Table 2.

**Table 2.** The classes of the value of  $I_{geo}$

$I_{geo}$	Class	<b>Soil quality</b>
$I_{geo} \leq 0$	1	Practically unpolluted
$0 < I_{geo} < 1$	2	Unpolluted to moderately polluted
$1 < I_{geo} < 2$	3	Moderately polluted
$2 < I_{geo} < 3$	4	Moderately to strongly
$3 < I_{geo} < 4$	5	Strongly polluted
$4 < I_{geo} < 5$	6	Strongly to very strong
$5 < I_{geo}$	7	Very strong pollution

*Enrichment Factor* (EF) can be evaluated considering the differences between the natural and the anthropogenic contribution of the metals in soil, according to the next formula:

$EF = \left[ \frac{X}{Fe} \right]_{sample} / \left[ \frac{X}{Fe} \right]_{crust}$  (5), where  $\left[ \frac{X}{Fe} \right]_{sample}$  and  $\left[ \frac{X}{Fe} \right]_{crust}$  represent the ratio of average concentrations of the target metal and Fe in the studied sample and earth crust, respectively.

EF is classified in five contamination categories, as appears in Table 3.

**Table 3.** The classes of the value of EF

EF < 2	Depletion to minimal enrichment
2 < EF < 5	Moderate enrichment
5 < EF < 20	Significant enrichment
20 < EF < 40	Very high enrichment
EF > 40	Extremely high enrichment