# A STATISTICAL ANALYSIS OF MOSS DATA

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***Abstract:*** *The qualitative estimation of atmospheric pollution by moss biomonitoring assumption supposes a grid network of sampling locations. The present study investigated the precision of the biological tool used for heavy metal mapping purposes. The variance analysis estimated the associated variability for each cell of the sampling network.*

The epiphytic mosses are very good absorbents of airborne pollutants, including anthropogenic trace heavy metals. Additionally, they are widely spread in Europe and this fact makes them the desired passive biomonitors.

In the present study, mosses are used to characterize statistical variations of selected inorganic pollutants using common statistical tools in data interpretation.

## MATERIAL AND METHODS

### *Statistical theory applied to moss data*

In the followings the main steps and measures of usual statistical analysis applied on moss data are presented and discussed.

Let suppose that we have a set of n subjects and m measured variables. The variables and the number of subjects form the Y matrix, $Y=(y_{ij})$, i=1,2,.., m, j=1,2,..,n.

The average value:

$$\overline{y}_i = \frac{\sum_{j=1}^{n} y_{ij}}{n} \text{, i=1..m} \quad (1)$$

Standard deviation.

$$s_i = \sqrt{\frac{\sum_{j=1}^{n}(y_{ij}-\overline{y}_I)^2}{n-1}} \text{, i=1..m} \quad (2)$$

Covariance

$$s_{ik} = \frac{\sum_{j=1}^{n}(y_{ij}-\overline{y}_i)(y_{kj}-\overline{y}_k)}{n-1} \text{, i=1..m} \quad (3)$$

Correlation coefficients (correlation matrix R)

$$r_{ik} = \frac{\sum_{j=1}^{n} (y_{ij} - \overline{y}_i)(y_{kj} - \overline{y}_k)}{\sqrt{\sum_{j=1}^{n} (y_{ij} - \overline{y}_i)^2 (y_{kj} - \overline{y}_k)^2}} = \frac{s_{ik}}{s_j s_k} \text{, i=1,2,..,m} \qquad (4)$$

Standard (normated) matrix

$$z_{ij} = \frac{y_{ij} - \overline{y}_i}{s_i} \text{, i=1,2,..,m, j=1,2,..,n} \qquad (5)$$

Correlation coefficient wrote with the Z matrix elements

$$r_{ik} = \frac{\sum_{j=1}^{n} z_{ij} z_{kj}}{\sqrt{\sum_{j=1}^{n} z_{ij}^2 \sum_{j=1}^{n} z_{kj}^2}} = s_{ik} = \frac{\sum_{j=1}^{n} z_{ij} z_{kj}}{n-1} \qquad (6)$$

$$\frac{ZZ'}{n-1} = R = S, \qquad (7)$$

The main goal of factor analysis is to write any variable like a linear combination of r<m factors.

$$z_{ij} = \sum_{l=1}^{r} a_{il} p_{lj} \qquad (8)$$

The same relation in the matrix form:

Z=AP (9)

The main goal of factor analysis is to determine the A matrix (factor loading) and factor score. To obtain this matrix it is necessary to solve the eigenvalues problem for the matrix of correlation R.

$$\mathbf{R}\boldsymbol{\alpha}_1 = \lambda_l \boldsymbol{\alpha}_1 \text{ sau } (\mathbf{R} - \lambda_l \mathbf{I})\boldsymbol{\alpha}_1 = \mathbf{0} \tag{10}$$

where $\{\lambda\}$= the set of the eigenvalues.

In practice, the data were subjected to analysis of statistical parameters by using the statistical package SPSS 4.0.

## RESULTS AND DISCUSSIONS

Deposition from the atmosphere forms the input of airborne pollutants to the moss plant body. Deposition is dry as well as wet, and the sum of both parts give the real value of the moss atmospheric supply.

The moss data were computed in terms of descriptive statistics indexes (i.e. average concentration, median concentration, minimum concentration, maximum concentration, standard deviation, etc.) and further the correlation matrix of data interrelationships was calculated. All this procedure was largely described in earlier studies of the author, than we'll focus the discussion here mainly on moss bioindication. We used the bioindication index defined as

$$B_{moss} = Maxconc / Minconc \tag{11}$$

where *Maxconc* and *Minconc* are measured in μg/g,

which measure the variability in the accumulated contamination loads in mosses (Table 1). The highest concentrations were determined for Cr, Fe, Co, Ni, Cu, Zn, As, Se, Mo, Ag, Cd, Sb, Ba, W and U in Transylvania Plateau. The bioindication index (here, maximal/minimal elemental concentration) ranged from 15 to 50 in the four studied regions. These trends characterizing the corresponding differences in elemental concentrations in mosses indicate a similar variation in atmospheric pollution between regions. Much larger differences in bioindication indexes were found for atmospheric pollutants as antimony (573), silver (117), cadmium (117) molybdenum (113) and arsenic (90). Higher bioindication indexes were found also for elements like samarium (325), lanthanum (129) uranium (98) and thorium (78) that can be explained by windblown soil dust. The higher bioindication indexes found for wolfram (up to 142) can be attributed to analytical uncertainties.

The variation shown by mean concentrations of selected elements in moss samples distinguished clearly between background and impact areas.

*Table 1*

**The bioindication indexes (Max/Min) of elements in mosses collected**

| Region/ Element | Eastern Carpathians | Southern and Western Carpathians | Transylvania Plateau | South of Romania |
|---|---|---|---|---|
| **Na** | 44 | 20.6 | 22.6 | 7.7 |
| **Mg** | 13.1 | 14.3 | 14.3 | 8.6 |
| **Al** | 22.6 | 14.2 | 27.8 | 10.4 |
| **Cl** | 8.5 | 5.9 | 8.2 | 2.6 |
| **K** | 5.6 | 37.1 | 3.3 | 11.1 |
| **Ca** | 12.9 | 13.7 | 18.8 | 3.6 |
| **Sc** | 25.4 | 18.2 | 25 | 5.8 |
| **V** | 15.8 | 8.7 | 1.6 | 9.1 |
| **Cr** | 76.3 | 9.8 | 16.4 | 11.6 |
| **Mn** | 32 | 16 | 54.4 | 4.7 |
| **Fe** | 29.1 | 13 | 14.1 | 6.7 |
| **Co** | 20.3 | 22.8 | 19.0 | 4.2 |
| **Ni** | 18.2 | 5.2 | 31 | 8.7 |
| **Cu*** | 40.3 | 36.1 | 16.7 | |
| **Zn** | 11.1 | 9.4 | 20 | 3.7 |
| **As** | 90 | 9.6 | 18.3 | 4.2 |
| **Se** | 16.1 | 7 | 20.5 | 17.2 |
| **Br** | 4.2 | 3.6 | 10.3 | 6.7 |
| **Rb** | 24.5 | 8.3 | 8.7 | 4 |
| **Sr** | 81 | 15.5 | 11.3 | 12 |
| **Zr** | 67.3 | 33.5 | 47.4 | 6.2 |
| **Mo** | 52.7 | 12.4 | 15.7 | 113 |
| **Ag** | 71.3 | 49.2 | 116.7 | 19.5 |
| **Cd*** | 28 | 24.3 | 48 | |
| **Sb** | 573 | 6.4 | 61 | 3.1 |
| **I** | 5.7 | 5.0 | 7.3 | 6.8 |
| **Cs** | 73.5 | 14.4 | 21.2 | 6.4 |
| **Ba** | 43.3 | 8.2 | 13.3 | 5.9 |
| **La** | 129.1 | 87 | 42.1 | 11.8 |
| **Ce** | 45.6 | 15.6 | 45.7 | 9.6 |
| **Sm** | 51.2 | 56.8 | 325.4 | 7.2 |
| **Tb** | 32 | 21.4 | 75.4 | 5.2 |
| **Yb** | 73.5 | 15.8 | 35.6 | 5.5 |
| **Hf** | 66 | 18.4 | 23.3 | 7.7 |
| **Ta** | 61.7 | 13.4 | 49.4 | 6.5 |
| **W** | 141.7 | 19.5 | 75.9 | 6.4 |
| **Au** | 28.5 | 19.2 | | 12.1 |
| **Pb*** | 8.6 | 25.5 | 26.9 | |
| **Th** | 75.398 | 16.0 | 19.6 | 8.7 |
| **U** | | 13.3 | 32.4 | 6.8 |

## CONCLUSIONS

The statistical methods offer a simple way to study different patterns of airborne pollutants that are deposited in mosses. Terrestrial mosses are passive, show good accumulation properties in yearly-developed segments and are easy to handle.

The results show how statistical tools can be employed to indicate depositions of airborne pollutants in terrestrial mosses. It is suggested that on the basis of a statistically selected network (for example, using neural algorithms), analysis of contaminant patterns in mosses could be used for the evaluation of the possible ecotoxicological effects of airborne pollutants on forest ecosystems.

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