QUICK RISK ASSESSMENT OF METAL POLLUTION IN AGROECOSYSTEMS USING BIOCONVERSION FACTORS

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Abstract
A quick approach for reliable prediction of metal concentrations in agricultural plants within an ecosystem using one reference plant and earlier derived bioconversion factors (the ratios of pollutant concentration in reference plant to its concentration in another plant) is proposed. The bioconversion factors for Al, Ba, Ca, Cd, Cr, Co, Cu, Fe, K, Mg, Mn, Ni, Pb and Zn for apple, pear and sunflower in 7 ecosystems with different anthropogenic burden are determined in respect to maize as a reference plant. Mean values and variation ranges of the concentration ratios fruits/leaves and corns/leaves and the bioconversion factors are presented. An example for quick risk assessment of metal pollution of fruits is given using the presented data.

Introduction
Monitoring of the metal concentrations in agroecosystems is an important part of the ecological investigations, especially in view of the danger of the distribution of pollutants along the trophic chains and their accumulation in living organisms. The risk assessment of metal contamination in agroecosystems requires a large number of chemical analysis due to the specific abilities of plants to accumulate toxic metals. Therefore the investigations, aimed to define the environmental status and the risk for human health appear to be rather time-consuming and expensive.

The aim of the present paper is to propose an approach for quick evaluation of the distribution of different elements and assessment of the risk in agroecosystems using bioconversion factors. Bioconversion factors are defined by the ratio of the pollutant concentration in a well-studied indicator (reference) plant to its concentration in another plant (growing in the same ecosystem) (1). The knowledge of bioconversion factor intervals gives the possibility the metal concentrations of plant species to be predicted only after analysis of the indicator plant. In the present study bioconversion factors for 14 different toxic and essential elements in 7 agroecosystems are determined using agriculture maize as a reference plant. The mean values of the bioconversion factors and their ranges of variation for background ecosystems and ecosystems under different degree on anthropogenic burden are summarized. The established data are basis for further investigations, aiming to define more precisely the bioconversion factor values. This will enable the quick and cheap risk characterization of the environment.

Methods

The concentrations of 14 essential and toxic elements in leaf and fruit samples of 4 plant species, taken from 7 agroecosystems with different anthropogenic contamination (including background region) were determined. Sampling, sample preparation and the analytical instrument, used for the analysis of the plant samples were described in (2). Bioconversion factors were calculated using the following concentration ratio:

$$\text{Bioconversion factor (BF)} = \frac{\text{leaf concentration in reference plant [mg/kg]}}{\text{leaf concentration in another plant [mg/kg]}}$$

On the basis of previous investigations performed by us (2) the plant species maize was chosen for a reference (indicator) plant.

Risk assessment of lead contamination of apple fruits was performed by calculation of “predicted fruit concentration” [mg/kg] (determined for dry weight), using the presented bioconcentration factors and the fruits/leaves ratios.

$$\text{Predicted fruit concentration (PFC)} = \frac{\text{leaf concentration in reference plant [mg/kg]}}{\text{BF}} * \text{fruits/leaves ratio}$$

The present approach was performed, presuming the highest predictable risk (highest predictable degree of pollution) and highest predictable metal concentrations in fruits. For that reason the lowest value of the determined variation range of BF and the highest value of the concentration ratio fruits/leaves were used for the calculation of PFC, presented below.

The predicted fruit concentration values were compared to the concentrations measured by us. Conclusions about the applicability of the bioconversion factors for risk assessment of metal contamination of fruits were done in respect to the maximum allowable concentrations (AC) of lead in fruits approved according (3).

Results

Table 1 presents the mean values and the variation ranges of the concentration ratios fruits/leaves for apple and corns/leaves for maize. The present values were summarized from data, obtained for 7 agroecosystems with different anthropogenic burden.

Table 1: Mean values and variation ranges of the concentration ratios fruits/leaves for apple and corn/leaves for maize for regions with different degree of anthropogenic contamination

Element	Apple		Maize	
	Mean value	Min-Max value range	Mean value	Min-Max value range
Al	0.34	0.1 – 0.77	0.06	0.03 - 0.09
Ba	0.17	0.04 – 0.44	0.21	0.16 – 0.23
Ca	0.72	0.63 – 0.88	0.026	0.023 – 0.030
Cd	0.17	0.09 – 0.22	0.04	0.02 – 0.071
Co	0.42	0.37 – 0.67	0.06	0.044 – 0.090
Cr	0.45	0.37 – 0.67	0.25	0.13 – 0.39
Cu	1.14	0.95 – 1.45	0.022	0.015 – 0.027
Fe	0.39	0.24 – 0.75	0.09	0.053 – 0.12
K	1.41	0.92 – 2.05	0.55	0.38 – 0.75
Mg	1.02	0.10 – 3.16	0.48	0.17 – 0.64
Mn	0.55	0.34 – 0.79	0.17	0.10 – 0.25
Ni	0.53	0.15 – 0.95	0.07	0.06 – 0.08
Pb	0.16	0.10 – 0.25	0.09	0.07 – 0.12
Zn	0.26	0.13 – 0.38	0.08	0.05 – 0.11

Table 2 shows the variation ranges of the bioconversion factors, determined in respect to maize for 3 different plants.

Table 2: Ranges of bioconversion factors, summarized for 7 ecosystems with different degree of anthropogenic contamination

Element	Maize/Pear	Maize/Apple	Maize/Sunflower
Al	0.32 – 0.82	0.46 – 3.27	0.28 – 1.11
Ba	0.18 – 0.57	0.17 – 0.21	0.06 – 0.25
Ca	0.47 – 0.87	0.27 – 2.94	0.65 – 1.38
Cd	0.73 – 6.00	0.28 – 1.17	0.40 – 4.0
Co	0.40 – 0.76	0.18 – 0.54	0.47 – 1.33
Cr	1.54 – 3.27	0.40 – 2.96	1.70 – 2.53
Cu	0.41 – 2.22	0.70 – 1.33	0.29 – 0.92
Fe	0.56 – 2.53	0.76 – 1.98	0.50 – 1.55
K	0.56 – 1.86	0.73 – 1.14	0.43 – 1.38
Mg	0.53 – 1.00	0.35 -1.64	0.50 – 1.64
Mn	0.76 – 1.50	0.47 – 1.03	0.78 – 1.94
Ni	0.56 – 1.27	0.49 – 1.11	0.35 – 0.93
Pb	0.30 – 1.13	0.96 – 2.42	0.72 – 2.03
Zn	2.14 – 5.35	3.42 – 5.53	0.42 – 1.41

Discussion

Concentration ratios fruits/leaves

The concentration ratios fruit/leaves presented in Table 1 indicate that the fruits have always much lower content of potentially toxic elements and that the ratios are relatively constant. It is worth mentioning that the higher the level of anthropogenic pollution, the lower the ratio fruit/leaves. This is a good confirmation that leaves react better to pollution, accumulating to a higher extent and are more suitable for monitoring studies on the one hand. On the other hand the relative stability of the ratio permits its use in risk assessment studies. The use of the lowest value of the ratio for prediction is justified not only because it would allow obtaining the highest probable concentration in the fruit (highest risk) but because this ratio corresponds better to regions with higher pollution level.

Bioconversion factors – variation ranges

The variation ranges obtained for three of the investigated plants (Table 2) in respect to maize may be evaluated as reasonably narrow. In all cases but Cd for maize/sunflower and Ca for maize/apple the intervals are well below one order of magnitude. Keeping in mind that the normal individual variations in the chemical concentration in plants are above 25% (4), and the variations of the transfer factors soil/plant for the chemical elements are normally well overt one order of magnitude (5) the intervals in Table 2 may be considered as very stable. Nevertheless compared to the BF intervals we obtained for park ecosystems (1) the present ones are larger. This is quite understandable since in agroecosystems usually different kinds of fertilizers and irrigation are used which contribute for higher differences between sites. The established data present an initial attempt to determine the variation ranges of BF for agroecosystems. The obtained variation ranges of BF may be used for quick risk assessment of pollutant concentrations in agroecosystems with different anthropogenic contamination.

The more precisely definition of the variation ranges of BF requires further investigations with various plants and ecosystems.

Risk assessment of lead concentration in apple fruits using bioconversion factors and concentration ratio fruits/leaves:

As an example for the applicability of the approach the evaluation of the risk assessment of Pb contamination in apple fruits in three ecosystems is presented. The predicted fruit concentrations are calculated using the concentrations of Pb in maize leaves in the three ecosystems; the BF ratio maize/apple leaves and the ratio apple/apple leaves. As already discussed above the lowest values of the ratios are used. The predicted concentrations are compared to the measured concentrations in the apples fruits. The results are presented in Table 3 together with the maximum allowable concentrations of Pb for dry fruits (all values are for dry weight).

For all three agroecosystems the predicted fruit concentrations are higher than the experimentally determined. This can easily be explained by the fact that the highest probable metal concentration in fruits is determined.

In case, that the obtained predicted fruit concentrations are lower than the allowable concentrations (Dimitrovgrad and Parvomaj in the present example) the lack of risk of metal pollution is to be concluded. Values higher than allowable concentrations (Sedlovina) are an indication for high extent of contamination. This fact shows the necessity for determination of this concentration more precisely. Therefore a direct analysis should be performed. In case, that the measured concentration exceeds the allowable concentrations again (as the present data for Sedlovina) the conclusion about highly polluted ecosystem and a danger of health damage by the consummation of the fruits can be done.

Table 3: Use of bioconversion factors for quick risk assessment of lead pollution

Ecosystem	Pb [mg/kg] in maize leaves	Lowest value of BF	Highest value of the ratio fruits/leaves	Pb [mg/kg] PFC	Pb [mg/kg] in apple fruits Measured	Pb [mg/kg] in fruits AC
Sedlovina	72 ± 7	0.96	0.25	19	7.6 ± 0.7	3
Dimitrovgrad	7.9 ± 0.4			2.06	1.3 ± 0.03	
Parvomaj	7.6 ± 0.7			2.0	0.40 ± 0.03	

AC – Allowable concentration
BF – Bioconversion factor
PFC – Predicted fruit concentration

Conclusion

The results in the present paper demonstrate the successful use of the bioconconversion factor for risk assessment in agroecosystems using one reference plant. To accept this approach however it is necessary to investigate further plants and agroecosystems in order to obtain more results and confirm the values of the BF as well as the ratios fruit/leaves.

References

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