Soil contamination and ecological risk of heavy metals in alkaline vineyard soil

Nhung Thi Ha Pham*, Izabella Babcsányi, Andrea Farsang

Department of Physical Geography and Geoinformatic, University of Szeged, Dugonics square 13, Szeged, Hungary, HU-6720

**Corresponding author:*
E-mail address: hanhung@geo.u-szeged.hu (Nhung T.H. Pham)

1. Introduction

- Heavy metals, which are the leading pollution elements with a high potential ecological risk to the environment, can accumulate and exist for a prolonged period of time, then exert impacts on soil environment and agricultural production.

- Due to the long-term use of Cu-fungicides and chemical fertilizers, the vineyard soils not only have faced the pollution problems but also could be suffered ecological risk by heavy metals.

- The aims of this study are to: (1) determine the concentration and degree of heavy metals (Zn, Cd, Pb, Co, Ni, Cr, Cu) in the vineyard topsoils; (2) evaluate the ecological risk of target metals in the vineyard soil.

2. Study area

Hétszőlő vineyard (1.4 ha) with an alkaline reaction in soil (the average soil pH of the 0-10 cm soil layer was 8.02), which is located along and on the southern slope of Tokaj-hill, Tokaj-Hegyalja, Hungary was chosen as study area of this study.

2. Methods

Soil sampling collection

Soil analysis

- Soil pH
- Total heavy metal contents

- Enrichment factor (EF)
- Pollution load index (PLI)
- Contamination factor (Cf)

- Ecological risk factor (Ei)
- Potential ecological risk index (PER)

2. Methods

- The EF is calculated based on a reference element assumed - Scandium (Sc) as an element not associated to human activities, as follows:

$$EF = \frac{[E]_{SH}/[E_{Sc}]_{SH}}{[E]_{RH}/[E_{Sc}]_{RH}}$$

where [E] is the concentration of any target metals, [ESc] is the concentration of Sc, SH refers to the surface horizon (0-10 cm) and RH refers to the reference horizon (the deepest sampled layer 180-200 cm) in the same sampling point.

- The equation for contamination factor is as follows:

$$Cf = \frac{E_{soil}}{E_{background}}$$

where E_{soil} and $E_{background}$ are the concentration of individual metal in the soil sample and in the local forest soil, respectively.

- PLI is determined by using the Cf of each metal with the following formula:

$$PLI = \sqrt[n]{Cf_1 \times Cf_2 \times Cf_3 \times \cdots \times Cf_n}$$

where Cf_1 to Cf_n are the contamination factor of the first to the n^{th} metal.

- Ecological risk factor (Ei):

$$Ei = Cf_i \times T_i$$

where Cf_i is the single metal contamination factor and T_i is the biological toxic factor of an individual target metal.

- Potential ecological risk (PER): is utilized to evaluate the overall ecological risk of all studied heavy metals

$$PER = \sum_{i=1}^{7} Ei$$

3. Result and discussion

Table 1. The average heavy metal concentrations (mg/kg) in the vineyard topsoils

Heavy metals	Zn	Cd	Pb	Co	Ni	Cr	Cu
Mean	57.8	0.3	9.8	8.8	46.9	78.9	48.1
Minimum	53.4	0.3	9.2	8.2	29.3	40.7	39.9
Maximum	61.3	0.3	10.4	9.2	69.9	128.1	55.0
SD	2.8	0.0	0.6	0.4	14.2	31.0	5.3
Limit value *	200	1.0	100	30	40	75	75

* The Hungarian pollution limits according to Joint Decree (6/2009. (IV. 14) KvVM-EüM-FVM

- Analysis results showed that all of the heavy metals had very lower total contents on average compared with the limit value, except for Cu, Ni, and Cr. The topsoil of Hétszőlő vineyard in Tokaj was contaminated by Ni, Cr, and Cu at a moderate level.

3. Result and discussion

Table 2. The soil contamination indices in this research

	Heavy metals	Zn	Cd	Pb	Co	Ni	Cr	Cu
Cf	**Mean**	**1.1**	**0.8**	**0.7**	**1.0**	**1.6**	**2.2**	**2.0**
	Median	1.1	0.8	0.7	1.0	1.5	2.0	2.0
	Minimum	1.0	0.7	0.6	0.9	1.0	1.2	1.7
	Maximum	1.1	0.8	0.7	1.0	2.5	3.7	2.3
	SD	0.05	0.04	0.04	0.05	0.50	0.88	0.22
	Low contamination (Cf < 1); moderate contamination ($1 \leq$ Cf < 3); considerable contamination ($3 \leq$ Cf < 6); high contamination ($6 \leq$ Cf).							
PLI	**Mean**	**1.2**	Unpolluted (PLI ≤ 1); slightly polluted ($1 <$ PLI ≤ 2); moderately polluted ($2 <$ PLI ≤ 3); high polluted ($3 <$ PLI).					
	Minimum	1.0						
	Maximum	1.5						
EF	**Mean**	**1.18**	**1.01**	**1.03**	**0.97**	**1.60**	**2.21**	**2.57**
	Median	1.14	1.04	0.99	0.92	1.42	1.95	2.49
	Minimum	1.05	0.82	0.93	0.85	0.90	1.01	1.98
	Maximum	1.44	1.19	1.26	1.28	2.98	4.06	3.66
	SD	0.14	0.13	0.12	0.16	0.75	1.12	0.59
	EF ≤ 1: Metal is not enriched in the topsoil; EF > 1: Metal is enriched in the topsoil; EF > 2: Implying anthropogenic input source of metals.							

3. Result and discussion

Table 3. The ecological risk indices in this research

	Heavy metals	Zn	Cd	Pb	Co	Ni	Cr	Cu
Ti		1	30	5	5	6	2	5
Ei	Mean	**1.1**	**22.9**	**3.4**	**4.9**	**9.9**	**4.5**	**10.0**
	Min	1.0	21.6	3.2	4.5	6.2	2.3	8.3
	Max	1.1	24.5	3.6	5.2	14.7	7.3	11.4
	SD	0.05	1.07	0.20	0.24	2.98	1.77	1.10
	$Ei < 40$: Low ecological risk; $40 \leq Ei < 80$: Moderate ecological risk; $80 \leq Ei < 160$: Considerable ecological risk; $160 \leq Ei < 320$: High ecological risk; $320 < Ei$: Very high ecological risk.							
PER	Mean	**56.6**	PER < 90: Low risk; $90 \leq PER < 190$: Moderate risk; $190 \leq PER < 380$: Considerable risk; $380 \leq PER$: High risk					
	Min	47.1						
	Max	67.9						

3. Result and discussion

- Cu, Cr, and Ni were enriched moderately in the Hétszőlő vineyard topsoil.
- The EF values illustrated the anthropogenic origin of Cu, Cr, and Ni while Zn, Cd, Pb, and Co were enriched mainly by the geogenic process.
- A low soil contamination degree of Cd, Pb, and Co is determined while a moderate soil contamination is considered for remaining metals.
- The topsoil of Hétszőlő vineyard was considered in the moderate pollution status with PLI was 1.2.
- Target metals in the vineyard topsoil showed a low ecological risk, with the descending order of contaminants was Cd > Cu > Ni > Co > Cr > Pb > Zn.
- The mean PER value revealed a low ecological risk of heavy metals in the vineyard soil.

4. Conclusion

- The topsoil of Hétszőlő vineyard in Tokaj was contaminated by Ni, Cr, and Cu at a moderate degree. And these metal also were enriched in the vineyard topsoil at a moderate level. The results of the soil contamination for all studied metals indicated the moderate pollution status for study area. The moderate level pollution of heavy metals and the continuous enrichment process can make the more dangerous situation for the winegrowing region.

- Even though there was a low potential ecological risk of heavy metals in the Hétszőlő vineyard topsoil, the long-term and continuous using chemical compounds in viticulture could cause serious risk pollution by heavy metals in the future.

The research was funded by the ‘Thematic Network for the Sustainable Use of Re-sources – RING2017’ project (program code: EFOP-3.6.2-16-201700010);
and by the support of OTKA 1K 116981, "In situ wind channel experimentation based on in situ wind channel experiments on different soil types, on site and off site effects"