SPECIFICITY OF HEAVY METAL ACCUMULATION IN VEGETABLE SPECIES AND HEALTH RISK ASSESSMENT IN RELATION TO CULTIVATION SITE

Nataša Nikolić, Slobodanka Pajević, Danijela Arsenov, **Milan Borišev***, Milan Župunski

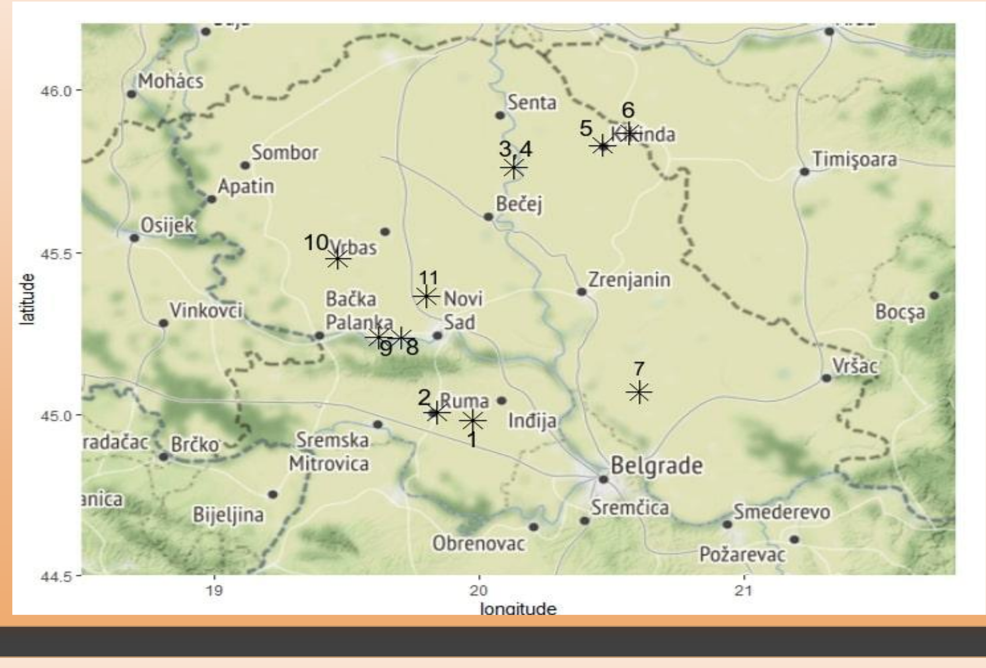
Department of Biology and Ecology, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 2, Novi Sad, Serbia

***Presenting author: milan.borisev@dbe.uns.ac.rs**

Enrichment of the environment by heavy metals (HM) due to various human activities occurs at the global scale. Besides the essential mineral nutrients, edible food crops simultaneously absorb and accumulate metals whose role in plant metabolism has not been discovered yet (e.g. cadmium, lead, chromium). Concentration of HM in edible cultivated plants above the recommended values (i.e. maximum permitted concentration) poses significant human health risks due to dietary exposure to high levels of the pollutants (Ogunkunle et al., 2017), considering the tendency of plant-based food increase in regular diet of the modern man. Concentration of heavy metals in edible parts of cultivated plants depends on plant species, soil characteristics, and the metal in question (Murray et al., 2009).

The objective of the study was determination of Cd, Ni, Cr, and essential elements (K, Na, Ca, P) concentration of vegetables cultivated at different localities and human health risk related to chronic consumption of potentially contaminated vegetables, and summarizing variation among species by principal component analysis.

Randomly selected samples of parsley (*Petroselinum crispum* (Mill.) Fuss), celeriac (*Apium graveolens* L.), carrot (*Daucus carota subsp. Sativus) and parsnip (Pastinaca sativa* L.) were produced by individual producers at small farms located in various districts (Srem, Banat, Bačka) of the Vojvodina Province.



Calculations: The total heavy metal concentration in edible parts of studied vegetable species was assessed by Metal pollution index (MPI) $=(C_1 x C_2 x C_3 \ldots Cn)^{1/n}$, where C_1, C_2, ... C_n represent concentration of n heavy metals measured in plant samples.

The hazard quotient (HQ) = DxCmetal/R_fDxBO, where D represent daily intake of vegetables (kg/day), Cmetal is the concentration of metal (mg/kg), R_fD is a reference oral dose of certain metal (mg/kg of body weight per day), and BO is the average body weight (kg).

Average concentration of heavy metals and mineral nutrients, and hazard quotient (HQ; male – HQm, female – HQw, children - HQc) for consummation of vegetables originating from different cultivation sites

Carrot root *(MPI=0.16)*

	Ni	Cd	Cr
mg/kg FW	0.178	0.109	0.278
HQm	0.032	0.386	<0.001
HQw	0.038	0.467	<0.001
HQc	0.042	0.519	<0.001

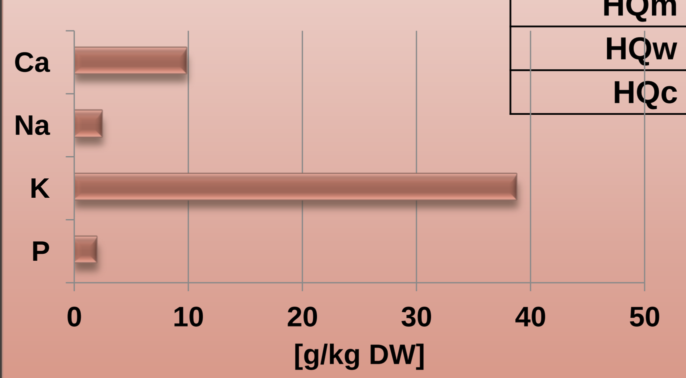


Photo by Kander, https://commons.wikimedia.org/wiki/File:Carrots.JPG

Parsley root *(MPI=0.33)*

	Ni	Cd	Cr
mg/kg FW	0.440	0.260	0.385
HQm	0.078	0.923	<0.001
HQw	0.094	1.115	0.0011
HQc	0.105	1.239	0.0012

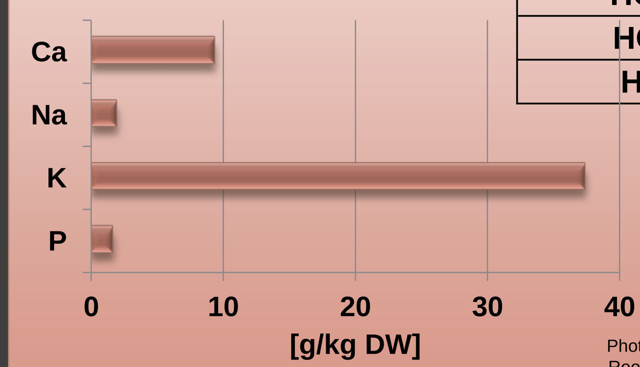


Photo by Zyance ,https://upload.wikimedia.org/wikipedia/commons/thumb/6/68/Root_z08_petersil.JPG/800px-Root_z08_petersil.JPG, licence CC-BY-SA-2.5

Parsley leaves *(MPI=0.54)*

	Ni	Cd	Cr
mg/kg FW	0.721	0.328	0.800
HQm	0.043	0.388	<0.001
HQw	0.051	0.469	<0.001
HQc	0.060	0.547	<0.001

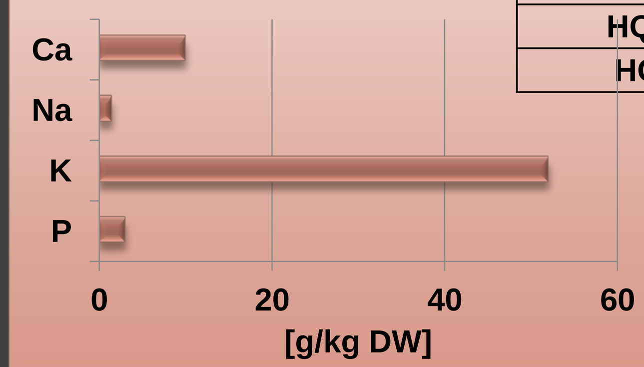


Photo by H. Zell. https://upload.wikimedia.org/wikipedia/commons/thumb/0/0b/ Petroselinum_crispum_003.JPG/800px-Petroselinum_crispum_003.JPG, licence CC-BY-SA-3.0.

Parsnip root *(MPI=0.35)*

	Ni	Cd	Cr
mg/kg FW	0.454	0.327	0.398
HQm	0.080	1.161	<0.001
HQw	0.097	1.403	0.0011
HQc	0.108	1.559	0.0013

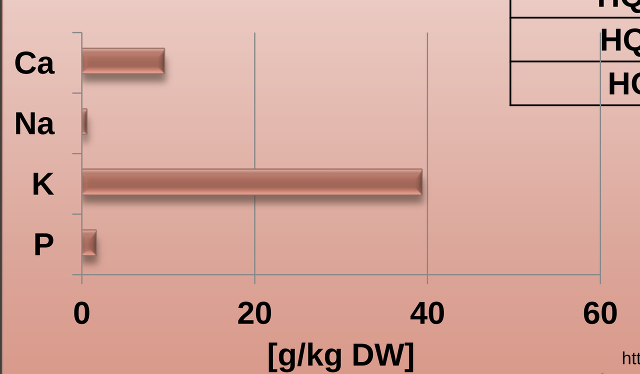


Photo by Jeffery Martin, https://upload.wikimedia.org/wikipedia/commons/thumb/8/86/Parsnips_with_greens.jpg/800px-Parsnips_with_greens.jpg, Licence CC-Zero 1.0.

Celeriac root *(MPI=0.26)*

	Ni	Cd	Cr
mg/kg FW	0.443	0.262	0.770
HQm	0.026	0.309	<0.001
HQw	0.032	0.374	<0.001
HQc	0.037	0.436	<0.001

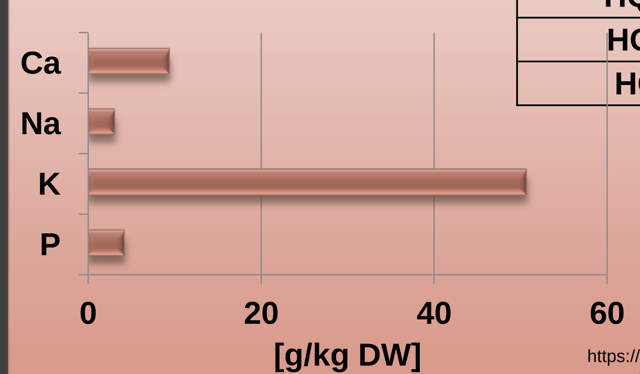


Photo by Jamain, https://upload.wikimedia.org/wikipedia/commons/thumb/f/f7/Celeriac_J2.jpg/800px-Celeriac_J2.jpg, licence CC-BY-3.0, 2.5, 2.0, 1.0

Celeriac leaves *(MPI=0.42)*

	Ni	Cd	Cr
mg/kg FW	0.303	0.261	0.378
HQm	0.054	0.926	<0.001
HQw	0.065	1.120	0.0011
HQc	0.072	1.244	0.0012

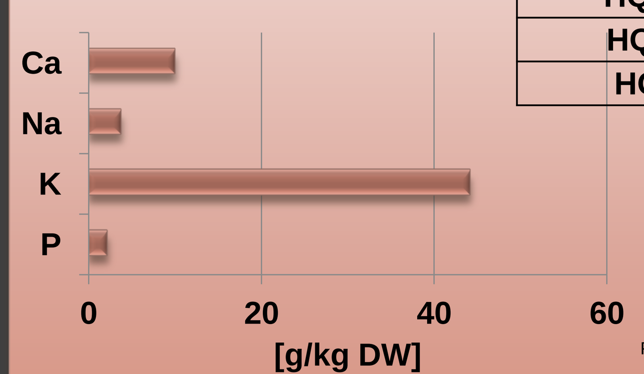


Photo by Jamain, https://upload.wikimedia.org/wikipedia/commons/thumb/5/51/Celeriac_J1.jpg/448px-Celeriac_J1.jpg, licence CC-BY-3.0, 2.5, 2.0, 1.0

❖Carrot showed the lowest potential for Cd, Ni and Cr accumulation while the highest potential was shown for parsley leaves

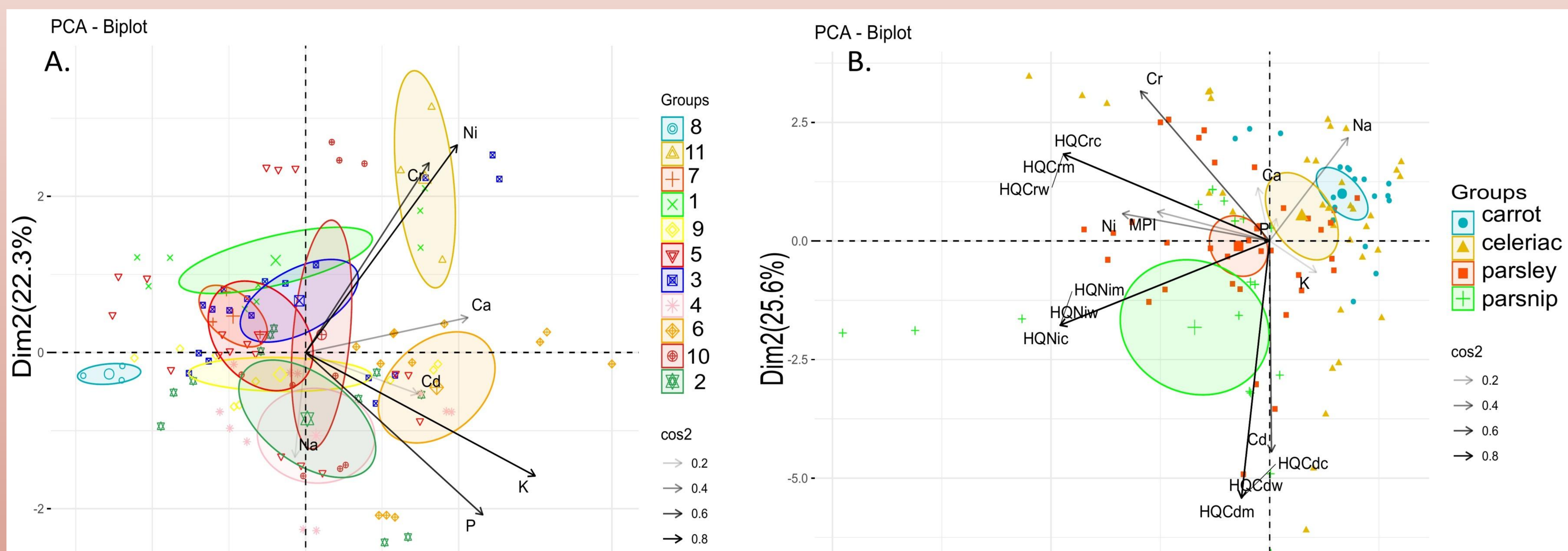
❖The hazard quotient (HQ) values revealed highest values for Cd, followed by Ni and Cr

❖Concentration of K was higher than of Ca, P and Na in all analysed species

❖PCA analysis indicated differences in plants ability to accumulate certain nutrients and pollutants, while samples diversification was closely related to cultivation localities properties

Biplot of mineral elements and heavy metals content among investigated localities

Biplot of analyzed data among tested plant species



Ellipses on biplot represents confidence level of 95%; cos2 value is the square loadings for variables, presenting the quality of the representation of variables. Dim1 and Dim2 correspond to the first (PC1) and second (PC2) principal components. Variable symbols legend: MPI – metal pollution index, HQ – hazard quotient, m – men, w – women, c- children

Positive Pearson correlation between Cr and Ni has been observed in many cases suggesting the possibility of simultaneous occurrence of high Cr and Ni concentrations in studied vegetables

Vegetables		Cd	Cr	P	Na	K	Ca
Carrot root	**Ni**			0.6864**		0.7321**	0.5245*
Parsley root	**Ni**			0.5586*			
Parsley leaves	**Ni**	-0.4873*		-0.6353**			-0.6363**
Parsnip root	**Ni**		0.7451***				0.6254**
Celeriac root	**Ni**		0.6500**			-0.8980***	0.6402**
Celeriac leaves	**Ni**		0.8705***	-0.7789***	0.5229*		0.6038**

CONCLUSION

Results obtained in the present work suggest the absence of health risk due to consumption of studied vegetables, with respect to HQ of Cr and Ni, while HQ of Cd calculated for adults and/or children exceeded the threshold value of 1 in several cases.

Research was conducted and funded within the project entitled: ''Biologically active components and medical potential of functional food grown in Vojvodina Province, Serbia'' no. 114-451-2149/2016-03, financed by the Provincial Secretariat for Science and Technological Development, Autonomous Province of Vojvodina, Serbia. Also, the authors acknowledge financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant No. 451-03-9/2021-14/ 200125)

References: Murray et al., 2009. Botany. 87: 702-711. Ogunkunle et al., 2017. Pollution, 3(2): 285-300, Usero et al., 1997. Environment International, 23(3), 291–298. Harmanescu et al., 2011. Chemistry Central Journal, 5, 64. Pérez et al., 2014. Environmental Research, 135, 181–189. US Environmental Protection Agency (US EPA) (1989). Risk assessment guidance for superfund: Human health evaluation manual [part A]: Interim final. U.S. Environmental Protection Agency, Washington, DC, USA [EPA/540/1–89/002]. US Environmental Protection Agency US-EPA (2010). Risk-based concentration table. United State Environmental Protection Agency, Washington, DC. US Environmental Protection Agency US-EPA (2013). Reference dose (RfD): description and use in health risk assessments. Background Document 1A, Integrated Risk Information System (IRIS). United States Environmental Protection Agency (EPA): Washington, DC. Maksimović et al., 2016. Public Health Nutrition, 19(12), 2246–2255. Results of the National Health Survey of the Republic of Serbia 2013 (2014) The Institute of the Public Health of Serbia "Dr Milan Jovanović Batut", Belgrade, Serbia. Available at: http://www.batut.org.rs/download/publikacije/ 2013SerbiaHealthSurvey.pdf