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*Original Research*

# Heavy Metal Content in Common Sorrel Plants (*Rumex Acetosa* L.) Obtained from Natural Sites in Małopolska Province

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**Abstract**

17 samples of common sorrel were collected from natural sites in the Małopolska region. The content of selected heavy metals (zinc, copper, manganese, iron, chromium, nickel, lead and cadmium) were determined in individual plant organs. The greatest diversification occurred for cadmium, manganese and zinc; the smallest differences were noted for copper. Correlation coefficients between total soil heavy metal concentrations and their content in sorrel were generally low and very low; only the coefficients for cadmium and lead may be considered as high and very high. Allowable lead content was exceeded in all samples of sorrel leaves, whereas cadmium concentrations were in about 90% of the samples. Sorrel roots most strongly accumulated the metals, whereas the smallest content was found in the stems.

**Keywords:** common sorrel, accumulation, metals, consumer safety

## Introduction

Common sorrel is a vegetable crop consumed for its characteristic pleasant acidic taste originating from free oxalic acidic and its soluble potassium and sodium salts. Its wild form differs exceptionally little from its cultivated form and is as willingly used in the kitchen as the latter. It is found in local markets throughout Europe [1-3]. In Poland wild sorrel is readily gathered, particularly in the spring season, when the demand for fresh vegetables is particularly great [4]. Sorrel is used in phytotherapy as well [5]. Recently the possibility of its use in phytoremediation has been considered, because as a plant with small requirements, sorrel may be encountered in many ecosystems: in meadows, wastelands, forests, parks and in the vicinity of waters [6].

The present paper aims to examine the safety of consuming sorrel obtained from natural sites. Assessed were the contents of zinc, copper, manganese, iron, chromium, nickel, lead and cadmium in sorrel plants collected in different locations in Małopolska; determined was also the way in which they become accumulated in the individual plant parts. Metal concentrations in sorrel were compared with the obligatory standards of maximum pollutant concentrations in leaf vegetables and their correlation with heavy metal contents in soil under the plants.

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## Experimental Procedures

Common sorrel plants (*Rumex acetosa* L.) were gathered at the initial stage of flowering from 15 to 20 May 2006. The plant material was obtained from natural sites located at least 20 meters from roads, so as not to be exposed immediately to heavy metals emitters. The collecting points were situated in the following counties of Małopolska (Lesser Poland) province:

**County - Collecting points**

1. Bochnia - Bochnia town;
2. Brzesko - Niedzieliska village;
3. Kraków - Radziszów, Rudawa, Poskwitów, Szklary and Zielonki villages;
4. Limanowa - Dobra village;
5. Myślenice - Wierzbanowa village;
6. Olkusz - Olkusz town;
7. Oświęcim - Stawy Monowskie village;
8. Proszowice - Nowe Brzesko town;
9. Sucha Beskidzka - Zawoja and Zembrzyce villages;
10. Wadowice - Jaroszowice village and Kalwaria Zebrzydowska town;
11. Wieliczka - Kokotów village.

There were a total of 17 sorrel samples collected, comprising about 50 whole plants and simultaneously soil samples were taken from the 0-20 cm layer. The plants were thoroughly washed under running water and divided into five parts: roots, stems, lower leaves, upper leaves and flowers. Basal, petiolated leaves were considered the lower ones, whereas the stalked, sessile leaves were assumed as the upper ones. The plant material was dried at 65ºC in a Binder drier with hot air circulation and ground in a laboratory Retsch mill. Dry mineralization was conducted at 450ºC and the obtained oxide mixture was dissolved in nitric acid 1:2. Metal concentrations in sorrel were analyzed using atomic absorption in Varian SpectAA-20 spectrometer in acetylene-air flame [7].

Air-dried soil was sifted through a sieve with 0.1mm mesh and subjected to wet mineralization in the MDS-2000 microwave oven in the presence of nitric acid 1:2. Total metal contents in soil were assessed using atomic absorption.

The results were elaborated statistically using the method of variance in randomized pattern on the significance level 0.05. Correlation between metal concentrations in sorrel parts and in the soil was computed using Statistica, 7.1 programme.

## Results

Table 1 shows the reaction and total content of heavy metals in soil samples collected from 17 sites of common sorrel.

The reaction of four soil samples was lower than 6.0 (Kalwaria Zebrzydowska 5.90, Stawy Monowskie 5.54, Zawoja 5.67 and Zielonki 5.86), in two samples it was higher than 7.0 (Nowe Brzesko 7.19 and Rudawa 7.60). In a majority of collected samples the soil pH oscillated between 6.0 and 7.0. Zinc content in soil (703 $mg \cdot kg^{-1}$ d.m.) exceeded its permissible content only in one case; in the other soils it remained within the norm. Copper, chromium and nickel concentrations did not exceed the permissible values in any of the examined samples, while the contents of iron and manganese were within the limits of these average metals contents in Polish soils. Three time higher than allowable lead content was assessed in the soils from Nowe Brzesko - 178.5 $mg \cdot kg^{-1}$ d.m., Olkusz – 285.8 $mg \cdot kg^{-1}$ d.m. and Rudawa - 185.8 $mg \cdot kg^{-1}$ d.m.. Cadmium concentrations exceeded the allowable limit in three cases: in Kokotów – 10.25 $mg \cdot kg^{-1}$ d.m., Nowe Brzesko – 15.15 $mg \cdot kg^{-1}$ d.m., and Olkusz – 4.30 $mg \cdot kg^{-1}$ d.m.).

Table 2 presents the contents of analyzed heavy metals in collected sorrel plants. Sorrel roots accumulated the largest amounts, on average 27.0 $mg \cdot kg^{-1}$ f.m of the analyzed metals, whereas lower leaves, inflorescences and


Fig. 1. The locations from which samples of sorrel were collected.

Table 1. Soil pH and heavy metal concentrations in soil from various sites of sorrel (mg·kg$^{-1}$d.m.).

| | pH | Zinc | Copper | Manganese | Iron | Chromium | Nikel | Lead | Cadmium |
|---|---|---|---|---|---|---|---|---|---|
| | 5.54 – 7.60 | 62 – 703 | 15.3 – 86.8 | 336 – 1183 | 4,225 – 27,550 | 4.2 – 62.8 | 5.8 – 52.6 | 40.2 – 285.8 | 0.05 – 15.15 |
| | x = 6.53 | x = 148.4 | x = 28.9 | x = 629 | x = 15,740 | x = 22.1 | x = 22.8 | x = 92.5 | x = 2.43 |
| *, ** | | 300*<br>50** | 150*<br>15** | 1,500 –<br>3,000** | 10,000 –<br>30,000** | 150*<br>29 – 60** | 100*<br>1 – 100** | 100*<br>12.5 – 20.0** | 4*<br>0.15 – 0.20** |

x – arithmetic mean
* Allowable heavy metal concentrations in soil [8]
** Average contents of metals in soils [9]

Table 2. Contents of heavy metals in common sorrel plants gathered on 17 natural sites in Małopolska province (mg·kg$^{-1}$ f.m.)

| | Plant part | | | | | Allowable content* |
|---|---|---|---|---|---|---|
| | Roots | Stems | Lower leaves | Upper leaves | Inflorescences | |
| **Zinc** | 9.1 – 93.6<br>x = 27.0 e** | 2.5 – 10.6<br>x = 7.3 a | 4.0 – 45.8<br>x = 17.0 d | 3.5 – 32.4<br>x = 13.6 b | 5.0 – 27.7<br>x = 15.7 c | 10 |
| **Copper** | 1.29 – 3.64<br>x = 2.27 c | 0.60 – 11.27<br>x = 0.82 a | 1.40 – 1.95<br>x = 1.63 b | 1.37 – 2.07<br>x = 1.72 b | 1.77 – 3.22<br>x = 2.42 c | Not specified |
| **Manganese** | 15.5 – 115.9<br>x = 58.6 d | 2.1 – 15.0<br>x = 6.8 a | 10.8 – 89.6<br>x = 41.1 c | 10.4 – 94.9<br>x = 44.7 c | 8.0 – 56.5<br>x = 26.9 b | Not specified |
| **Iron** | 334 – 1452<br>x = 768 d | 8.0 – 38.7<br>x = 21.6 a | 44.9 – 223.1<br>x = 106.5 c | 49.1 – 137.1<br>x = 59.1 b | 49.7 – 225.8<br>x = 87.3 bc | Not specified |
| **Chromium** | 3.02 – 19.22<br>x = 8.11 d | 0.11 – 1.33<br>x = 0.48 a | 0.31 – 2.21<br>x = 1.04 b | 0.32 – 1.80<br>x = 1.02 b | 0.52 – 3.56<br>x = 1.43 c | Not specified |
| **Nickel** | 2.67 – 10.19<br>x = 5.14 e | 0.10 – 1.00<br>x = 0.37 a | 0.49 – 1.89<br>x = 0.97 c | 0.36 – 1.90<br>x = 0.84 b | 0.44 – 2.10<br>x = 1.19 d | Not specified |
| **Lead** | 0.79 – 13.69<br>x = 3.45 d | 0.17 – 1.16<br>x = 0.48 a | 0.53 – 2.95<br>x = 1.22 b | 0.64 – 3.00<br>x = 1.16 b | 1.31 – 4.71<br>x = 2.08 c | 0.3 |
| **Cadmium** | 0.14 – 1.54<br>x = 0.76 d | 0.01 – 0.31<br>x = 0.09 a | 0.04 – 0.96<br>x = 0.28 c | 0.04 – 0.60<br>x = 0.18 b | 0.03 – 0.26<br>x = 0.11 ab | 0.05 |

*Allowable heavy metal content in leaf vegetables [11]
**Values marked with the same letter within the same element do not differ significantly

upper leaves placed next. Definitely smaller amounts of this metal were found in stems, where its concentrations (7.3 mg·kg$^{-1}$ f.m.), were half smaller than in the other aboveground parts and almost 4 times lower than in roots. The greatest amounts of zinc were registered in all analyzed parts of sorrel gathered in Olkusz. The plants collected in Poskwitów had the smallest quantities of this metal in all their analyzed parts.

The highest content of copper, 2.27 and 2.42 mg·kg$^{-1}$ f.m., became accumulated in roots and inflorescences of sorrel. About 1/3 smaller quantity was registered in leaves, either the lower or the upper ones. Stems revealed 2/3 lower copper concentrations than the inflorescences. Sorrel gathered in Radziszów was most copper abundant, whereas the most copper deficient were the plants from Niedzieliska.

Sorrel roots contained the highest amounts of manganese, on average 58.6 mg·kg$^{-1}$ f.m. Slightly smaller contents of this metal were found in the lower and upper leaves, without any noticeable differences between them. 6.8 mg·kg$^{-1}$ f.m. of manganese was found in stems, i.e. 9 times less than in the roots. Sorrel plants form Niedzieliska most strongly accumulated manganese, whereas the smallest amounts were found in the plants from sites in Rudawa and Nowe Brzesko.

Sorrel roots had on average 768 mg·kg$^{-1}$ f.m. of iron. Much smaller quantities were found in the aboveground parts: between 7 times in the lower leaves and 35 times in stems. The highest content of iron was assessed in sorrel collected in Radziszów, the smallest amounts were found in the plants from Niedzieliska.

Table 3. Correlation coefficients for metal content in soil and sorrel parts.

| | Roots | Stems | Lower leaves | Upper leaves | Inflorescences |
|---|---|---|---|---|---|
| Zinc | 0.39 | 0.02 | 0.07 | -0.01 | 0.01 |
| Copper | -0.12 | -0.08 | 0.03 | 0.28 | -0.11 |
| Manganese | 0.38 | -0.03 | 0.05 | 0.04 | -0.03 |
| Iron | 0.73 | 0.42 | 0.58 | 0.47 | 0.56 |
| Chromium | -0.15 | -0.03 | -0.06 | -0.00 | 0.02 |
| Nickel | -0.13 | -0.20 | -0.01 | -0.01 | -0.11 |
| Lead | 0.93 | 0.53 | 0.88 | 0.88 | 0.68 |
| Cadmium | 0.61 | 0.21 | 0.48 | 0.39 | 0.61 |

N = 17. Determined correlation coefficients with $p<0.05$ are significant over 0.48.

Chromium concentrations in sorrel roots were on average 8.11 mg·kg$^{-1}$ d.m. Inflorescences contained 6 times smaller amounts of this metal, the lower and upper leaves 8 times less, whereas 17 times smaller chromium concentrations were determined in stems. The plants from Radziszów contained the greatest quantities of chromium, those from Olkusz the least.

Sorrel roots accumulated the largest amounts of nickel, on average 5.14 mg·kg$^{-1}$ d.m. The inflorescences had four times smaller quantities, leaves eight times less, while 14 times lower concentrations of this element were found in stems. Sorrel picked in Radziszów most strongly accumulated nickel, while the smallest concentrations were assessed in the material from Rudawa and Olkusz.

Average lead content in sorrel roots (3.45 mg·kg$^{-1}$ d.m.) was 1.5 times higher than in the inflorescences and about 3 times bigger than in leaves, irrespective of their placement. 7 times smaller lead quantities were found in stems than in roots. Sorrel gathered in Olkusz revealed the highest concentrations of this metal and the amounts were obviously larger than in sorrel from the other localities. Sorrel from Jaroszowice contained the lowest quantities of lead.

Cadmium became most strongly accumulated by sorrel roots, where on average 0.76 mg Cd·kg$^{-1}$ d.m. was assessed. About thrice smaller quantities of cadmium were found in plant lower leaves and 4-times smaller in the upper ones. The lowest content of cadmium was registered in inflorescences and stems – 7 and 8 times lower than in roots. The highest cadmium concentrations were detected in the plants from Kokotów and on the same site the highest content of this metal was revealed in all analyzed plant parts. The smallest amounts of cadmium were noted in all its parts of sorrel picked in Jaroszowice.

## Discussion of Results

The intensity of metal accumulation by sorrel plants differed considerably depending on locality. Zinc concentrations in sorrel collected in Olkusz were eight times higher in comparison with the samples from Poskwitów, and also manganese content in sorrel from Rudawa was eight times greater than in the plants gathered on the site in Niedzieliska. Diversification of iron contents in sorrel plants was 3:1. Sorrel from Kalwaria Zebrzydowska contained four times higher contents of chromium than the plants from the plants from Poskwitów, and 2.5 times higher nickel concentrations than the plants from Szklary. The most stable copper was accumulated in sorrel tissues within the 1:1.5 range, depending on the sample origin. The contents of lead and cadmium, of almost exclusively anthropological origin, in the most and the least polluted places revealed five-fold (Olkusz and Jaroszowice) and twelve-fold differences (Kokotów and Jaroszowice). Also in comparison with other research on microelements and trace elements in sorrel tissues [10, 11] these results point to a considerable potential of this plant for concentrating minerals depending on the environment in which it is growing.

No standard determining their allowable concentrations in vegetables has been established for zinc, manganese, copper, iron, chromium and nickel. Greater or smaller diversification of these metals contents in the collected plant material is associated with different composition and properties of soil and with a more or less active mechanism of their uptake by plants. Computed correlation coefficients between the total content of these metals in soil and their concentrations in sorrel parts are low and very low, except for iron, for which these coefficients assume moderate values, whereas for roots the correlation is high (Table 3).

The allowable content of lead and cadmium in leaf vegetables has been established by a regulation of the Polish minister of health [12] as 0.30 and 0.05 mg·kg$^{-1}$ f.m. Exceeded values of lead content were detected in all samples of roots, upper and lower leaves and inflorescences. Only in sorrel stems from four sites: in Kalwaria Zebrzydowska, Wierzbanowa, Dobra and Zembrzyce this content was not exceeded; in the other 76% of sites, stems also did not meet the required norm either. Exceeded permissible limits of cadmium were registered in all root samples, in 16 samples of lower leaves (94%), in 15 samples of upper leaves and inflorescences (88%) and in 10 samples of stems (59%). The obtained results fall within a similar range as noted for sorrel originating from Warsaw [13] and from Szczecin [14] neighbourhood and are clearly higher than assessed in sorrel from the Lublin region [15]. The sources of contamination of the studied sorrel samples are not always possible to point out. High concentrations of lead in plants from Olkusz were undoubtedly associated with multi-year operations of silver and lead mines in this region. Considerable quantity of cadmium in the plants from Kokotów is the legacy of being in close vicinity to the Lenin Ironworks, which degrades the natural environment within its range of influence. In case of a majority of the other sites, pollution may result from the far range industrial emission or small local emitters, or motorization. Correlation coefficient of lead content in the soil and sorrel roots points to very high correlation, whereas such coefficients for the lower and upper leaves point to high correlation. In the case of cadmium, correlations calculated for the soil and roots, for the lower leaves and inflorescences correspond to moderate correlation.

Roots are sorrel parts, which most strongly accumulate metals. This property is connected with their function of a barrier limiting translocation of the metals absorbed from the soil to the aboveground parts [16, 17]. The ability to fix heavy metals by plant roots is one of the mechanisms of their tolerance to these components. According to Antosiewicz [18], the content of metals bound by roots grows with increasing plant tolerance. Iron, chromium and nickel should be distinguished among the eight analyzed metals, since their contents in the lower sorrel leaves were between 7 and 8 times lower than in roots. Also, cadmium and lead are to a considerable degree restrained by roots. Leaves had thrice lower amounts of these elements in comparison with their root concentrations. Zinc, copper and manganese most easily passed to the aboveground parts; only between 30 and 40% smaller quantities of these metals were registered in the lower leaves than in roots. The ratios of tested metal concentration in leaves to that in roots range from 0.128 to 0.718 (e.g. below 1.0), which allows to include sorrel among excluders, according to the Baker classification [19].

The lowest metal content was assessed in sorrel stems. It was between thrice (for copper) and 35 times lower in roots, which undoubtedly is associated with this organ's poorer ability for mineral component accumulation. Atilla and Mathe-Gaspar [6] made similar observations.

The obtained results show that sorrel reveals considerable tolerance to iron, chromium and nickel, but also (to a slightly lesser degree) to lead and cadmium. Easy bioaccumulation of heavy metals associated with a tolerance to their activity cause common sorrel to be a plant of great potential for phytoremediation [19-22]. However, transfer coefficients calculated by Kadar and Daood [23], e.g. 0.07 for cadmium and 0.006 for lead, show that the use of this plant would be sensible for medium-polluted soils, where the cleaning process could be conducted within a not-too-far time horizon.

Considerable ability of common sorrel for metal accumulation, particularly lead and cadmium, recommends great caution while consuming this vegetable. Although it does not belong to the plants often used for cooking or in large quantities, it should be gathered in places only slightly polluted with heavy metals and areas where there is no ecological hazard.

## References

1. ERTUĞ F. Wild edible plants in the Bodrum Area (Muğla, Turkey). Turk. J. Bot. **28**, 161, **2004**.
2. PARDO-DE-SANTAYANA M., TARDIO J., BLANCO E., CARVALHO A. M., LASTRA J. J., SAN MIGUEL E., MORALES R. Traditional knowledge of wild edible plants used in northwest of the Iberian Peninsula (Spain and Portugal): a comparative study. J. Ethnobiol. Ethnomed. **3**, 27, **2007**.
3. PARDO-DE-SANTAYANA M., TARDIO J., MORALES R. The gathering and consumption of wild edible plants in the Campoo (Cantabria, Spain). Int. J. Food Sci. Nutr. **56** (7), 529, **2005**.
4. ŁUCZAJ Ł., SZYMAŃSKI W. M. Wild vascular plants gathered for consumption in the Polish countryside: a review. J. Ethnobiol. Ethnomed. **3**, 17, **2007**.
5. DUKE J. A. Handbook of medicinal herbs. CRC Press: Boca Raton, Fl, pp. 683-684, **2002**.
6. ATTILA A., MATHE-GASPAR G. Factors affecting heavy metal uptake in plant selection for phytoremediation. Z. Naturforsch. **60c**, 244, **2005**.
7. JĘDRZEJCZAK R., SZTEKE B. Atomic absorption spectrometry (ASA) method for determination of cadmium and lead in plant material. Roczn. PZH. **41**, 223, **1990** [In Polish].
8. Regulation of the Minister of Environment of 9th September 2002 on the standards of soil quality and standards of land quality. Dziennik Ustaw **2002**, nr 165, poz. 1359 [In Polish].
9. KABATA-PENDIAS A., PENDIAS H. Biogeochemistry of trace elements. PWN, Warszawa, **1993** [In Polish].
10. MACIEJEWSKA M. Content of microelements in some species from grass communities in the Szczecin-Police-Gryfino agglomeration. J. Elementol. **9** (3), 383, **2004** [In Polish].
11. OHLSON M. Variation in tissue element concentration in mire plants over a range of sites. Holarctic Ecol. **11**, 267, **1988**.
12. Regulation of the Minister of Health of 27th December 2000 on the list of acceptable quantities of food additives and other substances added to foodstuffs as well as condiments, and contaminants occurring on foodstuffs or condiments. Dziennik Ustaw **2001**, nr 9, poz. 72 [In Polish].
13. CZARNOWSKA K. GWOREK B. Trace elements in leafy vegetables and fruits from allotment gardens of Warszawa-Mokotów district. Roczn. Gleb. **XLV** (1/2), 37, **1994** [In Polish].
14. DZIDA M. PODSIADŁO C., FURMANEK T. The effect of lead pollution of habitats on the content of macro- and microelements in the selected species of herbs. Folia Univ. Agric. Stetin. Agricultura. **242** (98), 31, **2004** [In Polish].
15. CZECH A., RUSINEK E. The heavy metals, nitrates and nitrites content in the selected vegetables from Lublin area. Roczn. PZH. **56** (3), 229, **2005** [In Polish].
16. SALIM R., AL-SUBU M. M., ATALLAH A. Effects of root and foliar treatments with lead, cadmium, and copper on the uptake distribution and growth of radish plants. Env. Int. **19**, 393, **1993**.

17. SALIM R., AL-SUBU M. M., DOULEH A., CHENARIER L., HAGEMEYER J. Effects of root and foliar treatments of carrot plants with lead and cadmium on the growth, uptake and the distribution of uptake of metals in treated plants. J Environ. Sci. Health. **A27** (7), 1739, **1992**.
18. ANTOSIEWICZ D. M. Mineral status of dicotyledonous crop plants in relation to their constitutional tolerance to lead. Env. Exp. Botany. **33** (4), 575, **1993**.
19. BAKER A. J. M. Accumulators and excluders-strategies in the response plants to heavy metals. J. Plant Nutr. **3**, 643, **1981**.
20. QUING-REN WANG, YAN-SHAN CUI, XIU-MEI LIU, YI-TING DONG, CHRISTIE P. Soil contamination and plant uptake of heavy metals at polluted sites in China. J. Env. Sci. Health. **A38** (5), 823, **2003**.
21. SHIRONG TANG, WILKE B. M., CHANGYONG HUANG. The uptake of copper by plants dominantly growing in copper mining spoils along the Yangtze River, the People's Republic of China. Plant and Soil. **209**, 225, **1999**.
22. TOLRA R. P., POSCHENRIEDER CH., LUPPI B., BARCELO J. Aluminium-induced changes in the profiles of both organic acids and phenolic substances underlie Al tolerance in Rumex acetosa L. Env. Exp. Botany. **54**, 231. **2005**.
23. KADAR J., DAOOD H. Effect of microelement loads on garden sorrel grown on calcareous chernozem soil. Agrokemia es Talajtan. **52** (1-2), 93, **2003**.