Oecologia Montana 2015,
24, 41-49

Fallopia japonica (Houtt.) Ronse Decr. as bioindicator of pollution in the experimental study area Ružomberok

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Abstract. The purpose of this work was to use the species *Fallopia japonica* for monitoring of environmental burden in the vicinity of Mondi SCP Ružomberok. The species was selected, because it is hyperaccumulator and it creates huge colonies in the field. 11 sampling sites were selected in study area. In addition, one site was selected in a relatively uncontaminated area. With respect to accummulation, underground (rhizomes) and aboveground parts of plants (leaves, shoots, flowers) were compared. The results are compared with the location in the Tatranská Javorina, which is situated in a relatively clean environment. The following elements were determined by X-ray spectrometry: S, Cl, K, Ca, Mn, Fe, Zn, Rb, Sr, Mo, Sb, Pb. The results were submitted to ordination analysis (CANOCO), to factor analysis, correlation analysis and analysis of variance (STATISTICA). Lead and rubidium are predominantly accumulated in flowers, iron in rhizomes and calcium in leaves.

Key words: Biondication, *Fallopia japonica*, MONDI SCP Ružomberok, multivariate analysis, Slovakia

Introduction

Investigated area is situated in the north of Slovakia in Liptov Basin. The most significant immissions producers are sites oriented NW at a distance of 150-200 km, i. e. Ostrava region, Kraków region or Silesia region (Rak *et al.* 1982). In 1980, throughout the Liptov and Spiš regions, there was a production of total 55,733 tonnes of solid emissions and 72,427 tonnes of gaseous emissions, while the largest producer of sulphur dioxide was Mondi SCP Ružomberok. As regards to the solid emissions, compounds of Fe, Mn, Mo and Cr are produced by OPZ Istebné (Rak *et al.* 1982). Less substantial resources are oriented eastwards, Copper Smelter Krompachy and Chemosvit Svit. In 2000, the Copper Smelter Krompachy, instigated a modernisation of production methods and the plant has been constantly upgrading the technologies it uses to minimize the impact on the environment. Chemosvit Svit halted the production method based on viscose which releases large volume of sulphur compounds and is now involved in the production of flexible films intended for packaging.

Fallopia japonica is a rhizomatous perennial geophyte (Beerling *et al.* 1994) and it belongs to the *Polygonaceae* Family. The plant starts to grow up by the end of April, but the main growing period is May and June (Alberternst and Böhmer 2011) and blooming season is from September to October (Horn 1997). This plant reaches the height of 3 m (Barney *et al.* 2006) and creates rich and dense aboveground biomass. Underground part of *Fallopia japonica* is created by huge rhizome system, which is able to spread 15-20 m far from stands (Pauková 2013) and penetrates the soil 2 m below the ground. This system serves as a reservoir of nutrients during winter, so in the spring, it is able to grow really rapidly, 4.6 cm per day (Horn 1997). *Fallopia japonica* is well known for its ability to spread aggressively via vegetative reproduction. Even small pieces of stem or rhizome system are able to develop into vital new plant (Cvachová and Gojdičová 2008). According to Brock and Wade (1992), fragments as small as 0.7 grams are capable of regenerating. Also, rhizomes buried to soil in depths of 2 m are able to regenerate (Kosmale 1976). It has been observed, that stem and leaf tissues are also able to regenerate new plants (Brock and Wade 1992). It is occuring in alttitude ranging from sea level to 1050 m a.s.l. (Hollingsworth and Bailey 2000). Reason, why *Fallopia japonica* can occur on different habitats is, that it does not have special demands for growth conditions, due to the fact that it is able to grow in wet or dry soils in different pH level, in nutrient-poor soils (Barney *et al.* 2006, Soltysiak and Brej 2013) or even in soils contaminated by heavy metals (Soltysiak *et al.* 2011). *Fallopia japonica* is currently probably the most dangerous neophyte. Apparently it has found suitable conditions in many places in Slovakia, as it creates stable, viable and flourishing populations with abundance of mostly 100 %, where almost no other plant species is able to survive in competition (Medvecká *et al.* 2009). The species is broadly regarded as one of the most invasive plant species in Europe, also listed by the World Conservation Union as one of the world's one hundred worst plant invaders (Dumitrascu *et al.* 2012).

Although *Fallopia japonica* hasn't been used as a bioindicator, the ability to accumulate elements has been examined (Soltysiak *et al.* 2011). *Fallopia japonica* was chosen for purpose of bioindicating, while it is able to grow in soils contaminated by heavy metals (Soltysiak *et al.* 2011). The species is considered to be efficient hyperaccumulator of heavy metals, as it grows fast, requires no treatment and is able to accumulate high amount of heavy metals, which are then built into massive biomass (Dwiecki and Koziol 2005) particularly in rhizomes, stems, leaves or flowers. Moreover, it is very widespread plant, which creates huge and dense stands, so it is easier to find and collect samples. So, the research was focused on:

1. How accumulated elements are distributed in the tissues of *Fallopia japonica*.
2. How accumulated elements are correlated.
3. How the immission distribution reflects the local environmental contamination.

Material and Methods

Sampling and sampling sites

Samples were collected during autumn 2014 and spring 2015 in the west to east trajectory, while Mondy SCP, the supposed factor of pollution, was in the centre of our interest. For the purpose of assessing the impact of the imission load of MONDI Ružomberok, windward and leeward sites against MONDI have been chosen. The geographical coordinates are recorded in the system WGS84.

All samples were collected from Liptov Basin in autumn 2014 and spring 2015 (Fig. 1). In the centre of interest was Mondy SCP and its impact on the surrounding environment. According to the official measurements of the SHMÚ, the prevailing direction of air blowing is from west to east and that is why the samples were collected in this trajectory, usually close to roads, close to railway or along the river Váh. Some rich sites remained unsampled, because of private property. Some sites were affected by human activities, like waste spots. The following parts of *Fallopia japonica* were sampled: rhizomes, shoots, flowers and leaves. Majority of sites create small stands (10-15 m²). However, these stands seem to be young, that means that they are supposed to grow into large monocultures in the future, unless some restrictions will be done. Sites 7 and 9 create bigger stands (25 m² or more). Unfortunately, some sites were not sampled completely. Because the bush blooms in the autumn it attracts massive swarm of bees. So, for the sake of my safety, I gave up collecting of few samples of flowers. Also I gave up sampling of some rhizomes, because shaking with plants during pulling out rhizomes might have been cause of some accident.

List of sampling sites and their geographical features:

1. Liptov Basin, opposite to the train station Ružomberok, 474 m a.s.l., coordinates E19° 18,390’, N49° 05,101’, (18.09.2014)
2. Liptov Basin, Likavka village, 485 m a.s.l., coordinates E19° 17,937’, N49° 05,272’, (18.09.2014)
3. Liptov Basin, close to Gypsy settlements, altitude 473 m a.s.l., coordinates E19° 17,627’, N49° 05,166’, (18.09.2014)
4. Liptov Basin, between Rybárpole and Hrboltová villages, altitude 489 m a.s.l., coordinates E19° 16,129’, N49° 05,561’, (18.09.2014)
5. Liptov basin, between Hrboltová and Černová villages, altitude 467 m a.s.l., coordinates E19° 15,248’, N49° 05,908’, (18.09.2014)
6. Liptov Basin, between Černová and Ružomberok, altitude 467 m a.s.l., coordinates E19° 16,054’, N49° 05,434’, (18.09.2014)
7. Liptov Basin, western part of Ružomberok, a road to Malinô Brdo, altitude 489 m a.s.l., coordinates E19° 16,770’, N49° 04,838’, (18.09.2014)
8. Liptov basin, site opposite to Mondy SCP, altitude 494 m a.s.l., coordinates E19° 18,832’, N49° 04,895’, (18.09.2014)
9. Liptov Basin, at the beginning of Lisková village, altitude 492 m a.s.l., coordinates E19° 20,433’, N49° 05,267’, (19.09.2014)
10. Liptov Basin, Liptovská Teplá village- near rails, altitude 504 m a.s.l., coordinates E19° 24,666’, N49° 05,927’, (19.09.2014)
11. Liptov Basin, between Liptovská Teplá and Bešeňová villages, altitude 511 m a.s.l., coordinates E19° 25,066’, N49° 05,492’, (19.09.2014)

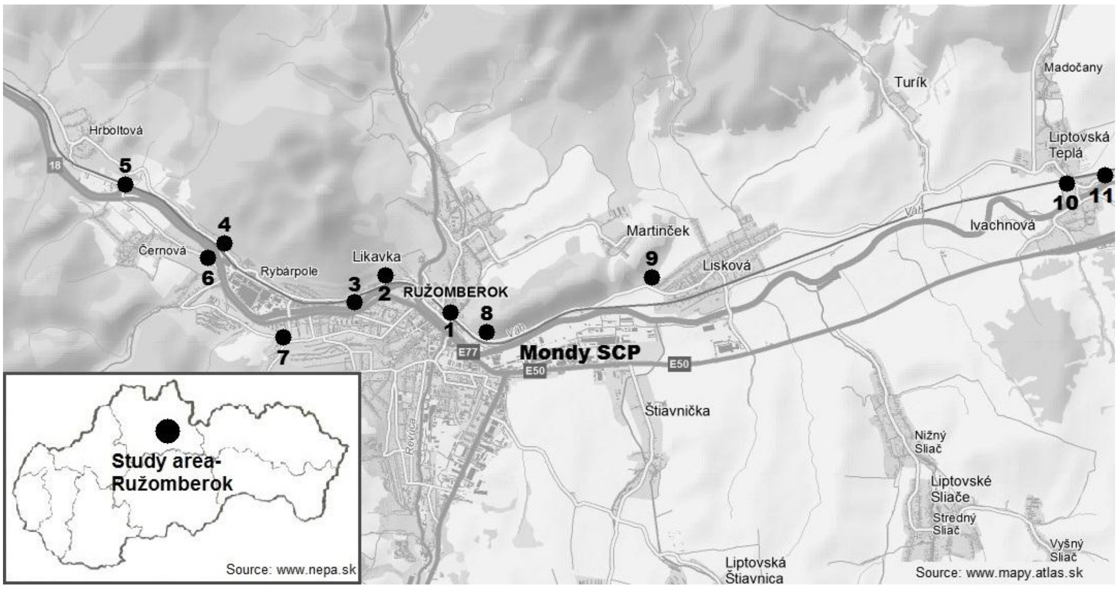

Fig. 1. Investigated area, sampling sites.

As the control sampling was chosen the site in Tatranská Javorina (E20° 08,744', N49° 16,122'), it is out of the investigated area, situated in a relatively clean environment, without local imission sources and long-distance imission transfer is not supposed too.

Instrumental analysis

The tissue samples were analyzed by X-ray spectrometry, using the hand-held XRF spectrometer DELTA CLASSIC (USA). The following elements were determined: S, Cl, K, Ca, Mn, Fe, Zn, Rb, Sr, Mo, Sb, Pb. The plant material was grinded by the laboratory ball mill into extra fine powder. The ball mill was made of hardened steel to eliminate iron contamination. The samples, placed in resealable plastic bags, are stored in the Institute of High Mountain Biology, Uniesity of Žilina in Tatranská Javorina, Slovakia.

Statistics

Multivariate exploratory techniques, factor analysis and Varimax raw factor rotation have been used to determine the site ordination in relation to factor loadings. For statistical analysis, the CANOCO for Windows 4.5 package was used (Ter Braak and Šmilauer 2002). To analyse the relation of environmental variables (element concentrations) and analysed plant segments, we had only single data set of variable. As the length of the first gradient in the log report was 0.76, we used the principal component analysis, the PCA. For ordination analysis we used ordinal elements concentration data without transformation. Statistical graphics system STATISTICA, Release 7 have been used for the correlation analysis and for analysis of variance (Stephens and Calder 2004). Except for individual differentiation, the samples were sorted into groups according to location (windward and leeward sites). The differences between ecological groups were tested with one-way analysis of variance (ANOVA) of the component scores.

Results

Following tables (Table 1, 2, 3, 4) present results of chemical analysis in observed parts of *Fallopia japonica* - rhizome, shoot, flower and leaf.

	***Jav**	**1**	**2**	**4**	**5**	**8**	**9**	**10**	**11**
S	674	492	626	424	622	651	373	351	483
Cl	2,165	2,234	1,304	753	884	6,502	1,058	776	2,741
K	14,307	19,935	8,959	10,090	15,007	23,516	9,099	4,534	32,448
Ca	10,512	13,931	22,214	4,537	13,511	9,803	7,868	4,194	12,268
Mn	67	77	59.3	21	30	37	22	25	33
Fe	1,756	2,903	1,390	271	657	430	357	47	885
Zn	25	61	36.6	33	45	62,5	47	32	64
Rb	15.6	17.3	10.2	16.5	11.7	14.9	9.8	14.1	16.3
Sr	26	27.4	39.8	18.5	49.9	29	18.5	12.4	40
Mo	4.9	3.6	4.0	5.3	4.1	5.5	5.6	6.4	5.6
Sb	4	22	20	5	24	26	5	25	32
Pb	8.6	17	7.1	8	6	14.5	8	13	10

Table 1. Results of chemical analysis in rhizomes (ppm). *Jav= sampling site in Tatranská Javorina.

	***Jav**	**1**	**2**	**3**	**4**	**5**	**8**	**9**	**10**	**11**
S	714	489	480	470	560	897	530	365	707	510
Cl	2,923	3,478	3,622	1,699	1,106	1,783	9,454	2,079	1,568	3,777
K	34,939	25,012	38,678	16,482	33,093	82,960	42,608	26,197	17,548	11,884
Ca	16,176	3,039	14,790	6,758	12,603	9,207	8,685	5,900	10,413	13,309
Mn	33	22	24	20.6	29	25	22	20	29	19
Fe	92	45	80	66.5	102	90	80	80	45	80
Zn	20	23	23	17	20	71	44	30	23	46
Rb	20.5	14.0	10.9	13.76	21.9	21	14.3	9.6	19.8	12.3
Sr	16.2	7.5	26.6	25.5	34	34	25.8	12.7	27.5	45
Mo	6.5	5.1	5.07	5.7	4.8	4.70	4.6	5.1	5.0	7.0
Sb	5	19	20	5	4	19	10	26	10	16
Pb	13	12	9.7	10.3	14	8	8	9	12	7

Table 2. Results of chemical analysis in shoots (ppm). *Jav= sampling site in Tatranská Javorina.

	*Jav	1	2	3	4	5	6	7	9	10	11
S	552	750	607	768	1,008	803	830	626	907	739	636
Cl	1,372	4,065	4,405	3,744	4,178	3,255	3,346	3,546	3,015	3,632	4,403
K	22,349	25,166	33,466	37,267	37,824	37,851	28,233	16,644	29,837	22,248	28,192
Ca	3,549	5,933	9,100	5,510	10,644	6,393	4,625	6,248	7,932	4,979	4,905
Mn	28	26	41	33	57	38	21	20	35	19	27
Fe	305	452	761	834	1707	346	49	49	173	547	87
Zn	44	55	67	62	76	70	49	37	61	34	73
Rb	27.5	19	16.8	24.8	48	27.2	12	18.4	15.3	46	19.2
Sr	3.00	9.7	17.1	9.9	22	12.1	9.8	24.2	13.7	17.2	6.2
Mo	7.0	3.4	6.80	5.7	7.2	8.3	5.5	5.7	4.8	4.0	5.9
Sb	25	31	32	16	17	15	22	15.1	16	16	15.1
Pb	14.2	10	10	9	11	10	8	9	7	6	6

Table 3. Results of chemical analysis in flowers (ppm). *Jav= sampling site in Tatranská Javorina.

	*Jav	1	2	3	4	5	6	7	8	9	10	11
S	508	871	819	931	750	703	527.7	777	618	860	462	837
Cl	2,791	5,296	1,179	1,929	1,637	582	3,155	3,979	5,316	3,187	1,812	4,495
K	16,110	10,206	12,215	9,314	8,510	11,800	15,051	8,937	8,142	15,072	8,221	12,192
Ca	17,040	23,215	32,510	45,256	33,319	21,174	16,623	31,864	25,718	14,905	18,275	19,403
Mn	53	46	68.3	45	57	47	39.3	103	58.3	53	34	66
Fe	204	759	321.6	1,044	667	359	84	69	487	179	606	250
Zn	24	42	76.6	23	30	26	33.5	38	43	34	25	60
Rb	19.2	12.8	9.1	15.0	21.1	19.4	10.5	17.5	12.3	9.8	28.6	14.3
Sr	13.3	27.3	31.1	102	86	37.9	36	72	34	21.1	46	49
Mo	6.50	5.90	5.7	4.0	5.3	6	8	4.8	5.4	6.6	4.9	5.3
Sb	21	27	20	10	14	18	39	10.1	40	10	10	10.1
Pb	8.8	9	6.4	7	7	7	9	7	10.7	7	7	9

Table 4. Results of chemical analysis in leaves (ppm). *Jav= sampling site in Tatranská Javorina.

In order to better understand the accumulation process in the new sprouts, we have made three spring sprout sampling (May 1, May 5 and May 10, Table 5a, 5b, 5c).

Site	S	Cl	K	Ca	Mn	Fe	Zn	Rb	Sr	Mo	Pb
1	1,332	5,147	43,593	4,498	27	206	91	26.5	3.6	6.9	10
2	1,254	4,510	43,455	7,132	32	219	74	18.6	6.9	4.4	7
3	1,504	1,510	33,943	5,586	22	248	97	25.8	5.7	5.2	9
4	1,722	2,556	37,221	9,380	40	140	83	16.4	16	8	9
5	1,497	2,728	44,468	11,184	51	460	89	33.8	16	5.4	8
6	1,318	2,328	45,986	8,415	34	120	73	12.6	13.8	4.9	7
7	1,761	3,963	48,624	11,015	29	*	91	27.6	24.6	6.2	8
8	1,566	6,476	43,169	10,368	31	199	102	26.4	11.2	5.4	10
9	2,002	4,151	51,875	7,055	32	188	124	22.8	6.3	5.3	11
10	1,772	2,816	48,396	4,175	23	100	99	29.2	2.5	4.8	6
11	1,279	3,742	49,474	7,125	65	305	142	26.2	6.3	8.3	11

Table 5a. Sampling May 1. * Bellow detection limit.

Site	S	Cl	K	Ca	Mn	Fe	Zn	Rb	Sr	Mo	Pb
1	1,621	2,972	35,737	4,051	23	185	98	25.4	*	4.9	7
2	1,364	3,978	47,928	4,255	33	169	109	18.9	2.6	5.1	7
3	1,672	1,871	40,274	4,591	23	177	119	27.6	1.9	5.6	9
4	1,699	2,141	37,017	4,387	34	78	95	15.1	8.5	3.6	10
5	1,632	2,123	39,446	6,546	43	261	101	33.2	7.8	4.8	8
6	1,867	2,433	41,928	4,215	36	105	104	13.1	4	4.4	6
7	1,865	2,779	43,137	4,879	22	69	126	26.8	7.1	2.6	6
8	1,776	4,150	43,469	4,592	33	154	131	28.6	1.6	5.5	8
9	1,833	2,629	40,812	3,904	30	125	102	21.2	*	5.7	8
10	1,588	1,936	39,448	3,633	21	76	123	26.8	*	5.2	6
11	1,533	2,523	38,889	2,504	32	148	119	22.3	*	7.3	*

Table 5b. Sampling May 5. * Bellow detection limit.

Site	S	Cl	K	Ca	Mn	Fe	Zn	Rb	Sr	Mo	Pb
1	1,859	3,737	37,185	4,832	37	354	118	25.5	*	7.3	7
2	1,494	2,386	38,983	10,265	76	134	129	15.1	5.7	3.5	*
3	1,675	2,374	37,237	4,427	31	106	121	26.7	2.5	4.8	*
4	1,428	2,827	35,261	4,078	35	58	80	17.2	*	6.6	8
5	1,827	2,036	34,877	7,589	54	206	99	30.9	8.2	3.7	7
6	1,837	2,568	37,397	4,918	41	62	107	15.8	2.8	6.5	*
7	1,669	3,363	39,265	6,930	36	54	102	30.9	11.5	5.3	8
8	1,499	4,536	38,018	6,022	46	129	90	22.5	4.2	4.6	8
9	1,594	2,882	38,502	4,431	33	134	108	18.4	*	4.5	6
10	1,693	2,572	42,778	5,221	28	67	90	28.7	2.5	4.3	7
11	1,633	2,928	40,167	4,408	52	124	101	24.7	2.4	6.3	*

Table 5c. Sampling May 10. * Bellow detection limit.

All the elements except for sulfur had the highest concentration in the segments collected after snowmelt (Fig. 2). We assume that the soil after the snow thawed has been enriched by accumulated emissions. Sulfur is of local origin.

While PC 1 explains 84.9% of variance, PC 2 explains 15 % of variance. Molybdenum positively correlates with the first axis, manganese, antimony and strontium correlate with this axis in a lower extent. Sulphur negatively correlates with the second axis. Lead and rubidium are predominantly accumulated in flowers, iron in rhizomes and calcium in leaves. These trends can be seen on the Fig. 3.

In Table 6, there are compared determined concentrations of elements in flowers with concentrations in rhizomes, shoots and leaves. The values measured in shoots and flowers differ only slightly. In the rhizomes are lower concentrations of chlorine and potassium, but higher concentration of calcium. Comparing flowers to leaves, significantly higher concentrations of calcium and lower potassium concentrations are shown in the leaves.

Correlation coefficients of shoots and flowers in relation to the rhizomes of site 2 (Table 7) indicate

Variable	Correlations		
	Rhizomes	Shoots	Leaves
Flowers	0.90	1.00	0.53

Table 6. Correlation coefficients, comparisson of the determined concentrations of elements in flowers with concentrations in rhizomes, twigs and leaves.

	Shoots	Flowers	Leaves
Javorina	0.97	0.87	0.98
Site 1	0.86	0.91	0.81
Site 2	0.62	0.53	1.00
Site 5	0.79	0.82	0.93
Site 9	0.86	0.88	0.99
Site 10	0.97	0.84	0.90
Site 11	0.86	0.98	0.75

Table 7. Correlation coeficients, element correlation in shoots, flowers and leaves, compared to rhizomes.

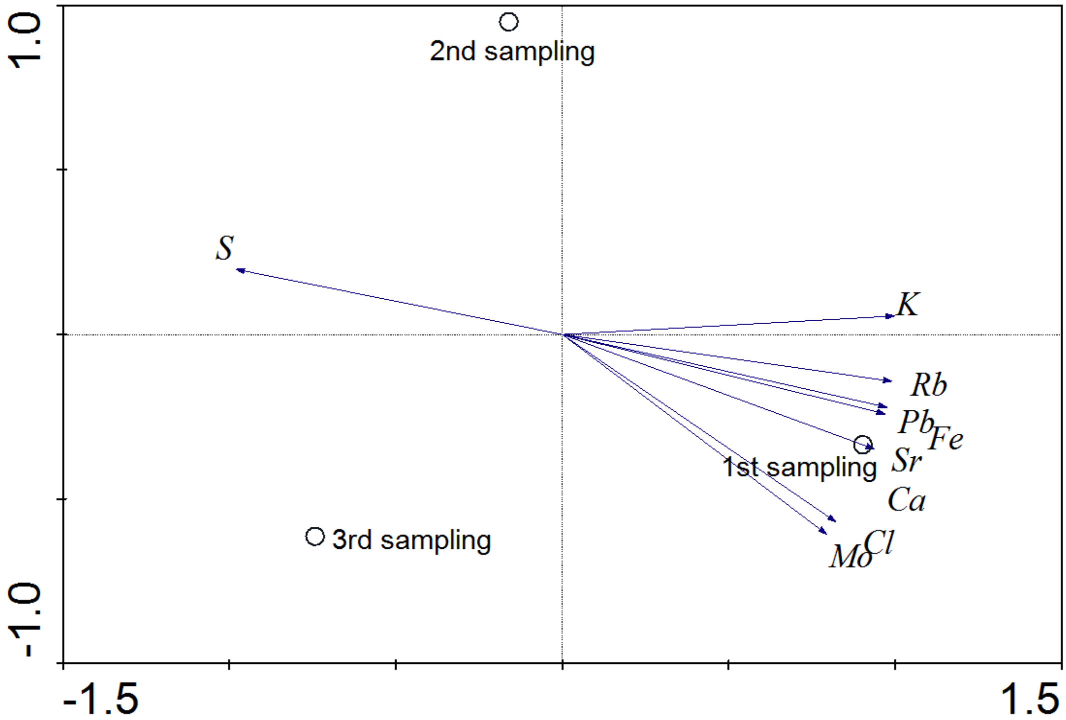

Fig. 2. PCA, ordination of analysed elements, spring sampling.

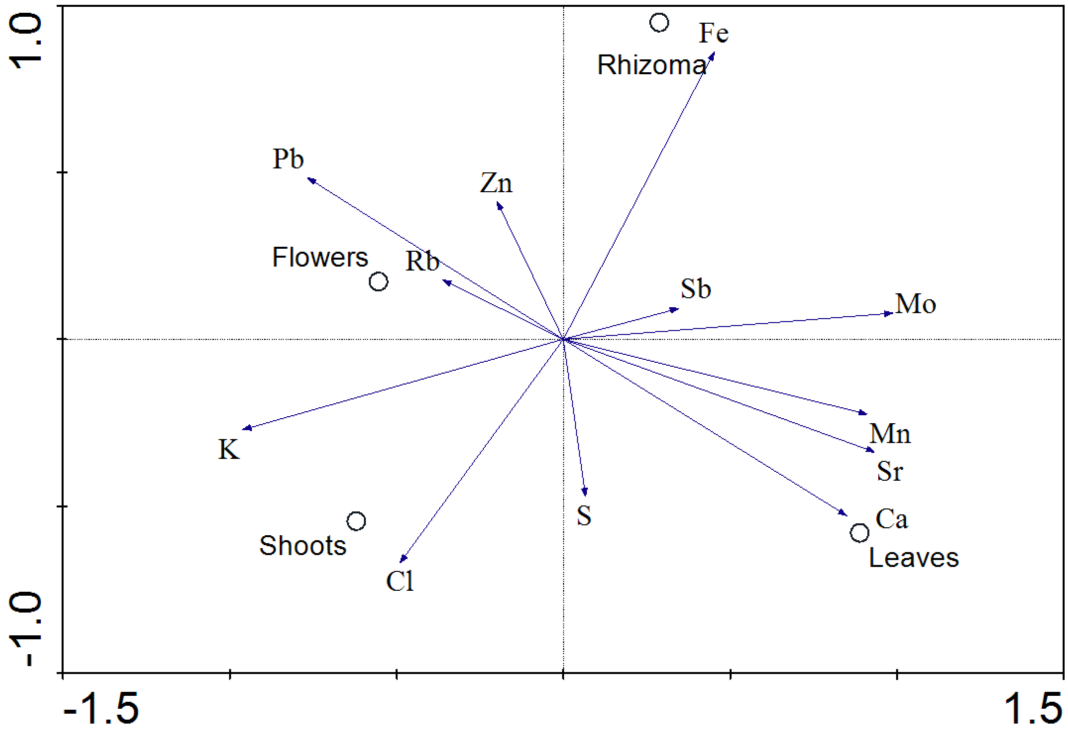

Fig. 3. Principal component analysis (PCA), biplot, relationship between parts of plants (rhizomes, flowers, shoots and leaves) and heavy metal concentrations (including sulphur).

dissimilarity compared to other sites. The disproportion of site 2 compared with Tatranská Javorina indicates also the Table 8, where the correlation coefficient (rhizomes) is 0.82, while in other cases is close to 1.0. To identify the site ordination in relation to the factor loadings, factor analysis was used (Fig. 4). The results of factor analysis confirmed the different level of accumulation of chemical elements.

Rhizomes, as an underground parts of the plant, are not directly exposed to the imissions from the air. Thus, we have considered element concentrations in the rhizomes for the dependent variable. The concentration of elements in the rhizomes highly correlates with the concentrations of the elements in the shoots, flowers and leaves, except for the site 2.

The sampling site Tatranská Javorina is out of the investigated area. The site Tatranská Javorina is situated in a relatively clean environment, without

Site	1	2	3	4	5	6	7	8	9	10	11
rhizomes	1.00	0.82	*	0.97	0.99	*	*	0.95	0.99	0.99	0.95
shoot	0.94	1.00	1.00	1.00	0.94	*	*	0.96	0.97	0.99	0.89
flower	0.99	0.99	1.00	0.99	1.00	1.00	0.97	*	0.99	0.99	1.00
leaves	0.92	0.90	0.82	0.85	0.96	1.00	0.86	0.88	1.00	0.93	0.97

Table 8. Correlation coeficients, element correlation in rhizomes, shoots, flowers and leaves, compared to the site in Tatranská Javorina.

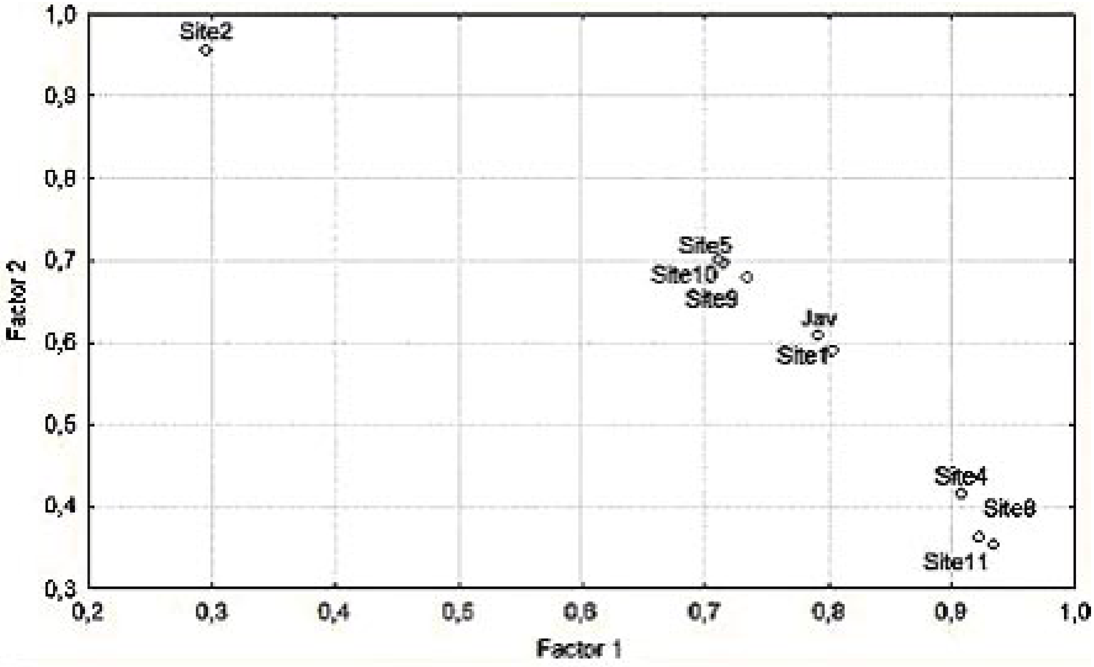

Fig. 4. Factor analysis, sites ordination. Rotation: Varimax raw, Extraction: Principal components.

the local imission sources and long-distance imission transfer is not supposed, too. For this reason, level of the elements in the site Tatranská Javorina we consider to be dependent variable. Despite the fact, that the site Tatranská Javorina is located in different environment, the concentrations of lement highly correlate (Table 8).

Discussion

For the purpose of assessing the impact of MONDI SCP Ružomberok on environmental contamination, the samples of *Fallopia japonica* have been collected on 11 sites. Sites 1-8 are on the windward situation and sites 9-11 on leeward situation.

To the one way analysis of variance (ANOVA) have been submitted Zn, Sr, Pb, Mn, Fe, Rb and Mo. As categorical predictor has been chosen windward and leeward sites in relation to the MONDI SCP Ružomberok. Significance was found in the case of lead, sulphur and molybdenum. Lead shows significantly lower concentrations in flowers in the leeward sites. While sulphur shows significantly lower concentration in the rhizomes in the leeward sites, in the case of molybdenum, we've seen significantly higher concentrations in the rhizomes in the leeward sites (Table 9). Vigaš and Šoltés (2013) came to the conclusion, that sulfur resources have a local nature, while sources of molybdenum are different - it gets here from sources situated north-west of study area Ružomberok (Rak *et al.* 1982) and this is the reason, why molybdenum distribution is different in study area. As we can see in the Fig. 3, iron shows significantly higher concentrations in the underground parts of the plants-rhizomes. This fact is proved by the research done by Soltysiak *et al.* (2011). Site 2 is seen in left hand corner up, standing against the group of other sites (Fig. 4). For this deviation are responsible high concentrations of iron, but especially calcium (Table 1). Site 2 is different from the other sites, this one is close to the Gypsy settlement, just in the place of the old dum. We assume old contamination (construction waste, scrap metal) and as *Fallopia japonica* is considered hyperaccumulator (Dwiecki and Koziol 2005), this explains the high concentrations of Fe and Ca in the rhizomes (Table 1, Fig. 3).

In the case of Tatranská Javorina, concentrations of elements highly correlate (Table 8). This phenomenon can be explained by the fact, that the element concentration in rhizomes is directly influenced by the concentration of these elements in the soil. Dassonville *et al.* (2007) noted, that F*allopia japonica* enhances nutrient cycling rates probably

Sulphur	F	p
Rhizomes	0.586	0.052
Flowers	0.110	0.920
Shoots	0.139	0.720
Leaves	2 072	0.184

Zinc	F	p
Rhizomes	0.000	0.997
Flowers	0.105	0.754
Shoots	0.000	0.993
Leaves	0.003	0.956

Strontium	F	p
Rhizomes	0.961	0.365
Flowers	0.392	0.549
Shoots	0.113	0.746
Leaves	0.659	0.438

Lead	F	p
Rhizomes	0.004	0.954
Flowers	27.61	0.001
Shoots	0.345	0.576
Leaves	0.052	0.825

Manganese	F	p
Rhizomes	1.750	0.234
Flowers	0.658	0 441
Shoots	0.160	0.701
Leaves	0.279	0.610

Chlorine	F	p
Rhizomes	0.292	0.608
Flowers	0.092	0.769
Shoots	0.308	0.596
Leaves	0.057	0.817

Iron	F	p
Rhizomes	1.099	0.335
Flowers	0.856	0.382
Shoots	0.397	0.549
Leaves	0.362	0.562

Rubidium	F	p
Rhizomes	0.102	0.760
Flowers	0.115	0.743
Shoots	0.415	0.540
Leaves	0 497	0.449

Molybdenum	F	p
Rhizomes	6.393	0.045
Flowers	1.447	0.263
Shoots	2.087	0.192
Leaves	0.003	0 961

Table 9. ANOVA – element distribution along Liptov Basin, windward and leeward sites in relation to the MONDI.

due to nutrient uplift and the plant may contribute to soil homogenization in invaded landscapes. This mechanism probably explains the high correlation of elements even in remote locations and in different environment. But in the case of strong anthropogenic contamination this self-regulatory mechanism fails, e.g. Site 2 (Table 7, 8, Fig. 4).

Table 7 shows correlation coeficients compared to rhizomes. *Fallopia japonica* has a well developed perennial rhizome, makes up 80% of the plant weight and is a nutrient reservoir for developing plant. Above-ground shoots are annual. It is not clear to what extent the above-ground organs are supplied by contaminants from the rhizome and the share of air borne contamination is unknown. Apart from heavily contaminated Site 2, correlation coeficients rhizomes-flowers vary in the range 0.82-0.98, and correlation coeficients rhizomes - leaves in the range of 0.75-0.98 (Table 7). Partly reduced correlation coeficients rhizomes-aboveground organs allow us to think that in the case of aboveground parts, in addition to the elements transport from the rhizome, also applies the air environmental contamination. Table 6 compares the levels of determined elements in flowers with other parts. Low correlation coefficient flowers-leaves (0.53, Table 6) suggests that such flowers as well as leaves uptake contaminants in a specific way. This accumulation characteristic indicates that *Fallopia japonica* is suitable to serve as an excellent bioindicator. Some authors turned attention to hyperaccumulation properties of *Fallopia japonica* (Dwiecki and Koziol 2005), but, unfortunately, *Fallopia japonica* has never been used as bioindicator. Flowers preferentially accumulate lead, rubidium and strontium, leaves accumulate with preference manganese and calcium, although, of course, environmental monitoring of calcium is marginal.

The phenology of *Fallopia japonica* is rather well known. The plant sprouts in late April, the main growing period is May and June (Alberternst and Böhmer 2011). The blooming season is from September to October (Horn, 1997). These phenological data are consistent with our observations. The plants began to sprout from April 21 to 29. On the April 30, we recorded plant height of 10 cm, on the May 5, the same plant was 33 cm high, the daily growth in the tracked period was 4,6 cm. Literature indicates the same daily growth 4,6 cm per day in the spring (Horn 1997).

During the spring 2015 we conducted sampling to track the course of elemental accumulation. The first sprouts we have recorded on April 30, 2015. It was found out that the samples collected in early spring contained relatively higher concentrations of certain elements, such as iron or calcium (Fig. 2). This is probably due to the accumulation of elements from melting snow.

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Conclusions

Fallopia japonica is suitable bioindicator. The study revealed several notable trends:

1. Lead and rubidium are predominantly accumulated in flowers.
2. Iron prefers rhizomes.
3. Calcium is predominantly accumulated in leaves

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