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DIVERSITY OF VASCULAR FLORA OF WASTE DUMPS AND DUMPING GROUNDS IN LOWER SILESIA

ANNA KOSZELNIK-LESZEK*, MAGDA PODLASKA, KLARA TOMASZEWSKA

University of Environmental and Life Sciences
Department of Botany and Plant Ecology
pl. Grunwaldzki 24a , 50-363 Wrocław
*Corresponding author's e-mail: anna.koszelnik-leszek@up.wroc.pl

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Abstract: The paper presents results of floristic investigation conducted within the territory of waste dumps in Lower Silesia: landfill of municipal waste Wrocław-Maślice, post–metallurgic waste heap in Siechnice, serpentine dumping grounds in Grochów and slag heaps in Bielawa.

The investigated flora was analyzed with regard to species composition, participation of geographical-historical groups, live forms (according to classification by Raunkiaer), as well as selected ecological factors: light indicator (L), thermal indicator (T), soil moisture (W), trophic indicator (Tr), soil reaction (pH), value of resistance to increased heavy metals content (M). On 4 waste dumps there were found 269 species of vascular plants, belonging to 51 families. Only 5 species occurred on 4 sites, which provides for 2% of all plants recorded. The most numerous families are *Asteraceae*, *Poaceae* and *Fabaceae*. Apophytes dominate in waste dumps flora Hemicryptophytes are the most numerous group.

Analysis of the floras (selected ecological factors) of investigated objects has shown general similarities, but also apparent differences. The most significant differences concerned two parameters: trophism (Tr) and resistance to increased heavy metals content (M).

INTRODUCTION

Mines exploitation, development of industry and urbanization bring about a considerable degradation of Earth surface, among others through depositing of different types of waste. Industry – degraded areas, in the form of landfills, waste dumps or dumping grounds, have become an interesting object of research involving vegetation of anthropogenic habitats [7, 8, 14, 28]. The mentioned areas are also of a significant biological value, regarding the possibility of recording geological factors and phenomena, as well as unique phytocenoses [6, 8, 16, 20]. Landfills and headings can be treated as specific "experimental plots", the sites used for observation of the processes taking place in the course of spontaneous succession and connected with invasion of pioneer species or mechanisms governing the development of plant communities [2, 6, 8, 16, 20, 27].

Investigation undertaken so far has mainly covered the objects of similar origin. This work concentrates on the results of floristic observation done on the area of 4 dumping grounds markedly differing, among others, in their genesis and landfill waste material. The aim of this study is comparison of vegetation inhabiting selected objects.

MATERIAL AND METHODS

Research was conducted on "Maślice" municipal waste dump of Wrocław, dumping ground of serpentine waste in Grochów (about 70 km from Wrocław), post-metallurgic waste dump in Siechnice (about 12 km from the centre of Wrocław), as well as slag dumping ground in Bielawa (about 60 km from Wrocław).

There were taken phytosociological photographs, covering 25 m^2, randomly distributed on each object, supplied with floristic index for particular areas not covered by the photos. The naming of plant species was accepted after Mirek *et al.* [15]. The flora of selected objects was also analyzed in the view of classification to geographic – historical groups, according to classification enclosed in the works by Zając and Zając [31], Zając and Zając [32] and Zając *et al.* [30]. For each species there was determined, after Zarzycki *et al.* [33], its live form (according to classification by Raunkiaer) and values of the following indices: light L, thermal T, moisture W, trophism Tr, reaction R and resistance to higher content of heavy metals M.

Characteristics of research areas

The objects subjected to examination differ in localization, size and type of landfill materials.

Serpentine waste dump in Grochów

The examined object is situated about 70 km south from Wrocław, south-west direction from Ząbkowice Śląskie, within the territory of Bardo community, in Lower Silesian voivodship.

Serpentine waste dump in Grochów was formed (1960–1994) due to exploitation of magnesite from a landfill within Grochów Massif. Serpentine rocks which build this massif are transformed ultraalkaline and alkaline rocks in deep fraction of contact metamorphism [6, 29]. Spontaneously progressing vegetation develops on detrial minerals and rock waste. Large angle of dump sloping favours erosion which, in turn, makes natural succession more difficult. The floristic investigations were carried out during the growing season of 2009.

Post-metallurgic slag dump in Siechnice

Slag dump originating from ferrochromium production in "Siechnica" Ironworks is localized on the territory of Saint Katarzyna community, in Lower Silesian voivodship. Waste dump was formed (1961–1990) as a result of nearly thirty-year lasting, depositing slag from low- and medium-carbon ferrochromium production, according to alkaline technology. Currently, it has accumulated 1581 thousand m^3 of waste. The main component of this dump is post-metallurgic slag, providing for over 85% of landfill waste mass. Apart from slag, there were deposited also other wastes connected with the existence of industrial plant, such as: used inflammable materials, municipal waste, landfill from plant sewage – treatment [8]. Besides, in the dump there can be found pieces of ferrochromium, varying in their size. As a result of 'wild' exploitation of waste dump by people searching for ferrochromium alloys, the layer subjected to soil reclamation, which was introduced to the dumping ground, has became devastated to a high degree. Dumping ground containing post-metallurgic waste remaining after closed "Siechnice" Ironwork , as well as currently working "Czechnica" heat and power generating plant, are situated in the close vicinity of water – bearing areas of Wrocław. The floristic investigations were carried out during the growing season of 2009.

Slag dumps of textile industry in Bielawa

Slag landfill in Bielawa remained after the activity of textile plant Bielawskie Zakłady Przemysłu Bawełnianego "Bieltex". The mentioned landfill involves two waste dumps of the total area of 4.67 ha. The quantity of deposited waste on dumping grounds amounts 152 000 m^3 and 150 000 m^3 respectively [10]. The waste dumps had been used until "Bieltex" plant was closed, i.e. 1994.

According to a land reclamation project [5, 35], on both dumping grounds there were deposited slag, dust, ash originating from burning coal in boilers of big industrial plants, stabilized municipal sewage waste, soil, stones and waste undergoing biodegradation. A smaller dumping ground underwent reclamation in 1996, while reclamation of a larger waste dump began in March 2009 [5]. Floristic tables, analyzed in this work, originate from 2008 .

Municipal waste dump Maślice

"Maślice" municipal waste landfill is situated in the north-west part of Wrocław (in Fabryczna district, in direct neighbourhood of Maślice Wielkie and Pracze Odrzańskie residentials). This waste landfill was active in the years 1967–2000; then it underwent preliminary land reclamation. The area of landfill base amounts 11.42 ha, of landfill plateau – 5 ha and of landfill canopy – 11.68 ha. The volume of accumulated waste is 1.9 mln m^3. Landfill mass is 48 m high and it is built of two levels. The landfill is situated close to the Odra River walls and approximately at 50–75 m distance from the river bank [3, 12, 18, 25, 36, 37].

Landfill reclamation involved geotechnological protection of waste dump, its surrounding by an underground insulating screen, introduction of a degassing system and preliminary biological reclamation (delivering of soil material, sowing with fabaceae-grass mixture). The reclamation layer consists of the ground of an anthropogenic origin (bricks, derbis, clay), featuring thickness from 0.8 m on its plateau to 1 m on landfill slopes. Decline in reclamation layer amounts about 8% [4, 24]. Floristic tables, analyzed in this work, originate from 2010 .

RESULTS AND DISCUSSION

On four objects, differing from one another, there were found 269 species of vascular plants (Tab. 1). Diversity of flora within particular objects was mainly affected by the quality of medium, land reclamation treatments applied, as well as the degree of succession advancement on particular objects.

Serpentine waste dump in Grochów

On waste dump in Grochów there were found 30 species of vascular plants, belonging to 16 botanic families (Tab.1). The presence of majority of species is the effect of natural

Table 1. List of vascular flora of the investigated objects

L.p.	Name of species	Family	Spoil heaps			
			Maślice	**Grochów**	**Siechnice**	**Bielawa**
1	*Acer negundo* L.	*Aceraceae*	+	.	.	.
2	*Acer platanoides* L.	*Aceraceae*	.	.	.	+
3	*Acer pseudoplatanus* L.	*Aceraceae*	.	.	.	+
4	*Achillea millefolium* L.	*Asteraceae*	+	+	.	+
5	*Aegopodium podagraria* L.	*Apiaceae*	.	.	.	+
6	*Ajuga genevensis* L.	*Lamiaceae*	.	.	+	.
7	*Allium rotundum* L.	*Liliaceae*	.	.	.	+
8	*Allium sibiricum* L.	*Liliaceae*	.	.	.	+
9	*Alnus glutinosa* (L.) Gaertn.	*Betulaceae*	.	.	.	+
10	*Alnus incana* (L.) Moench	*Betulaceae*	.	.	.	+
11	*Alopecurus pratensis* L.	*Poaceae*	+	.	.	.
12	*Amaranthus retroflexus* L.	*Amaranthaceae*	.	.	+	.
13	*Anchusa arvensis* (L.) M. Bieb.	*Boraginaceae*	.	.	.	+
14	*Anchusa officinalis* L.	*Boraginaceae*	.	.	.	+
15	*Anthoxanthum odoratum* L.	*Poaceae*	+	.	.	.
16	*Anthriscus silvestris* (L.) Hofm.	*Apiaceae*	+	.	.	.
17	*Anthylis vulneraria* L.	*Fabaceae*	.	+	.	+
18	*Arabis glabra* (L.) Bernh.	*Brassicaceae*	+	.	.	+
19	*Arctium lappa* L.	*Asteraceae*	+	.	.	.
20	*Arctium tomentosum* Mill.	*Asteraceae*	+	.	+	.
21	*Armoracia rusticana* P. Gaertn., B. Mey. & Scherb.	*Brassicaceae*	+	.	.	+
22	*Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl & C. Presl	*Poaceae*	+	+	+	+
23	*Artemisia absinthium* L.	*Asteraceae*	.	.	+	.
24	*Artemisia campestris* L.	*Asteraceae*	+	.	.	.
25	*Artemisia vulgaris* L.	*Asteraceae*	+	.	+	+
26	*Asperugo procumbens* L.	*Boraginaceae*	.	.	.	+
27	*Astragalus glycyphyllos* L.	*Fabaceae*	+	.	.	.
28	*Atriplex nitens* Schkuhr	*Chenopodiaceae*	+	.	.	.
29	*Ballota nigra* L.	*Lamiaceae*	+	.	+	+
30	*Barbarea vulgaris* R. Br.	*Brassicaceae*	+	.	.	.
31	*Berteroa incana* (L.) DC.	*Brassicaceae*	+	.	.	.
32	*Betula pendula* Roth	*Betulaceae*	.	+	.	+
33	*Brassica napus* L.	*Brassicaceae*	+	.	.	.

L.p.	Name of species	Family	Spoil heaps			
			Maślice	Grochów	Siechnice	Bielawa
34	*Bromus erectus* Huds.	*Poaceae*	.	+	.	+
35	*Bromus hordeaceus* L.	*Poaceae*	+	.	.	+
36	*Bromus inermis* Leyss.	*Poaceae*	.	.	+	.
37	*Bromus sterilis* L.	*Poaceae*	+	.	+	+
38	*Bromus tectorum* L.	*Poaceae*	+	.	.	+
39	*Bryonia dioica* Jacq.	*Cucurbitaceae*	+	.	.	.
40	*Bunias orientalis* L.	*Brassicaceae*	+	.	.	.
41	*Calamagrostis canescens* (Weber) Roth	*Poaceae*	.	.	+	.
42	*Calamagrostis epigeios* (L.) Roth	*Poaceae*	+	+	.	+
43	*Calystegia sepium* (L.) R. Br.	*Convolvulaceae*	+	.	.	.
44	*Campanula patula* L.	*Campanulaceae*	+	.	.	.
45	*Campanula rapunculoides* L.	*Campanulaceae*	.	.	.	+
46	*Campanula rotundifolia* L.	*Campanulaceae*	.	+	.	.
47	*Capsella bursa-pastoris* (L.) Medik.	*Brassicaceae*	+	.	.	+
48	*Cardaria draba* (L.) Desv.	*Brassicaceae*	+	.	.	.
49	*Carduus acanthoides* L.	*Asteraceae*	+	.	.	.
50	*Carduus crispus* L.	*Asteraceae*	+	.	.	.
51	*Carex hirta* L.	*Cyperaceae*	+	.	.	.
52	*Carex ovalis* Gooden.	*Cyperaceae*	.	.	+	.
53	*Carlina vulgaris* L.	*Asteraceae*	.	+	.	.
54	*Centaurea cyanus* L.	*Asteraceae*	+	.	.	.
55	*Centaurea jacea* L.	*Asteraceae*	+	.	.	.
56	*Centaurea stoebe* L.	*Asteraceae*	.	+	+	.
57	*Centaurium erythraea* Rafn	*Gentianaceae*	+	.	.	.
58	*Cerastium arvense* L.	*Caryophyllaceae*	.	.	.	+
59	*Cerastium holosteoides* Fr. emend. Hyl.	*Caryophyllaceae*	+	.	.	.
60	*Chaenorhinum minus* (L.) Lange	*Scrophulariaceae*	+	.	.	.
61	*Chaerophyllum temulum* L.	*Apiaceae*	.	.	.	+
62	*Chamomilla recutita* (L.) Rauschert	*Asteraceae*	.	.	+	.
63	*Chamomilla suaveolens* (Pursh) Rydb.	*Asteraceae*	.	.	.	+

L.p.	Name of species	Family	Spoil heaps			
			Maślice	Grochów	Siechnice	Bielawa
64	*Chelidonium majus* L.	*Papaveraceae*	+	.	.	+
65	*Chenopodium album* L.	*Chenopodiaceae*	.	.	+	+
66	*Chenopodium bonus-henricus* L.	*Chenopodiaceae*	.	.	+	+
67	*Chenopodium urbicum* L.	*Chenopodiaceae*	+	.	.	.
68	*Cichorium intybus* L.	*Asteraceae*	+	.	.	.
69	*Cirsium arvense* (L.) Scop.	*Asteraceae*	+	+	+	+
70	*Cirsium vulgare* (Savi) Ten.	*Asteraceae*	.	.	+	+
71	*Conium maculatum* L.	*Apiaceae*	+	.	+	+
72	*Convolvulus arvensis* L.	*Convolvulaceae*	+	.	+	+
73	*Conyza canadensis* (L.) Cronquist	*Asteraceae*	+	.	+	+
74	*Coronilla varia* L.	*Fabaceae*	+	.	.	.
75	*Cotoneaster integerrimus* Medik.	*Rosaceae*	.	.	.	+
76	*Crataegus monogyna* Jacq.	*Rosaceae*	+	.	.	+
77	*Crepis biennis* L.	*Asteraceae*	+	.	.	.
78	*Dactylis glomerata* L.	*Poaceae*	+	.	+	+
79	*Daucus carota* L.	*Apiaceae*	+	+	+	+
80	*Descurainia sophia* (L.) Webb ex Prantl	*Brassicaceae*	+	.	+	+
81	*Dianthus barbatus* L.	*Caryophyllaceae*	.	.	.	+
82	*Dianthus carthusianorum* L.	*Caryophyllaceae*	.	.	.	+
83	*Dipsacus sylvestris* Huds.	*Dipsacaceae*	+	.	.	+
84	*Echinochola crus-galli* (L.) P. Beauv.	*Poaceae*	+	.	.	.
85	*Echinocystis lobata* (F. Michx.) Torr. & A. Gray	*Cucurbitaceae*	+	.	.	.
86	*Echium vulgare* L.	*Boraginaceae*	+	+	+	+
87	*Elymus caninus* (L.) L.	*Poaceae*	+	.	.	.
88	*Elymus repens* (L.) Gould	*Poaceae*	+	.	+	.
89	*Epilobium parviflorum* Schreb.	*Onagraceae*	+	.	.	.
90	*Equisetum arvense* L.	*Equisetaceae*	+	.	.	.
91	*Erigeron annuus* (L.) Pers.	*Asteraceae*	+	.	.	.
92	*Erodium cicutarium* (L.) L'Hér.	*Geraniaceae*	+	.	.	.
93	*Eryngium campestre* L.	*Apiaceae*	.	.	+	.
94	*Erysimum cheiranthoides* L.	*Brassicaceae*	+	.	.	.

L.p.	Name of species	Family	Spoil heaps			
			Maślice	Grochów	Siechnice	Bielawa
95	*Eupatorium cannabinum* L.	*Asteraceae*	+	.	.	+
96	*Euphorbia cyparissias* L.	*Euphorbiaceae*	+	.	+	+
97	*Euphorbia marginata* PURSH	*Euphorbiaceae*	+	.	.	.
98	*Euphorbia peplus* L.	*Euphorbiaceae*	.	.	.	+
99	*Euphrasia rostcoviana* HAYNE	*Scrophulariaceae*	.	+	.	.
100	*Fallopia convolvulus* (L.) Á. LÖVE	*Polygonaceae*	+	.	+	+
101	*Festuca arundinacea* SCHREB.	*Poaceae*	+	.	.	.
102	*Festuca ovina* L.	*Poaceae*	+	+	.	.
103	*Festuca pratensis* HUDS.	*Poaceae*	+	.	.	+
104	*Festuca rubra* L.	*Poaceae*	.	.	.	+
105	*Festulolium* sp.	*Poaceae*	+	.	.	.
106	*Fragaria vesca* L.	*Rosaceae*	.	.	+	+
107	*Fraxinus excelsior* L.	*Oleaceae*	.	.	.	+
108	*Fumaria officinalis* L.	*Fumariaceae*	.	.	+	+
109	*Galega officinalis* L.	*Fabaceae*	+	.	.	.
110	*Galium aparine* L.	*Rubiaceae*	+	.	+	+
111	*Galium mollugo* L.	*Rubiaceae*	+	.	.	.
112	*Galium verum* L.	*Rubiaceae*	.	+	.	.
113	*Genista tinctoria* L.	*Fabaceae*	.	+	.	.
114	*Geranium pusillum* BURM. F. EX L.	*Geraniaceae*	+	.	+	+
115	*Geranium pyrenaicum* BURM F.	*Geraniaceae*	+	.	.	+
116	*Geum urbanum* L.	*Rosaceae*	+	.	.	.
117	*Glechoma hederacea* L.	*Lamiaceae*	+	.	.	.
118	*Helianthus tuberosus* L.	*Asteraceae*	+	.	.	+
119	*Heracleum sphondylium* L	*Apiaceae*	.	.	.	+
120	*Hieracium umbellatum* L.	*Asteraceae*	.	.	.	+
121	*Hippophaë rhamnoides* L.	*Oleaceae*	.	.	.	+
122	*Holcus lanatus* L.	*Poaceae*	+	.	.	+
123	*Holosteum umbellatum* L.	*Caryophyllaceae*	.	.	.	+
124	*Hordeum murinum* L.	*Poaceae*	.	.	.	+
125	*Humulus lupulus* L.	*Cannabaceae*	+	.	.	+
126	*Hyoscyamus niger* L.	*Solanaceae*	.	.	+	.
127	*Hypericum perforatum* L.	*Hypericaceae*	+	+	.	+

L.p.	Name of species	Family	Spoil heaps			
			Maślice	Grochów	Siechnice	Bielawa
128	*Hypochoeris glabra* L.	*Asteraceae*	+	.	.	.
129	*Iris barbata* Falk	*Iridaceae*	.	.	+	.
130	*Iris germanica* L.	*Iridaceae*	.	.	.	+
131	*Juglans regia* L.	*Juglandaceae*	.	.	.	+
132	*Koeleria macrantha* (Ledeb.) Schult.	*Poaceae*	.	+	.	.
133	*Lactuca serriola* L.	*Asteraceae*	+	.	.	.
134	*Lamium album* L.	*Lamiaceae*	.	.	.	+
135	*Lamium purpureum* L.	*Lamiaceae*	+	.	.	+
136	*Larix decidua* Mill.	*Pinaceae*	.	.	.	+
137	*Lathyrus pratensis* L.	*Fabaceae*	+	.	.	.
138	*Lathyrus sylvestris* L.	*Fabaceae*	+	+	.	.
139	*Lathyrus tuberosus* L.	*Fabaceae*	+	.	.	.
140	*Leontodon autumnalis* L.	*Asteraceae*	+	.	.	.
141	*Leontodon hispidus* L.	*Asteraceae*	.	+	.	.
142	*Leucanthemum vulgare* Lam.	*Asteraceae*	+	.	.	+
143	*Linaria vulgaris* Mill.	*Scrophulariaceae*	+	.	.	.
144	*Lolium multiflorum* Lam.	*Poaceae*	+	.	.	.
145	*Lolium perenne* L.	*Poaceae*	+	.	.	.
146	*Lotus corniculatus* L.	*Fabaceae*	+	+	+	+
147	*Malus silvestris* Mill.	*Rosaceae*	.	.	.	+
148	*Malva alcea* L.	*Malvaceae*	.	.	+	+
149	*Malva neglecta* Wallr.	*Malvaceae*	+	.	.	+
150	*Malva sylvestris* L.	*Malvaceae*	+	.	.	+
151	*Matricaria martima* subsp. *inodora* (L.) Dostál	*Asteraceae*	+	.	+	.
152	*Medicago lupulina* L.	*Fabaceae*	+	.	.	.
153	*Medicago sativa* L.	*Fabaceae*	+	.	.	+
154	*Melandrium album* (Mill.) Garcke	*Caryophyllaceae*	+	.	+	+
155	*Melilotus alba* Medik.	*Fabaceae*	+	+	+	.
156	*Melilotus officinalis* (L.) Pall.	*Fabaceae*	+	.	.	.
157	*Mentha longifolia* (L.) L.	*Lamiaceae*	.	.	.	+
158	*Mentha piperita* L.	*Lamiaceae*	.	.	.	+
159	*Myosotis stricta* Link ex Roem. & Schult.	*Boraginaceae*	+	.	.	.

L.p.	Name of species	Family	Spoil heaps			
			Maślice	Grochów	Siechnice	Bielawa
160	*Myosotis sylvatica* Ehrh. ex Hoffm.	*Boraginaceae*	.	.	.	+
161	*Oenothera biennis* L.	*Onagraceae*	+	.	.	+
162	*Onopordum acanthium* L.	*Asteraceae*	+	.	.	+
163	*Ornithogalum umbellatum* L.	*Liliaceae*	.	.	.	+
164	*Padus serotina* (Ehrh.) Borkh.	*Rosaceae*	.	.	.	+
165	*Papaver argemone* L.	*Papaveraceae*	+	.	.	.
166	*Papaver dubium* L.	*Papaveraceae*	+	.	.	+
167	*Papaver rhoeas* L.	*Papaveraceae*	+	.	+	+
168	*Papaver somniferum* L.	*Papaveraceae*	.	.	.	+
169	*Papaver strigosum* (Boenn.) Schur	*Papaveraceae*	.	.	+	.
170	*Persica vulgaris* Mill.	*Rosaceae*	+	.	.	.
171	*Phalaris arudinacea* L.	*Poaceae*	+	.	.	+
172	*Phleum pratense* L.	*Poaceae*	.	+	.	.
173	*Phragmites australis* (Cav.) Trin. ex Steud.	*Poaceae*	+	.	.	.
174	*Pimpinella major* (L.) Huds.	*Apiaceae*	.	.	+	+
175	*Pinus silvestris* L.	*Pinaceae*	.	+	.	.
176	*Plantago lanceolata* L.	*Plantaginaceae*	+	.	.	+
177	*Plantago major* L.	*Plantaginaceae*	+	.	.	+
178	*Plantago media* L.	*Plantaginaceae*	.	+	.	.
179	*Poa annua* L.	*Poaceae*	.	.	.	+
180	*Poa pratensis* L.	*Poaceae*	+	.	+	+
181	*Poa trivialis* L.	*Poaceae*	.	.	.	+
182	*Polygonum amphibium* L. fo. *terrestre*	*Polygonaceae*	+	.	.	.
183	*Polygonum aviculare* L.	*Polygonaceae*	+	.	.	+
184	*Polygonum lapathifolium* L. subsp. *pallidum* (With.) Fr.	*Polygonaceae*	+	.	.	.
185	*Polygonum lapathifolium* L. subsp. *lapathifolium*	*Polygonaceae*	.	.	+	.
186	*Polygonum persicaria* L.	*Polygonaceae*	.	.	.	+
187	*Potentilla anserina* L.	*Rosaceae*	+	.	.	+
188	*Potentilla argentea* L.	*Rosaceae*	+	.	+	.
189	*Potentilla recta* L.	*Rosaceae*	+	+	.	.
190	*Potentilla reptans* L.	*Rosaceae*	+	.	+	.

L.p.	Name of species	Family	Spoil heaps			
			Maślice	Grochów	Siechnice	Bielawa
191	*Potentilla supina* L.	*Rosaceae*	+	.	.	.
192	*Prunus cerasifera* Ehrh.	*Rosaceae*	.	.	.	+
193	*Pyrus communis* L.	*Rosaceae*	.	.	.	+
194	*Quercus rubra* L.	*Fagaceae*	.	.	.	+
195	*Ranunculus acris* L.	*ranunculaceae*	.	.	.	+
196	*Ranunculus polyanthemos* L.	*Ranunculaceae*	+	.	.	.
197	*Ranunculus repens* L.	*Ranunculaceae*	+	.	.	+
198	*Reseda lutea* L.	*Resedaceae*	+	.	+	+
199	*Reynoutria ×bohemica* Chrtek & Chrtková	*Polygonaceae*	+	.	.	.
200	*Robinia pseudacacia* L.	*Fabaceae*	+	.	+	+
201	*Rorippa amphibia* (L.) Besser	*Brassicaceae*	+	.	.	.
202	*Rorippa austriaca* (Crantz) Besser	*Brassicaceae*	+	.	.	.
203	*Rosa canina* L.	*Rosaceae*	.	.	.	+
204	*Rubus caesius* L.	*Rosaceae*	+	.	+	.
205	*Rubus plicatus* Weihe & Ness	*Rosaceae*	+	.	.	+
206	*Rumex acetosa* L.	*Polygonaceae*	+	.	.	.
207	*Rumex crispus* L.	*Polygonaceae*	+	.	.	+
208	*Rumex obtusifolius* L.	*Polygonaceae*	+	.	.	.
209	*Salix alba* L.	*Salicaceae*	.	.	.	+
210	*Salix matsudana* Koidz.	*Salicaceae*	.	.	.	+
211	*Salix repens* L. subsp. *rosmarinifolia* (L.) Hartm.	*Salicaceae*	.	.	.	+
212	*Sambucus ebulus* L.	*Caprifoliaceae*	.	.	.	+
213	*Sambucus nigra* L.	*Caprifoliaceae*	+	.	+	+
214	*Saponiaria officinalis* L.	*Caryophyllaceae*	+	.	.	.
215	*Scabiosa ochroleuca* L.	*Dipsacaceae*	.	+	.	.
216	*Scrophularia nodosa* L.	*Scrophulariaceae*	.	.	.	+
217	*Sedum acre* L.	*Crassulaceae*	.	.	.	+
218	*Senecio erucifolius* L.	*Asteraceae*	.	.	+	.
219	*Senecio jacobaea* L.	*Asteraceae*	+	.	.	.
220	*Senecio vernalis* Waldst. & Kit.	*Asteraceae*	+	.	.	.
221	*Senecio viscosus* L.	*Asteraceae*	.	.	.	+
222	*Senecio vulgaris* L.	*Asteraceae*	+	.	.	+
223	*Setaria pumila* (Poir.) Roem. & Schult.	*Poaceae*	+	.	.	.

L.p.	Name of species	Family	Spoil heaps			
			Maślice	Grochów	Siechnice	Bielawa
224	*Silene vulgaris* (Moench) Garcke	*Caryophyllaceae*	+	+	.	.
225	*Sinapis arvensis* L.	*Brassicaceae*	.	.	.	+
226	*Sisymbrium altissimum* L.	*Brassicaceae*	.	.	.	+
227	*Sisymbrium loeselii* L.	*Brassicaceae*	+	.	+	+
228	*Sisymbrium officinale* (L.) Scop.	*Brassicaceae*	.	.	.	+
229	*Solanum nigrum* L. emend Mill.	*Solanaceae*	+	.	.	.
230	*Solidago canadensis* L.	*Asteraceae*	+	.	.	.
231	*Solidago gigantea* Aiton	*Asteraceae*	+	.	.	+
232	*Sonchus asper* (L.) Hill	*Asteraceae*	.	.	.	+
233	*Sonchus oleraceus* L.	*Asteraceae*	+	.	.	.
234	*Sorbus aucuparia* L. emend. Hedl.	*Rosaceae*	.	.	.	+
235	*Stellaria media* (L.) Vill.	*Caryophyllaceae*	+	.	.	+
236	*Symphoricarpos albus* (L.) S. F. Blake	*Caprifoliaceae*	.	.	.	+
237	*Symphytum officinale* L.	*Boraginaceae*	+	.	.	+
238	*Tanacetum vulgare* L.	*Asteraceae*	+	.	+	+
239	*Taraxacum officinale* F. H. Wigg.	*Asteraceae*	+	.	.	+
240	*Thlaspi arvense* L.	*Brassicaceae*	+	.	+	+
241	*Thymus pulegioides* L.	*Lamiaceae*	.	+	.	.
242	*Tilia cordata* Mill.	*Tiliaceae*	.	.	.	+
243	*Trifolium arvense* L.	*Fabaceae*	+	.	+	.
244	*Trifolium campestre* Schreb.	*Fabaceae*	+	.	+	.
245	*Trifolium dubium* Sibth.	*Fabaceae*	+	+	.	+
246	*Trifolium hybridum* L.	*Fabaceae*	+	.	.	.
247	*Trifolium pratense* L.	*Fabaceae*	+	.	.	+
248	*Trifolium repens* L.	*Fabaceae*	+	.	.	+
249	*Tussilago farfara* L.	*Asteraceae*	+	.	.	+
250	*Urtica dioica* L.	*Urticaceae*	+	.	+	+
251	*Valerianella locusta* Laterr. emend. Betcke	*Valerianaceae*	.	.	.	+
252	*Verbascum densiflorum* Bertol.	*Scrophulariaceae*	+	.	.	.
253	*Verbascum phlomoides* L.	*Scrophulariaceae*	.	.	+	.
254	*Verbascum thapsus* L.	*Scrophulariaceae*	.	.	.	+
255	*Verbena officinalis* L.	*Verbenaceae*	+	.	.	.

L.p.	Name of species	Family	Spoil heaps			
			Maślice	Grochów	Siechnice	Bielawa
256	*Veronica arvensis* L.	*Scrophulariaceae*	.	.	.	+
257	*Veronica chamaedrys* L.	*Scrophulariaceae*	.	.	.	+
258	*Veronica persica* Poir.	*Scrophulariaceae*	+	.	.	+
259	*Veronica serpyllifolia* L.	*Scrophulariaceae*	.	.	.	+
260	*Veronica triphyllos* L.	*Scrophulariaceae*	.	.	.	+
261	*Vicia angustifolia* L.	*Fabaceae*	+	.	+	+
262	*Vicia cracca* L.	*Fabaceae*	+	.	.	.
263	*Vicia grandiflora* Scop.	*Fabaceae*	+	.	.	.
264	*Vicia hirsuta* (L.) Gray	*Fabaceae*	+	.	.	+
265	*Vicia sativa* L.	*Fabaceae*	+	.	.	+
266	*Vicia sepium* L.	*Fabaceae*	.	.	.	+
267	*Vicia villosa* Roth	*Fabaceae*	+	.	.	.
268	*Viola arvensis* Murray	*Violaceae*	.	.	.	+
269	*Viola tricolor* L.	*Violaceae*	+	.	.	.

succession, while some young trees were planted within the frames of preliminary reclamation of waste dump, destined as future forestation. Most numerously represented botanic families on the waste dump were: *Poaceae* (20%), *Fabacea*e (20%) and *Asteraceae* (17%). The remaining families were represented by a single species of ten dominant on the dumping ground, e.g. *Silene vulgaris* (*Caryophyllaceae*). This species had been reported to occur on serpentine dumping grounds, both in Poland and in Western Europe [7].

Relative floristic poverty of the waste dump results from extremely difficult environmental conditions [6, 7, 21, 34], as serpentine detrial features the whole set of unfavourable properties. Low moisture, high (alkaline) pH, low content of nitrogen, phosphorus, potassium and calcium, then high, potentially harmful, concentrations of magnesium, nickel, chromium and cobalt caused that on those soils perturbations and disorders in plants growth and development could be observed [6, 7, 34]. Taking into account synanthropic plants groups (Fig. 1), it should be stated that serpentine heaps in Grochów have been dominated by apophytes (100%). Among live forms, as many as 70% belong to hemicryptophytes (Fig. 2).

Nearly all species (97%) require a lot of light or are photophilous due to the shape of heap and material it has been formed of (Fig. 3). Approximately 47% of taxa require temperatures within the range of 4–3 (conditions moderately hot to moderately cold), and the species tolerating a wide range (T 5–3) constitute 20%. Only 10% of flora belong to the species characteristic of moderately hot areas (Fig. 4). Xerophyte species (Fig. 5) provide for about 23%, and mesophylls about 27%, dominant taxa (30%) are those featuring wider range of toleration (W 2–3).

On the area of objects in Grochów more numerous group of species occurring on soils moderately poor in plant nutrients is formed (Tr 3–47%), as compared to taxa typical

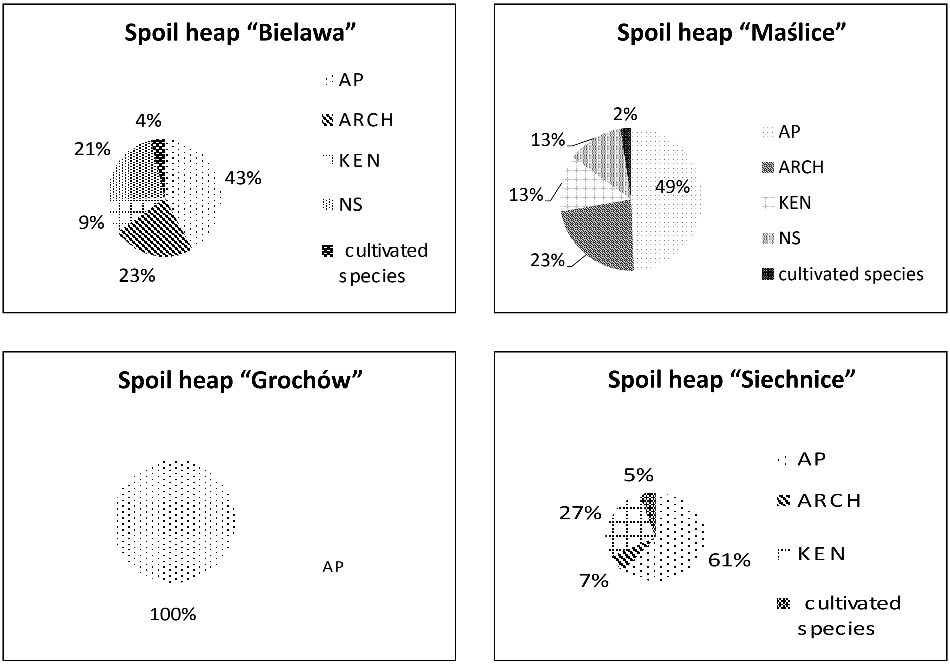

Fig. 1. Participation [%] of synantropic plant groups in investigated objects

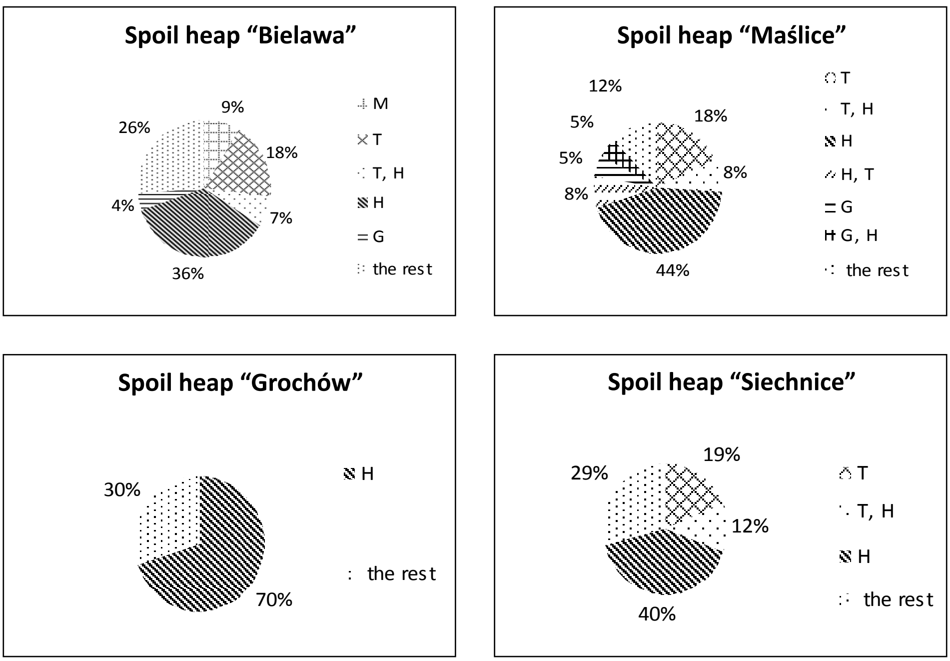

Fig. 2. Percentage of Raunkiaer's life grups of investigated objects

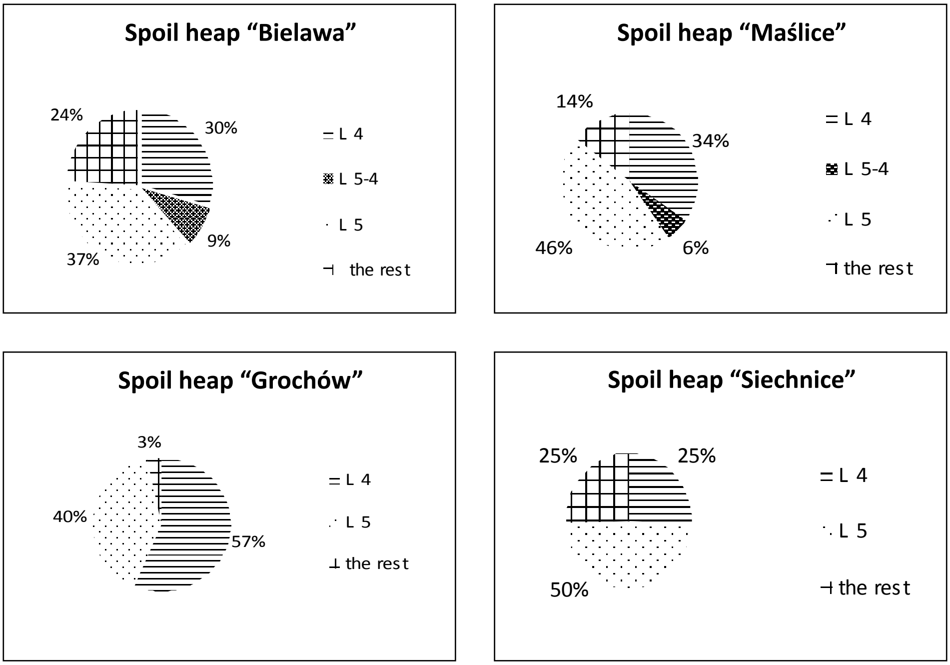

Fig. 3. Participation [%] of species representing a particular of the light indicator (L)

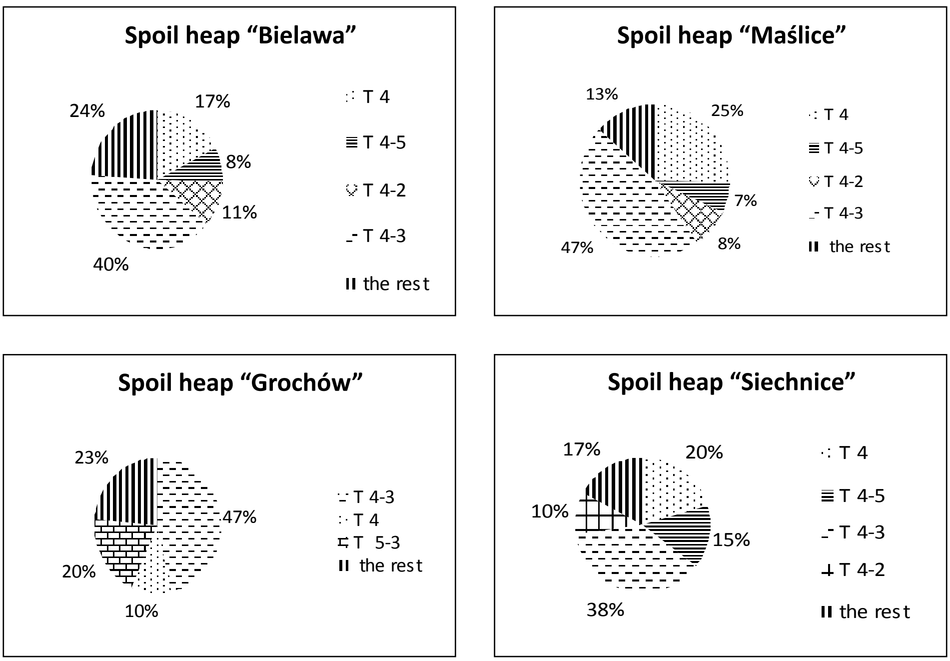

Fig. 4. Participation [%] of species representing a particular of the temperature indicator (T)

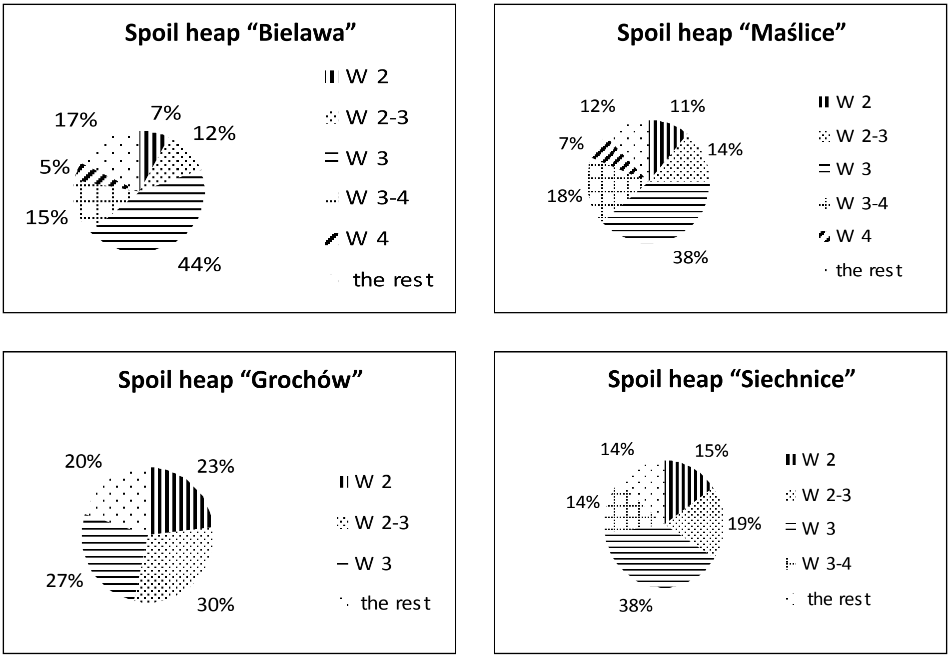

Fig. 5. Participation [%] of species representing a particular of the temperature indicator (T)

for rich habitats (Tr 4–13%) (Fig. 5). Considering requirements regarding soil reaction (Fig. 7), majority of taxa (nearly 43%) prefer neutral soils (R 4–17%), neutral and alkaline R 4–5 13% , as well as alkaline – neutral (R 5–4 13%) . The species of evidently wider (R 3–5) range of pH tolerance constitute more than 13%. It is an important fact that among 30 species determined on serpentine heaps, as many as 10 (33%) are taxa tolerating elevated values of heavy metals content in their growing medium (Fig. 8).

Post-metallurgic slag dump in Siechnice

On the examined object there were determined 59 species of vascular plants (Tab. 1), being representatives of 25 botanic families and among them the most numerous are: *Asteraceae* (18%), *Poaceae* (11%) and *Fabaceae* (10%). Family *Brassicaceae* is represented merely by 4 species (7%), but with a dominant species on all analyzed areas, namely *Sysiymbrium loeselii*. As many as 14 families are represented by only 1 species.

On the uncovered surfaces of deposited slag there was reported a dynamic development of plants, which was an initial stage of primary succession. A symptom of the latter process in plant communities is the presence of species classified to many phytosociological classes, characteristic of significantly different habitats. Phytocenoses with *Sysiymbrium loeselii* (synanthropic association *S. sophiae*) are one of the most common ruderal communities – thermophylous, developing on the devastated or formed by humans areas. They create the first stage of inhabiting ruderal areas, which is followed by giving place to communities of perennial species from *Artemisietea* class in subsequent stages of plant succession [13, 14, 17]. The main threat to the environment caused by already non – existing ironworks are heavy metals accumulated in the waste dump. Chromium concentration in soil and plant material exceeds permissible values for the soil, as well as critical values assumed for plants growth [8].

In floristic composition of a slag dump in Siechnice there prevail native species (apophytes), amounting 61% of flora (Fig. 1). Then come kenophytes, numbering 27%, while archeophytes are not numerous and amount about 7%. Hemicryptophytes occurred to be a dominant living form in waste dump vegetation, as they provide for 40% of the examined flora (Fig. 2), while the second most numerous group is formed by therophytes (19%).

Analysis of environmental requirements showed that nearly all species require a lot of light (50%) or are photophilous (25%) (Fig. 3). As far as thermal requirements are concerned (Fig. 4), the prevailing species (38%) are those of moderately hot to moderately cold habitats (T 4–3), as well as species characteristic of moderately hot areas (T 4 20%). The taxa of wide range of tolerance – thermal indicators values 4–5 and 4–2 –provide for 15% and 10% respectively of the examined flora.

In dumping ground composition the highest number of species (38%) are those preferring fresh habitats (W 3), less numerous group form xerophyte taxa (15%), numbers of species of wider tolerance spectrum regarding soil moisture amount nearly 19% for indicators 2–3 and about 14% for indicator values 3–4 (Fig. 5).

Analysis of trophic requirements (Fig. 6) proves that the most numerous groups formed by species of soils moderately poor in nutrients (30%) and smaller quantity belong to taxa typical of rich habitats (22%). Species of wider tolerance range regarding soil richness are represented in high numbers, since at indicator value 3–4 they constitute more than 14% and at indicator value 4–5 they provide for 15%. Considering soil reaction requirements (Fig. 7), taxa inhabiting neutral soils amount about 37%. A significant group (17%) is also formed by species of evidently wide tolerance range (indicator value 3–5) as far as soil pH tolerance is concerned. Only about 7% of species found feature tolerance of elevated values of heavy metals content in the soil (Fig. 8).

Textile industry slag dumps in Bielawa

On dumping grounds in Bielawa there were determined 149 species (Tab. 1), representing 42 botanic families. The highest quantity of representatives characterized: *Asteraceae* (12%), *Poaceae* (10%), *Fabaceae* (6%) and *Rosaceae* (6%). As many as 19 families were represented by only 1 species.

The dominant species in floristic composition of slag dump in Bielawa are native ones (Fig. 1), including apophytes (43%) and non synantrophic spontaneophytes (21%). A subsequent group, regarding numbers, are archeophytes, which provide for 23%. Kenophytes occur scarcely, constituting about 9%.

In dumping ground flora in Bielawa hemicryptophytes are most numerously represented (Fig. 2) providing for 36% of the examined flora. The second most numerous group (18%) is formed by therophytes. Approximately 9% of flora occurring on dumping grounds in Bielawa, subjected to research, (mainly in reclaimed part) was formed by megaphanerophytes , while geophytes provided for merely 4%.

Analysis of environmental requirements proved that the numbers of photophilous species and those requiring a lot of light (Fig. 3) were comparable, since it amounted 37% and 30% respectively. There were also found species (9%) tolerating wider spectrum of light indicator (L 5–4). According to thermal indicator analysis regarding the examined

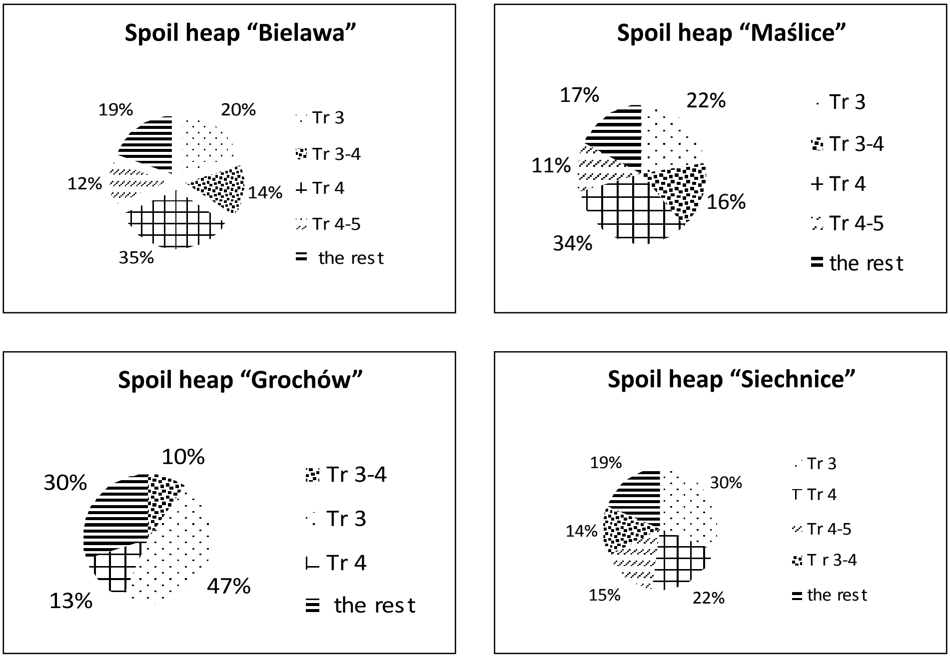

Fig. 6. Participation [%] of species representing a particular of the trophy indicator (T)

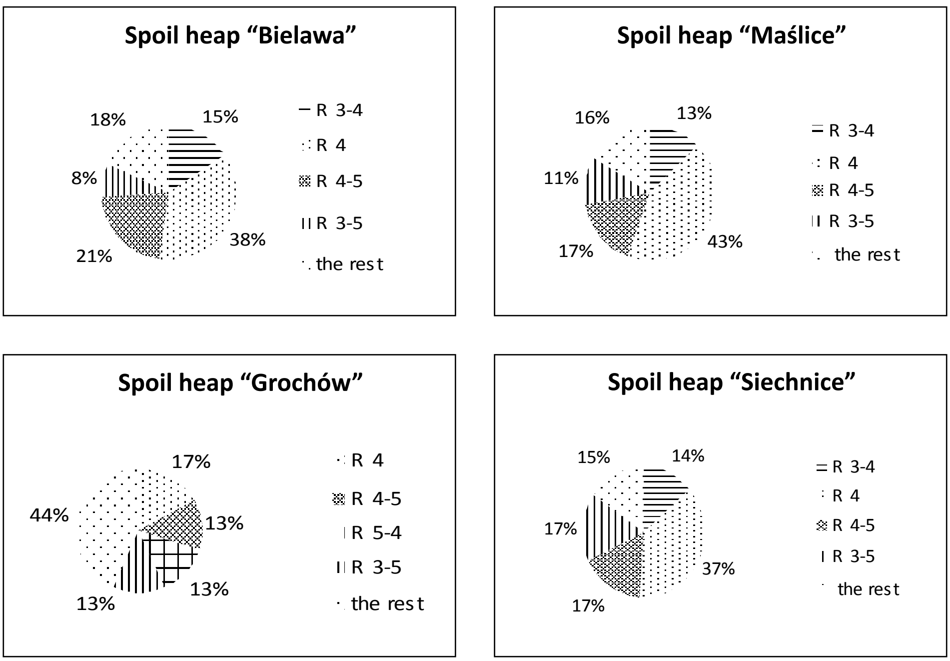

Fig. 7. Participation [%] of species representing a particular of the soil acidity indicator (R)

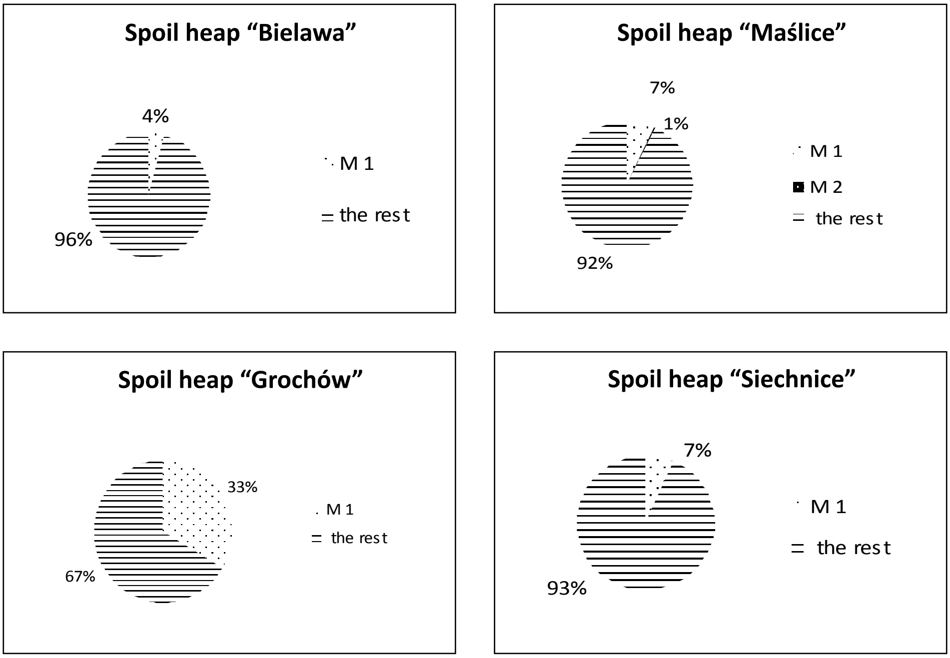

Fig. 8. Participation [%] of species representing a particular of the increased heavy metals content in the soil (M)

flora (Fig. 4), the highest (about 40%) significance features the species requiring moderately hot to moderately cold conditions (indicators values ranging 4–3). Less numerous (17%) were taxa characteristic of moderately hot areas. Plants tolerating a wide range of thermal conditions (4–2) provide for 11% of flora determined on dumping ground in Bielawa.

Definitely the most numerously (44%) represented in Bielawa were the species preferring fresh habitats (W 3) (Fig. 5). Numbers of species of wider range of tolerance involving moisture conditions equals 12% for indicator values 2–3, and for those amounting 3–4 they constitute 15%. Xerophilous taxa constituted only 7% of flora. Considering trophic requirements (Fig. 6), apparently most numerously represented (35%) were species preferring rich, eutrophic soils. A subsequent group was formed by mesotrophic taxa (20%) (Tr 3). The species tolerating wider range of soil richness occurred less numerously on dumping grounds in Bielawa; for indicator values 3–4 their share equaled 14%, while for indicator values 4–5 it amounted 12%. As far as soil reaction requirements are concerned (Fig. 7), taxa preferring neutral soils constitute 38% in dumping ground in Bielawa. Quite a significant group (21% of the mentioned flora) is formed also by species of wider spectrum regarding soil pH tolerance (R 4–5). Plants of moderately acid and neutral soils (R 3–4) constitute 15% of flora. Only 4% of the determined taxa feature tolerance of higher values of heavy metals content in the soil (Fig. 8).

Municipal waste dump in Maślice

On municipal waste landfill in Maślice there were found 166 taxa of vascular plants (Tab.1), representing 36 botanic families. The highest numbers of their representatives included: *Asteraceae* (about 19%), *Fabaceae* (about 14%) and *Poaceae* (about 13%). A considerable number of species belonging to families *Fabaceae* and *Poaceae* resulted partly from reclamation treatments (sown landfills with legume and grass mixture of unknown composition). A smaller number of representatives characterized the following families: *Brassicaceae* (about 8%), *Rosaceae* (6%), *Polygonaceae* (about 5%), as well as *Caryophyllaceae* (3%). Two families represented by 4 species, four families – by 3 species, nine families featured two representatives each and 14 families were represented by only 1 taxon.

Analysis of a landfill flora proved that native species were the dominant ones (Fig. 1), mainly apophytes (49%), and taking into account vicinity of semi-natural habitats, a significant contribution also belonged to non-antropic spontaneophytes (13%). Archeophytes (23%) and kenophytes (13%) could have got into that landfill together with reclamation material, similarly to the remaining species, which were crops or decorative species (2%). Hemicryptophytes (44%) definitely prevail among living forms (Fig. 2). Apparently smaller number belonged to therophytes (18%) and taxa which could be terophytes or hemicryptophytes (8%), as well as hemicryptophytes or therophytes (8%). There also occurred geophytes and species which could be geophytes or hemicryptophytes (each of them 5%). Nearly complete lack of phanerophytes, due to reclamation treatments introduced to that landfill, (regular cutting of a landfill) was quite evident.

Analysis of environmental requirements showed that apparently dominant were species requiring a lot of light (46%) and photophilous species (34%) (Fig. 3). There were also found plant species preferring intermediate conditions (6%) (L 5–4). On Maślice landfill thermophilous taxa dominated (Fig. 4): the most numerous group constituted species requiring from moderately hot to moderately cold habitats (T 4–3) – 47%, as well as those of moderately hot habitats (T 4) – 25%. Less numerous (7%) were the taxa preferring habitats from moderately hot to the hottest (T 4–5), or those of a very wide range of temperature tolerance (8%), from moderately hot to moderately cold (T 4–2). Moisture requirements (Fig. 5) of species growing on the whole landfill area were relatively diverse. The highest number of representatives featured taxa requiring fresh habitats (38%). Less numerous were taxa preferring fresh or wet habitats (W 3–4), as well as dry and fresh habitats (W 2–3), amounting 18% and 14% respectively. The species of more extreme moisture requirements were in a smaller number; those preferring dry habitats (W 2) provided for 11%, while those thriving in wet habitats (W 4) constituted 7%. Trophic requirements of taxa (Fig. 6) occurring on Maślice waste dump were diversified, although prevailing species required eutrophic (34%), as well as mesotrophic (22%) Habitats. The species of wider requirements, preferring habitats from eutrophic to hypertrophic (Tr 4–5) – 11%, or from mesotrophic to eutrophic habitats were definitely in a smaller number (Tr 3–4 – 16%).

On municipal waste landfills soil reaction is usually highly diversified (Fig. 7), which results from local accumulation of various types of waste. Because of the fact that landfill canopy after reclamation was covered with a relatively uniform ground of anthropogenic origin, soil pH range got slightly narrower and shifted towards neutral, or even alkaline reaction.

That phenomenon was caused by a considerable content of debris in a reclaimed layer. Taxa requiring neutral habitats (43%) were dominant there. A share of species tolerating wider pH range: R 4–5 – soils from neutral to alkaline (17%), R 3–4 – soils from moderately acid to neutral (13%) and R 3–5 – soils from moderately acid to alkaline (11%). On the landfill there definitely dominated (92%) taxa which were not resistant to heavy metals whose values were elevated in their growing medium. Only 7% of species occurring there featured tolerance to higher content of heavy metals (M 1), while merely 1 species (*Leontodon autumnalis*) requires increased content of heavy metals in the soil (M 2).

On the area of all objects there were recorded 269 species of vascular plants (Tab. 1). The highest number of taxa (166) was fund on municipal waste dump Maślice, not much lower number, 149, occurred on dumping grounds in Bielawa. Apparently fewer taxa (59) could be fund on post–metallurgic waste dump in Siechnice, while only 30 taxa were recognized on serpentine dumping grounds in Grochów.

Such high diversity of the number of species on the objects subjected to comparison could result from the degree of succession advancement [1, 6, 9, 11, 14, 19, 20, 21, 22, 23]. Succession of spontaneously formed on serpentine dumping grounds in Grochów and on ferrochromium dump in Siechnice takes place on the medium of anthropogenic origin, previously devoid of soil and plants cover, therefore this process is of a primary succession character. The latter process usually takes place in a very slow pace, due to the necessity of diasporas migration [1, 6, 9, 11, 19, 23]. That fact certainly did affect relatively small number of species recorded on both objects. Yet, undoubtedly the most significant effect on species composition formation on the objects in Grochów and Siechnice had a specific, rich in heavy metals growing medium [6, 7, 8].

Considerable richness in species occurring on dumping ground in Bielawa (149 taxa) and in Maślice (166 taxa) is probably caused by more advanced stage of succession. Maślice landfill was already covered with vegetation in the course of its exploitation. Both objects were also covered with a reclamation layer, originating from the areas where ruderal plants were growing. This fact enabled invasion of some species together with their seeds bank [12, 25]. Both objects underwent preliminary biological reclamation – the object in Maślice was sown with legume and grass mixture, while on the landfill in Bielawa [5] 11 species of trees and bushes (each), as well as the mixture of grass and fabaceae (2 species each) were introduced. The properties of a growing medium are also of not least importance, as it contains considerable amounts of toxic compounds (such as e.g. heavy metals).

Only 5 species (i.e. 2% of total number of taxa determined): *Arrhenatherum elatius*, *Cirsium arvense*, *Daucus carota*, *Echium vulgare* and *Lotus corniculatus* could be fund on all four waste dumps. 28 species were common for 3 dumps. In majority of cases they are common for the following dumps: Maślice, Siechnice and Bielawa (23 species); only 4 species were common for: Maślice, Grochów and Bielawa, while 1 species – for waste dumps in: Maślice, Grochów and Siechnice. 64 taxa were common for two dumps and combination Maślice – Bielawa (41 species) was a prevailing one, 8 species were common for Maślice and Siechnice, and 7 species – for waste dumps in Siechnice and Bielawa. Waste dumps in Maślice and Grochów shared 4 species, for Grochów and Bielawa – 3 species were common, while only 1 species was common for dumps in Grochów and Siechnice.

The remaining 172 taxa occurred only on particular dumps. The prevailing number of those species was present only in Maślice (80 species). On the waste dump in Bielawa there were found 66 taxa which did not occur on the remaining objects. The number of species growing solely on waste dumps in Grochów and Siechnice was smaller – on Siechnice waste dump there were 14 species, on the dump in Grochów – only 12 species. Diversity of flora on particular objects proved specificity of each of them. This refers especially to composition and richness of growing medium, as well as moisture conditions. Yet among taxa found there stenotropic species, e.g. metalophytes or halophytes were not determined.

The taxa which were found, represented as many as 51 botanical families. Their highest number was determined on the waste dump in Bielawa, fewer (36) on municipal dumping grounds in Maślice, 25 families were growing on the object in Siechnice, and only 17 – on serpentine dumps in Grochów. In spite of highly diversified flora (composition of species, number of families), on all the examined objects expansive representatives of families: *Asteraceae*, *Poaceae*, *Fabaceae* dominated. Less numerous proved to be represented *Brasicaceae* and *Rosaceae*. The presence of families mentioned above is typical of that kind of habitats, namely waste dumps and dumping grounds [7, 8, 11, 16, 19, 20, 23]. However, the dominance of *Chenopodiaceae* family, especially typical of municipal waste dumps, were not observed [26] which probably resulted from reclamation of waste dumps.

Geographic – historic classification

Analysis of geographic – historic composition of flora (Fig. 1) showed that species of native origin – apophytes, constituting from 43% (waste dump in Bielawa) to 100% of flora (serpentine dumping grounds) are dominant on waste dumps. This dominance probably results from the phenomenon of apophytization, a detailed symptom of synantropization, which consists in occupation of typically synantropic areas by the species native to our flora, thus better adjusted to particular environmental conditions [2]. Determined apophytization was likely to be caused by the neighborhood of natural and semi-natural plant communities, which, in turn, are the source of diaspores of species featuring higher tolerance of elevated values of heavy metal content in their growing medium. The mentioned phenomenon became apparent in the case of “chromium” dump in Siechnice and serpentine dump in Grochów. Similar dominance of native species reported Skrzypek [22] for post-flotation settlement flora (ZGH “Orzeł Biały”), as well as Rostański and Kapa [20] for vegetation of post-industrial regions of Upper Silesia. The dominance of native species (ranging even 85–90%) on waste dumps was also emphasized by Sudnik-Wójcikowska [26]. The same author also reported that on waste dumps, foreign species share was usually low and amounted about 10% (with dominance of archeophytes on post-coal mines dumps and with kenophytes – on post-metallurgic dumps). However, foreign flora of the examined objects (except for Grochów) was quite rich (archeophytes 7–23%, kenophytes 9–27%).

Live forms of plants

The share of live forms of plants proves, both in general flora and in floras determined for particular dumping grounds (Fig. 2), definite dominance of hemicryptophytes, typical of later stages of succession. There was also recorded numerous occurrence of terophytes in dumping ground flora in Maślice, Bielawa and Siechnice (about 18%). This can suggest a small – scale stabilization and ruderalization of those habitats, but also initial stages of succession [26]. These results confirm the data obtained in research conducted on different industrial objects by other authors [6, 16, 20], who additionally stress that the process of steep slopes erosion brings about the abruption of vegetation cover and formation of new space, easily available for "short-term colonizers". This kind of process can be observed in e.g. upper parts of dumping ground in Maślice. It should be also noticed that these processes cause that particular fragments of a waste dump can simultaneously face different stages of succession. It is also worth mentioning that goephytes feature an insignificant share in waste dumps flora (about 3% in dump flora of "Maślice" and "Siechnice") which is probably connected with a slow, yet continuous, succession.

Indicators analysis

Analysis of floras subjected to research, regarding their environmental requirements, shows both similarities and differences determined on every investigated type of waste dumps. Particular parts of the waste dump are characterized by different properties and in this way microhabitats are formed [26].

Light requirements

Analisis of selected floras proved (Fig. 3) that on the examined objects, in vast majority of cases species requiring a lot of light, as well as photophilous species (nearly 100% regarding serpentine dump) occur.

Thermal requirements

Thermal requirements of the examined dumping grounds flora proved to be highly diversified (Fig. 4). The most numerous group was formed by species requiring habitats from moderately hot to moderately cold (T 4–3). Less numerous were taxa preferring moderately hot habitats (T4). In the case of serpentine dump (Grochów), the second most numerous group of plants was the one tolerating wide range of temperature (T 5–3).

Moisture requirements

Moisture requirements of species growing on dumping grounds seemed to be highly diverse (Fig. 5.), which could result from both different conditions in their different parts and from the properties of deposited material on those dumps.

Analyzing the number of species characteristic of particular indicators, it is possible to state that in the case of waste dumps in Bielawia, Maślice and Siechnice, the taxa described on those objects require relatively fresh growing medium. A reclamation layer was introduced (at east partly) on the mentioned waste dumps. On serpentine dumping grounds (Grochów), devoid of reclamation layer, there occurred species preferring both fresh and dry kinds of a growing medium (W 2–3), although nearly the same number belongs to taxa requiring fresh (W 3) and dry habitats (W 2).

Trophic requirements

Trophic requirements of taxa occurring on selected waste dumps are diversified (Fig. 6). On serpentine dumping ground in Grochów and on waste dump in Siechnice there prevail species preferring growing media moderately poor in nutrients. A smaller number of representatives on both objects feature taxa requiring eutrophic habitats. On dumping grounds in Bielawa and Maślice there evidently dominate species of rich – eutrophic habitats, while mesotrophic species occur in a smaller number. On all the examined objects there can also be found plants tolerating wider ranges of that indicator, although they are less numerous than typical eutrophic or mesotrophic species.

Requirements of a growing medium reaction

Species composition determined on the examined objects is strictly connected with a growing medium reaction and for most of them it is determined as neutral or alkaline [3, 4, 5, 7, 8]. On all dumping grounds (Fig. 7) the species inhabiting neutral soils (R 4) were most numerously represented. A subsequent group, in the case of majority of analyzed waste dumps, were taxa tolerating a wider range of pH (R 4–5) – from neutral to alkaline. A considerable group is also formed by species preferring both neutral and slightly acid soils (R 3–4). On serpentine dump (Grochów), the taxa preferring definitely alkaline soils were present in quite a considerable number. That fact is probably connected with the properties of serpentine rock, characterized by high pH values [7, 29, 34].

Resistance to heavy metals

The higher number of species tolerating elevated values of heavy metals content were determined on serpentine dump in Grochow (Fig. 8). Such a numerous representation of species occurres probably due to the fact that serprntine rock is rich in heavy metals [6, 7, 21, 27, 34], which leads to its inhabiting by taxa adjusted to extreme environmental conditions.

CONCLUSION

1. Analysis of species composition of vascular flora of four waste dumps allowed to find similarities and differences between floras of the examined objects. Dumping grounds are built from materials of highly diverse origin and facing different stages of species succession. This results in the fact that analysis of floristic composition reveals certain differences, while analysis of ecological indicators of the investigated waste dumps also points to similarities between them.
2. Noticeable differences occur mainly in species composition and percentage share of geographic – historic groups. Ecological indicators, such as light, thermal and moisture requirements (except for serpentine dumping grounds), or soil reaction requirements, seem not to point to significant differences between particular waste dumps.
3. There were noticeable certain differences between ecological values referring to numbers of indicators, characterizing soil richness and resistance to heavy metals content. On dumping grounds in Maślice and Bielawa the prevailing species belonged to rich, eutrophic habitats, while on the remaining two objects (Grochów and Siechnice) the dominant species were those which, according to number of indicators, preferred moderately poor growing medium.
4. A considerable fact is high diversity of floristic composition of particular dumping grounds. Among 269 species of vascular plants growing on all the waste dumps, merely 5 taxa are common to all research objects. On waste dumps in Maślice and in Bielawa, where succession processes are more advanced, the number of common species already amounts 64.
5. Despite of significant diversity of species on the objects subjected to investigation, it is possible to notice evident dominance of three botanical families: *Asteraceae*, *Poaceae* and *Fabaceae*.

On the basis of analyses involving vascular flora diversity, there can be stated that dominant plants group (yet admitting percentage differences for particular areas) are native species (mainly apophytes),while the most numerously represented live form are hemicryphytes.

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ZRÓŻNICOWANIE FLORY NACZYNIOWEJ WYBRANYCH HAŁD I ZWAŁOWISK DOLNEGO ŚLĄSKA

Eksploatacja kopalin, rozwój przemysłu i urbanizacji powodują znaczną degradację powierzchni Ziemi, m.in. przez składowanie różnego typu odpadów. Zdegradowane przez przemysł obszary, w postaci zwałów, hałd, czy zwałowisk, stały się interesującymi obiektami badań roślinności siedlisk antropogenicznych [7, 8, 14, 28]. Tereny te przedstawiają także dużą wartość przyrodniczą, ze względu na możliwość dokumentowania faktów i zjawisk geologicznych oraz specyficznych fitocenoz [6, 8, 16, 20]. Zwały i wyrobiska to także swoiste „poletka doświadczalne", miejsca służące do obserwacji procesów zachodzących podczas spontanicznej sukcesji, związanych z wkraczaniem gatunków pionierskich, czy też mechanizmów rozwoju zespołów roślinnych [2, 6, 8, 16, 20 27].

Podejmowane do tej pory badania dotyczyły głównie obiektów o podobnej genezie. Niniejsza praca prezentuje natomiast wyniki florystycznych obserwacji prowadzonych na obszarze 4 zwałowisk, zdecydowanie różniących się m.in. pochodzeniem i składowanym materiałem. Celem opracowania jest porównanie roślinności zasiedlającej wybrane obiekty.