acta universitatis lodziensis
2009
Folia Biologica et Oecologica 5: 5–19
(Acta Univ., Lodz, Folia Biol. et Oecol.)

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APPLICATION OF FUNGAL WASTE BIOMASS ORIGINATING FROM STEROID HORMONE MANUFACTURE FOR HEAVY METALS REMOVAL

Abstract: The biomass of *Curvularia lunata*, used previously for hydrocortisone production, was investigated as a heavy metal biosorbent. Removal of lead, zinc and cadmium ions was evaluated as a function of biosorbent dosages, initial ion concentrations, mode of mycelium modifications, initial pH of metal solutions and when these metals ions where presented in binary as well in ternary combinations. The results presented in this paper indicate the potential utility of *C. lunata* waste biomass for lead and, to a lower extent, for zinc and cadmium ions removal from acid solutions.

Key words: *Curvularia lunata,* heavy metals, hydrocortisone production, waste biomass

1. INTRODUCTION

Pollution of the environment by heavy metals is a serious ecological problem. The main sources of these contaminants are wastes from metallurgical and metal finishing industries, galvanizing, electroplating, battery and chemical manufacturing. After being released into the environment, toxic ions of heavy

metals are bioaccumulated throughout food chain, which can cause ecological and health hazards (MALIK 2004; IQBAL, EDYVEAN 2004). There are two groups of methods for removing heavy metals from wastewaters: conventional and biological. Conventional processes include physico-chemical reactions such as filtration, precipitation, oxidation, reduction and ion exchange. The mentioned techniques appear to be costly and ineffective in case of effluents with low metal concentration, particularly in the range of 1-100 mg l^{-1} (SAEED *et al.* 2005). Due to this fact, biological methods, like biosorption, have focused a great deal of attention, as an attractive alternative for heavy metal removal (AHLUWALIA, GOYAL 2007).

Many studies demonstrated that diverse materials of biological origin such as plants, bacteria, algae, yeast and filamentous fungi can be successfully used to take up heavy metals from aqueous solutions (IQBAL, EDYVEAN 2004; SAEED *et al.* 2005; LO *et al.* 1999; SOARES *et al.* 2002; HAN *et al.* 2006; AKSU, DÖNMEZ 2006; MELGAR *et al.* 2007). Nevertheless, commercial application of sorbents originating from microorganisms may be limited due to the costs involved in the production of biomass. Filamentous fungi and yeast are widely used in a variety of industrial fermentation processes (e.g. production of antibiotics, organic acids, enzymes and in brewery industry). Additionally, since fungal biomass is an abundant by-product and is of little use, it may be an inexpensive source of biomaterial for heavy metal remediation processes. It is well documented that waste biomass derived from fungi of biotechnological importance (mainly species of *Aspergillus, Fusarium, Penicillium, Mucor* and *Saccharomyces*) can be used as heavy metal biosorbents (LO *et al.* 1999; KAPOOR *et al.* 1999; JIANLONG *et al.* 2001; GÖKSUNGUR *et al.* 2005; PARK *et al.* 2005; MUNGASAVALLI *et al.* 2007).

The 11β-hydroxylation of cortexolone is a transformation widely used in pharmaceutical industry. It is a direct way to obtain hydrocortisone, an effective anti-inflammatory drug as well as an important precursor of other pharmaceutical corticosteroids (FERNANDES *et al.* 2003). Filamentous fungus *Curvularia lunata* is one of the most promising cortexolone 11β-hydroxylators (PARASZKIEWICZ *et al.* 1998; LU *et al.* 2006). To our knowledge, no research has been carried out on the

heavy metal removal by waste mycelium of *C. lunata* obtained after cortexolone conversion to hydrocortisone.

The aim of the presented study was to investigate the ability of dead biomass of *C. lunata* to remove heavy metals from aqueous solutions. For experiments was chosen the wild strain of *C. lunata* IM 2901 with the confirmed ability of 11β-hydroxylation of cortexolone (WILMAŃSKA *et al.* 1992; PARASZKIEWICZ *et al.* 1998; KANWAL *et al.* 2001). The basic characterization of heavy metals binding by growing mycelium of this fungus and by its emulsifier had been previously described (PARASZKIEWICZ *et al.* 2007). Microbial uptake of metals is significantly decreased in wastewaters of low pH. In experiments described in this paper pH values of metal solutions were from 4 to 6 because we were particularly interested in the possibility of heavy metal removal from acidic wastewaters, without preliminary pH adjustment.

2. MATERIALS AND METHODS

2.1. Microorganism and maintenance

The filamentous fungus *Curvularia lunata* (Wakker) Boedijn IM 2901 from the collection of the Department of Industrial Microbiology and Biotechnology, University of Lodz was used in the study. The fungal strain was maintained on ZT slants (PARASZKIEWICZ *et al.* 2002) at 4°C and transferred at 2–month intervals.

2.2. Mycelium growth conditions and cortexolone hydroxylation

Mycelia originating from 10–day–old cultures on ZT slants were suspended in PL-2 medium (PARASZKIEWICZ *et al.* 2002) and incubated at 28°C for 24 h on a rotatory shaker (180 rpm). First–step preculture (10%) was used as inoculum for the second-step of cultivation, conducted in conditions described above. According to the method developed by PARASZKIEWICZ and DŁUGOŃSKI (1998), steroid hydroxylase induction was carried out for 6 h by adding to the 18-h-old second-step

preculture cortexolone dissolved in ethanol (final concentration of steroid 0.1g l^{-1} and ethanol in the culture 1% v/v). The achieved 24-h-old second-step culture (60 ml) was introduced into 2l-Erlenmeyer flasks containing 540 ml of the PL-2 medium and supplemented with cortexolone dissolved in ethanol (at final concentration of steroid 1.0 g l^{-1} and ethanol in the culture 1% (v/v)). Final cultures were incubated on a rotatory shaker in conditions described above for 48 hours.

2.3. Isolation and pretreatment of the fungal biomass

After fungal growth and cortexolone transformation to the whole 48-h-old culture a mixture of chloroform: acetone (9:1) was added. Steroid extraction was repeated three times. The collected waste biomass was washed several times with deionised water for culture broth and organic solvents removal and then lyophilised. In the next part of the work biomass prepared in this way was referred to as unmodified or waste biosorbent.

In some experiments mycelia modified (pretreated) with ethanol or sodium hydroxide (NaOH) were used. Ethanol treated samples of biosorbent were prepared by suspending 50 g of wet *C. lunata* biomass in 500 ml of 80% ethanol. The modification procedure was carried out at room temperature on a rotatory shaker (180 rpm) for 1 hour. After pretreatment procedure, the biomass samples were washed several times with deionised water and then lyophilised. Modification with NaOH was carried out according to the method described by KAPOOR *et al.* (1999). NaOH treated mycelium was prepared by boiling 50 g of wet biomass in 500 ml of 0.5 N NaOH solution for 15 min. Biomass pretreated with sodium hydroxide was washed with deionized water until the pH reached the near neutral range (pH 6.8-7.2) and then it was lyophilised.

2.4. Metal sorption studies

The standard stock solutions (0.2 M) were prepared by dissolving the respective nitrate salts of the metals in deionised water. The pH of working metal solutions (0.2 M) were adjusted to required values (4.0; 5.0 or 6.0) with 0.1 M HCl.

Sorption experiments were carried out in 250 ml Erlenmeyer flasks containing 100 ml of 0.2 or 5.0 mM single metal solution and lyophilized waste biomass (at a final concentration of 0.5 or 1.0 g l^{-1}). For studies on metal biosorption from binary and ternary solutions, the concentration of each metal ions in the solution was 0.2 mM. The samples were incubated on a rotatory shaker (180 rpm), at 28°C, for 2 hours. Then metal-loaded mycelium was separated by filtration (Millipore filters with 0.45 μm pore size) and dried at 105°C to constant weight. Metal concentration in the mycelium samples was analyzed in a Varian atomic absorption spectrometer (Spectra 300) according to the method described by SŁABA and DŁUGOŃSKI (2004). The efficiency of metal ions removal was calculated based on the weight of metal ions contained in the biomass per flask divided by the initial metal ions weight in the solution per 100%. All data represent the mean of three independent experiments. An average standard deviation was calculated.

3. RESULTS

3.1. Comparison of the effectiveness of different heavy metals removal by waste biomass of *C. lunata*

In the first part of the work the removal of seven various heavy metals was studied. Metal uptake was conducted by unmodified mycelium samples (at a concentration of 0.5 g l^{-1}) suspended in single metal solutions (0.2 mM), adjusted to pH 4. The removal efficiency for Pb^{2+}, Zn^{2+}, Cd^{2+}, Cu^{2+}, Cr^{2+}, Ni^{2+} and Co^{2+} was found to be 46.2, 30.7, 27.0, 22.6, 18.9, 11.8 and 2.4%, respectively (Fig. 1). Because the highest removal efficiency occurred in Pb^{2+}, Zn^{2+} and Cd^{2+} solutions, these three metals were selected for further investigations.

3.2. Effect of the biosorbent dosage and the initial concentration of lead, zinc and cadmium on the removal efficiency

Efficiency of Pb^{2+}, Zn^{2+} and Cd^{2+} removal was examined as a function of *C. lunata* biomass dosage (0.5 and 1.0 g l^{-1}) as well as the initial concentration of heavy

metal (0.2 and 5.0 mM). Metal uptake was conducted by unmodified biosorbent samples suspended in single Pb^{2+}, Zn^{2+} or Cd^{2+} solution, adjusted to pH 4. The removal efficiency of heavy metal ions was improved almost twice in the presence of a higher dose of biomass (Fig. 2). Moreover, as shown in Fig. 3, with the decrease in the initial concentration of heavy metal (from 5.0 to 0.2 mM) a significant increase in Pb^{2+}, Zn^{2+} and Cd^{2+} removal efficiency was achieved (from 7.0, 3.8 and 3.2% to 81.8, 55.9 and 47.4%, respectively). In conclusion, conditions: 1 g l^{-1} of fungal biomass and heavy metal ions at the initial concentration of 0.2 mM, promoting the removal of lead, zinc and cadmium were used in the next parts of the study.

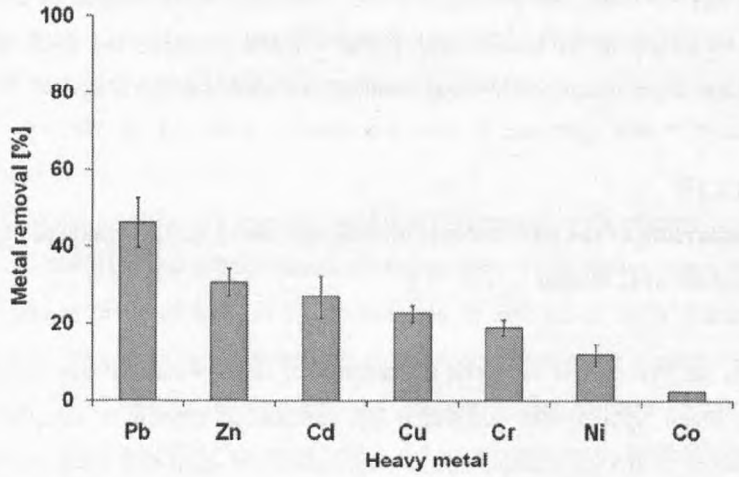

Fig. 1: Removal efficiency of Pb, Zn, Cd, Cu, Cr, Ni and Co from single metal solutions at pH 4 by waste biomass of *C. lunata* at a concentration of 0.5 g l^{-1}, suspended in single metal solutions (0.2 mM). Data are mean ± SD (n=3)

3.3. Effect of waste biomass modification on lead, zinc and cadmium removal efficiency

Effectiveness of heavy metal removal (from single metal solutions, at pH 4) by unmodified, NaOH pretreated and ethanol pretreated biomass samples of *C. lunata* reached for Pb^{2+}: 81.8; 30.5 and 3.7%, for Zn^{2+}: 55.9; 54.5 and 50.7% and for

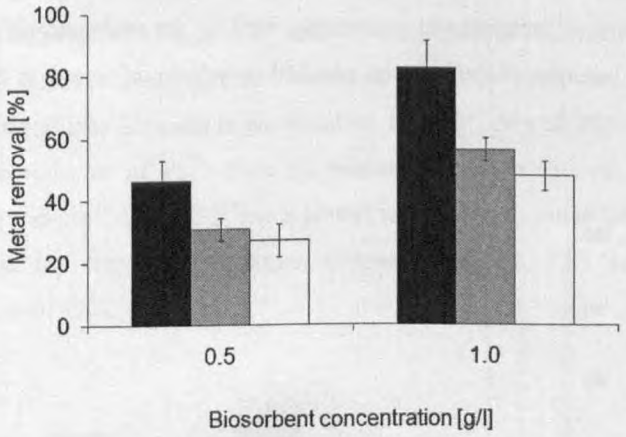

Fig. 2: The influence of biosorbent dosage on Pb^{2+}, Zn^{2+} and Cd^{2+} removal efficiency from single metal solutions (0.2 mM) at pH 4. Black bars – Pb; grey bars – Zn; white bars – Cd. Data are mean ± SD (n=3)

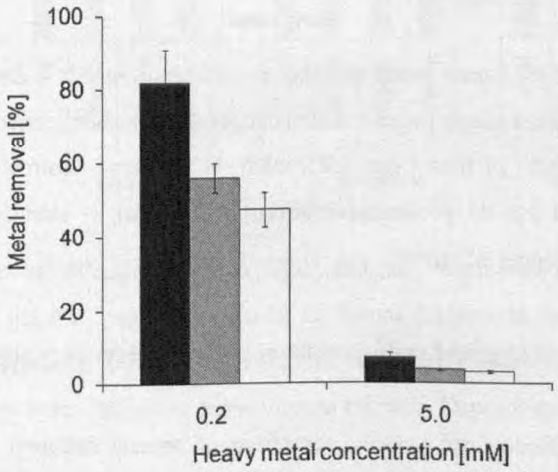

Fig. 3: The influence of the initial concentration of Pb^{2+}, Zn^{2+} and Cd^{2+}on these metal ions removal efficiency from single metal solutions at pH 4, by waste biomass of *C. lunata* at a concentration of 1 g l^{-1}. Black bars – Pb; grey bars – Zn; white bars – Cd. Data are mean ± SD (n=3)

Cd^{2+}: 47.4, 45.2 and 45%, respectively (Fig. 4). The data mentioned above revealed that both chemical pretreatment procedures used in the study strongly decreased Pb^{2+} sorption capacity of the biomass and had only little influence on Zn^{2+} or Cd^{2+} removal.

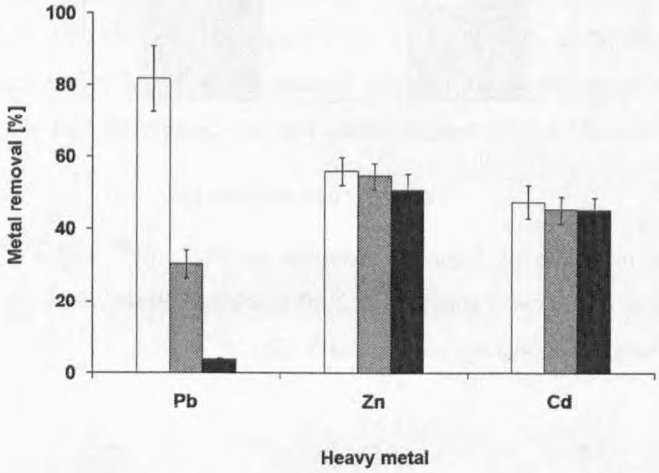

Fig. 4: Influence of *C. lunata* waste biomass modification on Pb^{2+}, Zn^{2+} and Cd^{2+} removal efficiency from single metal solutions at pH 4 (biosorbent concentration 1 g l^{-1}; initial concentration of heavy metal 0.2 mM). White bars – untreated biomass; grey bars – 0.2 M NaOH pretreated biomass; black bars – ethanol pretreated biomass. Data are mean ± SD (n=3)

3.4. Removal of lead, zinc and cadmium from binary and ternary solutions

Industrial effluents are usually composed of several different metal ions. Therefore removal of Pb^{2+}, Zn^{2+} and Cd^{2+} from single metal solutions was compared with the efficiency of this process recorded for binary as well as ternary metal combinations. Results presented in Fig. 5 revealed that biosorption capacity of zinc and cadmium ions decreased approximately by 25 and 30%, respectively when these two metals were presented together. The presence of Pb^{2+} significantly interfered in the sorption of zinc and cadmium ions. About 3-fold decrease in zinc removal

efficiency was detected from binary (Zn^{2+}+Pb^{2+}) and ternary (Zn^{2+}+Pb^{2+}+Cd^{2+}) systems as compared with single Zn^{2+} solution (respectively 17.2, 19.5% contrasted with 55.9%). Similar strong decline of removal efficiency was noted for cadmium when these metal ions occurred in combination with Pb^{2+} or with Pb^{2+} plus Zn^{2+}. In contrast, the removal of Pb^{2+} from all examined metal solutions: (Pb^{2+}+Zn^{2+}), (Pb^{2+}+Cd^{2+}) and (Pb^{2+}+Zn^{2+}+Cd^{2+}) was almost as efficient as noted for the sorption conducted in the single Pb^{2+} solution (respectively 79.2, 72.1 and 80.6% in comparison to 81.9%).

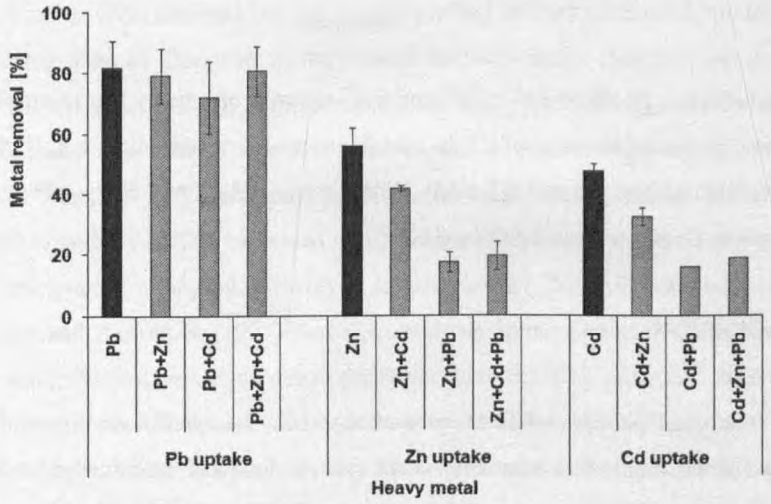

Fig. 5: Removal efficiency of Pb^{2+}, Zn^{2+} and Cd^{2+} from binary and ternary metal solutions at pH 4 by waste biomass of *C. lunata* (biosorbent concentration 1 g l^{-1}; initial concentration of each heavy metal 0.2 mM). Black bars – single metal solution; grey bars – binary or ternary metal mixture. Data are mean ± SD (n=3)

3.5. The effect of pH on lead, zinc and cadmium removal

As shown in Fig. 6 the uptake of Pb^{2+}, Zn^{2+} and Cd^{2+} conducted in single metal solutions occurred to be pH dependent. The increase in metal solution pH value from 4 to 6 accelerated the removal efficiency of Pb^{2+}, Zn^{2+} and Cd^{2+} from 81.9, 55.9 and 47.4% respectively to 94.0 75.4 and 62.6%.

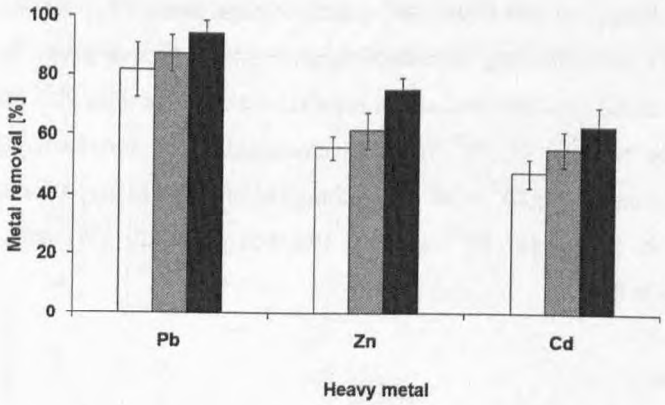

Fig. 6: Influence of pH on Pb^{2+}, Zn^{2+} and Cd^{2+} removal efficiency from single metal solutions by waste biomass of *C. lunata* (biosorbent concentration 1 g l^{-1}; initial concentration of heavy metal 0.2 mM). White bars – pH 4; grey bars – pH 5; black bars – pH 6. Data are mean ± SD (n=3)

4. DISCUSSION

The dead biomass of filamentous fungus *Curvularia lunata* obtained after hydrocortisone production via cortexolone conversion was examined as a heavy metal biosorbent. Among seven heavy metals (Pb, Zn, Cd, Cu, Cr, Ni and Co) tested, the mycelial biomass exhibited the highest removal efficiency for Pb^{2+}, Zn^{2+} and Cd^{2+}. A similar order of uptake intensity (Pb>Zn>Cd>Ni) was reported by YAN and VIRARAGHAVAN (2003) for dead mycelium of *Mucor rouxii* as a heavy metal biosorbent. The higher affinity of *C. lunata* mycelium to lead than to other heavy metal ions is in line with many studies on diverse fungal biosorbents (IQBAL, EDYVEAN 2004; MELGAR *et al.* 2007; KAPOOR *et al.* 1999; GÖKSUNGUR *et al.* 2005; SŁABA, DŁUGOŃSKI 2004). Three strains of filamentous fungi: *Curvularia lunata* IM 2901 (the same as used in this work), *Curvularia tuberculata* IM 4417 and *Paecilomyces marquandii* IM 6003 previously tested by us, during the growth in liquid medium also accumulated lead with higher efficiency than zinc and cadmium

(PARASZKIEWICZ *et al.* 2007). According to ZOUBOULIS *et al.* (1999) a greater sorption of Pb^{2+} than of many other heavy metals (e.g. Zn^{2+}, Cd^{2+}, Ni^{2+} or Cu^{2+}) may be partially explained by a high stability constant for Pb^{2+} binding to the ligands of fungal surface.

The possibility to enhance heavy metals removal as a result of physical or chemical pretreatment of plant and microbial biosorbents is pointed out by many researchers (SAEED *et al.* 2005; KAPOOR *et al.* 1999; GÖKSUNGUR *et al.* 2005; MUNGASAVALLI *et al.* 2007). The improvement of metal binding properties of modified biosorbents could be explained by the increase in metal ions access to the metal binding sites, attributed to the cleansing effect of the agents used, modification of binding sites or changing in the overall surface charge (KAPOOR *et al.* 1999; GÖKSUNGUR *et al.* 2005). Data presented in this paper revealed that additional modifications of *C. lunata* mycelium with NaOH or ethanol did not enhance either Pb^{2+} Zn^{2+} or Cd^{2+} sorption capacity. The same, experimental results indicate that ethanol as well as NaOH treatment of *C. lunata* biomass caused the removal or at least inactivation of the sites involved in lead uptake. Nevertheless, according to PURANIK and PAKNIKAR (1997) findings, while using the modified biosorbent on a large scale, the cost escalation due to pretreatment needs to be taken into account.

Sorption of lead, zinc and cadmium by *C. lunata* waste biomass was also examined by us when heavy metals ions where presented in binary as well in ternary combinations. Efficiency of the mycelium to remove lead ions from binary (Pb^{2+}+Zn^{2+} or Pb^{2+}+Cd^{2+}) as well as from ternary (Pb^{2+}+Zn^{2+}+Cd^{2+}) metal solutions occurred to be similar to the one achieved when Pb^{2+} was presented alone. Nevertheless, the presence of lead ions significantly decreased the sorption of Zn^{2+} and Cd^{2+}. Our results are in agreement with those obtained by KAPOOR *et al.* (1999) and indicate that antagonic interactions between various heavy metals may occur in multiple metal solutions. The drop in the sorption of Zn^{2+} and Cd^{2+} from two- and three-metal combinations indicates a competition among Zn, Cd and Pb ions for the same binding sites presented on the surface of *C. lunata* biomass. Greater affinity of lead than of two other examined heavy metals to the biosorbent was probably caused

by a larger ion size of Pb^{2+} in comparison to Zn^{2+} and Cd^{2+} (0.112, 0.074 and 0.097nm, respectively) (ANGYAL 1989).

In the present studies the uptake of heavy metals by *C. lunata* mycelium was found to be influenced by the initial pH of metal solution and rose due to the increase in pH value. The removal of Pb^{2+}, Zn^{2+} and Cd^{2+} from single metal solutions reached at pH 6 the highest levels of 94.0, 75.4 and 62.6%, respectively. According to PURANIK and PAKNIKAR (1997) lead and zinc uptake by waste biomass of *S. cinnamoneum* was also influenced by pH of the metal solution. The pH range (5.0-6.0) established in that study as the optimum for zinc uptake fits well with our results, but maximum the lead removal determined at pH 4.5 occured to be lower than for *C. lunata* biosorbent. Nevertheless, the pH of the lead solution increased from 4.0 to 6.5 during the adsorption process conducted by *S. cinnamoneum*. At pH 6 the maximum capacity of lead uptake was estimated with mycelium of *Mucor rouxii* as a metal biosorbent (LO *et al.* 1999). SAY *et al.* (2001) used biomass of filamentous fungus *Phanerochaete chrysosporium* for Pb^{2+} removal and also determined the optimum pH value for biosorption as 6.0. It has been commonly agreed that pH value of metal solution can strongly influence metal uptake intensity of biosobents (IQBAL, EDYVEAN 2004; MELGAR *et al.* 2007; GÖKSUNGUR *et al.* 2005; MUNGASAVALLI *et al.* 2007). Due to the increased hydrogen (H^+) and hydronium (H_3O^+) concentrations at the high acidic pH solution, these ions compete effectively with metal ions in binding to negatively charged groups on the biosorbent surface. Consequently, the increase in heavy metal uptake with increasing pH could be attributed to less ionic competition (PURANIK, PAKNIKAR 1997).

From the results presented in this study it can be concluded that *C. lunata* biomass, a potential waste by-product from hydrocortisone manufacture, could be considered as an inexpensive material for lead and, to a lower extent, zinc and cadmium ions removal from aqueous effluents.

Acknowledgements

This study was supported by the University of Lodz grant (No. 505/440).

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acta universitatis lodziensis
——— 2009 ———
Folia Biologica et Oecologica 5: 21–41
(Acta Univ., Lodz, Folia Biol. et Oecol.)

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THE VASCULAR FLORA OF THE RAILWAY GROUNDS OF THE PABIANICE TOWN

Abstract: In the paper a list and general characterization of vascular plants recorded on railway grounds of the town of Pabianice is presented. The great diversity of habitats within the railway grounds as well as their inclination to be colonized by numerous introduced species resulted in high variety of vascular plants there. This flora consists of 382 taxa.

Key words: flora, vascular plants, railway grounds, Pabianice, Central Poland.

1. INTRODUCTION

The vascular plants of the railway grounds of the town of Pabianice have not yet been the subject of complex research (see SOWA 1991). Fairly abundant data on vascular plant occurrence on the railway grounds of this town is given by MOWSZOWICZ (1960, 1978), and SOWA (1971). The floristic investigation that was carried out on the railway grounds of Pabianice in 2005 and 2006, enriched the list of taxa of this type of flora (WARCHOLIŃSKA, SUWARA-SZMIGIELSKA 2006).

The main aim of the floristic research carried out in 2005 and 2006 was compiling an updated list of vascular plants occurring in diverse habitats of

Pabianice railway grounds and working out a general characterization of the investigated flora.

2. MATERIALS AND METHODS

The present study encompassed the railway areas within the administrative borders of the Pabianice Town. The total lengh of railway tracks located in these areas is 5.3 km (Fig. 1). The areas are terrain between the rails and 10 meter wide belts adjoining the railways tracks on both sides, including those tracks that are situated on embankments.

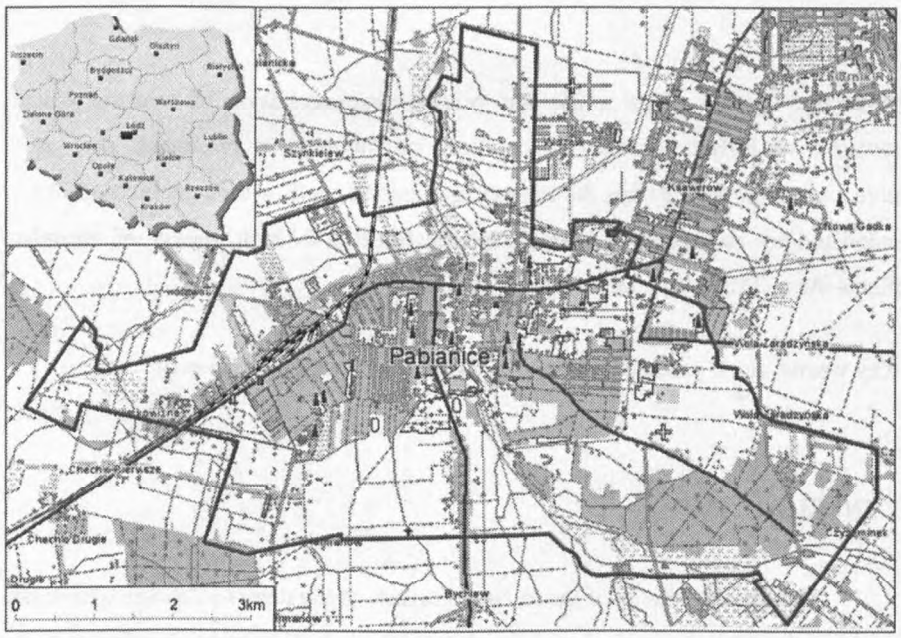

Fig. 1: Location of the study area (dashed line)

On the basis of data analysis a systematic list of taxa occurring in the investigated flora of Pabianice railway grounds was compiled and its general characterization was carried out.

The systematic arrangement of taxa was accepted after SZAFER *et al.* (1976), while the botanic nomenclature after MIREK *et al.* (2002). Studies by JACKOWIAK (1990), JANOWSKA (2002), LATOWSKI (1981, 2004), MOWSZOWICZ (1975), RUTKOWSKI (1998), WARCHOLIŃSKA (2004, 2005), were also employed.

Before and after the Latin names of taxa the following data were given:

- * - Plants recorded in 2005 and 2006;
- Life span of species (Shl – Short living plants, Per – Perennial plants);
- Life form (M – Megaphanerophytes, N- Nanophanerophytes, Ch – Woody chamaephytes, C – Herbaceous chamaephytes, G – Geophytes, H - Hemicryptophytes, T – Therophytes);
- Geographic-historical group (Ap – Apophytes; Anthropophytes: Ar – Archaeopchytes, Ep – Epoecophytes, He – Hemiagriophytes, Ho – Holoagriophytes, Ef – Ephemerophytes, Er – Ergaziophygophytes);
- Frequency classes (very rare, rare, rather frequent, frequent, common).

The following studies were employed to characterize the vascular plants of the area: JACKOWIAK (1990), JANOWSKA (2002), KORNAŚ *et al.* (1959), KORNAŚ (1968), LATOWSKI (1981, 2004), MIREK *et al.* (2002), SZAFER *et al.* (1976), WARCHOLIŃSKA (2004, 2005), ZAJĄC E. U., ZAJĄC A. (1975), ZARZYCKI *et al.* (2002).

3. RESULTS

3.1. List of taxa

Polypodiaceae

* 1. *Dryopteris filix-mas* (L.) Schott – Per, H, Ap, very rare.

* 2. *Pteridium aquilinum* (L.) Kuhn – Per, G, Ap, rare.

Equisetaceae

3. *Equisetum arvense* L. – Per, G, Ap, common.

* 4. *E. sylvaticum* L. – Per, G, Ap, rare.

* 5. *E. palustre* L. – Per, G, Ap, very rare.

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Pinaceae

6. *Pinus sylvestris* L. – Per, M, Ap, rare.

Cupressaceae

* 7. *Juniperus communis* L. – Per, N, Ap, rare.

Betulaceae

* 8. *Betula pendula* Roth – Per, M, Ap, frequent.

* 9. *Alnus glutinosa* (L.) Gaertn. – Per, M, Ap, very rare.

* 10. *Carpinus betulus* L. – Per, M, Ap, very rare.

* 11. *Corylus avellana* L. – Per, N, Ap, rare.

Fagaceae

* 12. *Quercus robur* L. – Per, M, Ap, rare.

* 13. *Q. rubra* L. – Per, M, He, rare.

Salicaceae

* 14. *Populus alba* L. – Per, M, Ap, rare.

* 15. *P. tremula* L. – Per, M, Ap, rather frequent.

* 16. *Salix fragilis* L. – Per, M, Ap, very rare.

* 17. *S. alba* L. – Per, N, Ap, very rare.

* 18. *S. cinerea* L. – Per, N, Ap, very rare.

* 19. *S. caprea* L. – Per, N, Ap, rare.

Moraceae

* 20. *Morus alba* L. – Per, M, Er, rare.

Cannabaceae

* 21. *Humulus lupulus* L. – Per, N, Ap, very rare.

Urticaceae

* 22. *Urtica urens* L. – Shl, T, Ar, frequent.

* 23. *Urtica dioica* L. – Per, H, Ap, rather frequent.

Polygonaceae

* 24. *Rumex maritimus* L. – Shl, T, Ap, very rare.

* 25. *R. conglomeratus* Murray – Per, H, Ap, very rare.

* 26. *R. obtusifolius* L. – Per, H, Ap, rather frequent.

27. *R. crispus* L. – Per, H, Ap, frequent.

28. *R. acetosa* L. – Per, H, Ap, rather frequent.
29. *R. acetosella* L. – Per, G, Ap, frequent.
* 30. *Polygonum bistorta* L. – Per, G, Ap, very rare.
* 31. *P. amphibium* L. – Per, G, Ap, very rare.
32. P. persicaria L. – Shl, T, Ap, common.
33. *P. lapathifolium* L. *subsp. pallidum* (With.) Fr. – Shl, T, Ap, frequent.
34. *P. lapathifolium* L. – Shl, T, Ap, rare.
* 35. *P. hydropiper* L. – Shl, T, Ap, very rare.
* 36. *P. minus* L. – Shl, T, Ap, very rare.
37. *P. aviculare* L. – Shl, T, Ap, common.
* 38. *Reynoutria sachalinensis* (F. Shmidt) Nakai – Per, G, Ep, very rare.
* 39. *R. japonica* Houtt. – Per, G, Ep, rare.
40. *Fallopia convolvulus* (L.) Á. Löve – Shl, T, Ar, common.
* 41. *F. dumetorum* (L.) Holub – Shl, T, Ap, very rare.

Chenopodiaceae

* 42. *Corispermum hyssopifolium* L. – Shl, T, Ep, very rare.
* 43. *Kochia scoparia* (L.) Schrad. – Shl, T, Ef, very rare.
* 44. *Chenopodium polyspermum* L. – Shl, T, Ap, very rare.
45. *Ch. opulifolium* Schrad. Ex W.D.J. Koch & Ziz – Shl, T, Ar, very rare.
46. *Ch. album* L. – Shl, T, Ap, common.
47. *Ch. glaucum* L. – Shl, T, Ap, very rare.
* 48. *Artiplex hortensis* L. – Shl, T, Ep, very rare.
49. *A. patula* L. – Shl, T, Ap, frequent.
50. *A. prostrata* Boucher Ex DC. – Shl, T, Ap, very rare.
* 51. *Salsola kali* L. *subsp. ruthenica* (Iljin) Soó – Shl, T, Ep, very rare.

Amaranthaceae

52. *Amaranthus retroflexus* L. – Shl, T, Ep, frequent.
53. *A. albus* L. – Shl, T, Ep, rare.
* 54. *A. blitoides* S. Watson – Shl, T, Ep, very rare.
* 55. *A. lividus* L. – Shl, T, Ep, rare.

Caryophyllaceae

56. *Dianthus deltoides* L. – Per, H, Ap, rare.
* 57. *Gypsophila muralis* L. – Shl, T, Ap, rather frequent.
58. *Saponaria officinalis* L. – Per, H, Ap, rather frequent.
59. *Melandrium album* (Mill.) Garcke – Shl, H, Ap, frequent.
60. *Silene vulgaris* (Moench) Garcke – Per, H, Ap, rather frequent.
* 61. *Arenaria serpyllifolia* L. – Shl, T, Ap, rather frequent.
62. *Stellaria media* (L.) Vill. – Shl, T, Ap, rather frequent.
63. *S. graminea* L. – Per, H, Ap, rather frequent.
64. *Cerastium arvense* L. S. S. – Per, C, Ap, frequent.
65. *C. holosteoides* Fr. Emend. Hyl. – Per, C, Ap, frequent.
66. *Scleranthus perennis* L. – Per, H, Ap, rather frequent.
67. *S. annuus* L. – Shl, T, Ar, frequent.
68. *Spergula arvensis* L. – Shl, T, Ar, frequent.
* 69. *S. morisonii* Boreau – Shl, T, Ap, rare.
70. *Spergularia rubra* (L.) J. Presl & C. Presl – Shl, H, Ap, rather frequent.
71. *Herniaria glabra* L. – Shl, H, Ap, rather frequent.
* 72. *H. hirsuta* L. – Shl, T, Ar, very rare.

Euphorbiaceae

73. *Euphorbia peplus* L. – Shl, T, Ar, rare.
74. *E. helioscopia* L. – Shl, T, Ar, rather frequent.
75. *E. cyparissias* L. – Per, H, Ap, frequent.
76. *E. esula* L. – Per, H, Ap, rare.

Ranunculaceae

77. *Consolida regalis* S. F. Gray – Shl, T, Ar, very rare.
* 78. *C ajacis* (L.) Shur – Shl,T, Er, very rare.
* 79. *Ranunculus bulbosus* L. – Per, G, Ap, rare.
80. *R. repens* L. – Per, H, Ap, rather frequent.
81. *R. acris* L. S. S. – Per, H, Ap, frequent.

Papaveraceae

* 82. *Papaver argemone* L. – Shl, T, Ar, rare.

83. *P. dubium* L. – Shl, T, Ar, rather frequent.

84. *P. rhoeas* L. – Shl, T, Ar, rare.

* 85. *P. somniferum* L. – Shl, T, Er, very rare.

86. *Chelidonium majus* L. – Per, H, Ap, rather frequent.

87. *Fumaria officinalis* L. – Shl, T, Ar, very rare.

Brassicaceae

* 88. *Rorippa sylvestris* (L.) Besser – Per, H, Ap, rather frequent.

89. *R. austriaca* (Crantz) Besser – Per, H, Ap, rare.

90. *Cardaminopsis arenosa* (L.) Hayek – Shl, H, Ap, rare.

91. *Sisymbrium officinale* (L.) Scop. – Shl, T, Ar, frequent.

92. *S. altissimum* L. – Shl, H, Ep, rather frequent.

93. *S. loeselii* L. – Shl, T, Ep, frequent.

94. *Descurainia sophia* (L.) Webb ex Prantl – Shl, T, Ar, common.

95. *Arabidopsis thaliana* (L.) Heynh. – Shl, T, Ap, frequent.

96. *Erysimum cheiranthoides* L. – Shl, T, Ar, rather frequent.

* 97. *Brassica napus* L. – Shl, T, Er, very rare.

98. *Erucastrum gallicum* (Willd.) O. E. Schulz – Shl, T, Ep, very rare.

* 99. *Sinapis arvensis* L. – Shl, T, Ar, rather frequent.

* 100. *S. alba* L. – Shl, T, Er, rare.

101. *Diplotaxis muralis* (L.) DC. – Shl, T, Ep, rare.

102. *Alyssum alyssoides* (L.) L. – Shl, T, Ap, very rare.

103. *Berteroa incana* (L.) DC. – Shl, T, Ap, common.

104. *Erophila verna* (L.) Chevall. – Shl, T, Ap, frequent.

* 105. *Armoracia rusticana* P. Gaertn., B. Mey. & Scherb. – Per, G, Ar, rare.

106. *Thlaspi arvense* L. – Shl, T, Ar, rare.

107. *Cardaria draba* (L.) Desv. – Per, H, Ep, rare.

108. *Lepidium campestre* (L.) R. Br. – Shl, T, Ar, very rare.

109. *L. sativum* L. – Shl, T, Er, very rare.

110. *L. ruderale* L. – Shl, T, Ar, frequent.

111. *L. densiflorum* Schrad. – Shl, T, Ep, very rare.

112. *Capsella bursa-pastoris* (L.) Medik. – Shl, T, Ar, common.

113. *Bunias orientalis* L. – Shl, T, Ep, very rare.
114. *Raphanus raphanistrum* L. – Shl, T, Ar, frequent.
* 115. *R. sativus* L. – Shl, T, Er, rather frequent.

Resedaceae

116. *Reseda lutea* L. – Shl, T, Ap, very rare.

Violaceae

* 117. *Viola odorata* L. – Per, H, Ap, rare.
* 118. *V. tricolor* L. S. S. – Shl, T, Ap, rather frequent.
119. *V. arvensis* Murray – Shl, T, Ar, rather frequent.

Clusiaceae

120. *Hypericum perforatum* L. – Per, H, Ap, rather frequent.

Crassulaceae

* 121. *Sedum maximum* (L.) Hoffm. – Per, G, Ap, very rare.
122. *S. acre* L. – Per, C, Ap, rather frequent.

Saxifragaceae

* 123. *Saxifraga granulata* L. – Per, H, Ap, rare.

Rosaceae

* 124. *Spiraea salicifolia* L. – Per, N, Er, very rare.
* 125. *Rosa rugosa* Thunb. – Per, N, Ar, very rare.
* 126. *R. canina* L. – Per, N, Ap, rather frequent.
* 127. *Rubus idaeus* L. – Per, N, Ap, rather frequent.
* 128. *R. caesius* L. – Per, N, Ap, frequent.
* 129. *Fragaria vesca* L. – Per, H, Ap, very rare.
* 130. *Potentilla argentea* L. S. S. – Per, H, Ap, very frequent.
131. *P. argentea* L. – Per, H, Ap, rather frequent.
132. *P. reptans* L. – Per, H, Ap, very rare.
* 133. *P. erecta* (L.) Raeusch – Per, H, Ap, very rare.
134. *P. anserina* L. – Per, H, Ap, frequent.
* 135. *Alchemilla monticola* Opiz – Per, H, Ap, very rare.
136. *Geum urbanum* L. – Per, H, Ap, rather frequent.
137. *Agrimonia eupatoria* L. – Per, H, Ap, very rare.

* 138. *Crataegus monogyna* Jacq. – Per, N, Ap, very rare.

* 139. *Pyrus communis* L. – Per, M, Ar, very rare.

* 140. *Sorbus aucuparia* L. Emend. Hedl. – Per, M, Ap, very rare.

* 141. *Prunus spinosa* L. – Per, N, Ap, very rare.

* 142. *P. domestica* L. subsp. *insititia* (L.) Bonnier & Layens – Per, N, Er, very rare.

* 143. *Padus serotina* (Ehrh.) Borkh. – Per, N, Ep, rare.

Fabaceae

* 144. *Sarothamnus scoparius* (L.) W. D. J. Koch – Per, N, Ap, rare.

* 145. *Lupinus polyphyllus* Lindl. – Per, H, He, very rare.

146. *Ononis arvensis* L. – Per, H, Ap, rare.

* 147. *Medicago falcata* L. – Per, H, Ap, very rare.

148. *M. sativa* L. – Per, H, Er, rather frequent.

149. *M. lupulina* L. – Shl, T, Ap, frequent.

150. *Melilotus alba* Medik. – Shl, H, Ap, frequent.

151. *M. officinalis* (L.) Pall. – Shl, H, Ap, rather frequent.

152. *Trifolium arvense* L. – Shl, T, Ap, rather frequent.

* 153. *T. dubium* Sibth. – Shl, T, Ap, rare.

154. *T. campestre* Schreb. – Shl, T, Ap, rather frequent.

155. *T. fragiterum* L.. – Per, H, Ap, very rare.

156. *T. repens* L. – Per, H, Ap, frequent.

* 157. *T. pratense* L. – Per, H, Ap, very rare.

* 158. *T. medium* L. – Per, H, Ap, rare.

* 159. *Lotus uliginosus* Schkuhr – Per, H, Ap, rare.

160. *L. corniculatus* L. – Per, H, Ap, frequent.

* 161. *Robinia pseudacacia* L. – Per, M, He, rather frequent.

* 162. *Caragana arborescens* Lam. – Per, N, Er, very rate.

* 163. *Astragalus glycyphyllos* L. – Per, H, Ap, very rare.

164. *Coronilla varia* L. – Per, H, Ap, frequent.

165. *Vicia hirsuta* (L.) S. F. Gray – Shl, T, Ar, frequent.

166. *V. tetrasperma* (L.) Schreb. – Shl, T, Ar, rather frequent.

167. *V. cracca* L. – Per, H, Ap, frequent.
168. *V. villosa* Roth. – Shl, T, Ar, rather frequent.
* 169. *V. sepium* L. – Per, H, Ap, rare.
* 170. *V. sativa* L. – Shl, T, Ar, very rare.
* 171. *V. angustifolia* L. – Shl, T, Ar, frequent.
* 172. *Lathyrus pratensis* L. – Per, H, Ap, rare.
* 173. *Pisum sativum* L. – Shl, T, Er, very rare.

Lythraceae

* 174. *Lythrum salicaria* L. – Per, H, Ap, rare.

Onagraceae

175. *Epilobium hirsutum* L. – Per, H, Ap, very rare.
* 176. *E. parviflorum* Schreb. – Per, H, Ap, rather frequent.
* 177. *Chamaenerion angustifolium* (L.) Scop. – Per, H, Ap, rare.
178. *Oenothera biennis* L. S. S. – Shl, H, Ap, frequent.

Malvaceae

* 179. *Alcea rosea* L. – Per., H, Er, very rare.
* 180. *Malva sylvestris* L. – Shl, H, Ar, rare.
* 181. *M. neglecta* Wallr. – Shl, H, Ar, frequent.

Tiliaceae

* 182. *Tilia cordata* Mill. – Per, M, Ap, very rare.

Oxalidaceae

* 183. *Oxalis fontana* Bunge – Per, G, Ep, rather frequent.

Geraniaceae

* 184. *Geranium pratense* L. – Per, H, Ap, rare.
185. *G. pusillum* Burm. F. ex L. – Shl, T, Ar, frequent.
* 186. *G. robertianum* L. – Shl, H, Ap, rare.
187. *Erodium cicutarium* (L.) L'Hér. – Shl, T, Ap, common.

Aceraceae

* 188. *Acer pseudoplatanus* L. – Per, M, Ap, very rare.
* 189. *A. platanoides* L. – Per, M, Ap, rather frequent.
* 190. *A. campestre* L. – Per, M, Ap, very rare.

* 191. *A. negundo* L. - Per, M, He, rather frequent.

Hippocastanaceae

* 192. *Aesculus hippocastanum* L. – Per, M, Er, rare.

Balsaminaceae

* 193. *Impatiens parviflora* DC. – Shl, T, Ho, rare.

Vitaceae

* 194. *Parthenocissus quinquefolia* (L.) Planch. in A. & C. DC. – Per, N, Er, rare.

Araliaceae

* 195. *Hedera helix* L. – Per, N, Ap, rare.

Apiaceae

* 196. *Sium latifolium* L. – Per, H, Ap, very rare.

197. *Carum carvi* L. – Shl, H, Ap, rather frequent.

* 198. *Aegopodium podagraria* L. – Per, H, Ap, rather frequent.

199. *Pimpinella saxifraga* L. – Per, H, Ap, frequent.

* 200. *Aethusa cynapium* L. – Shl, T, Ar, rare.

201. *Heracleum sibiricum* L. – Per, H, Ap, frequent.

* 202. *H. sphondylium* L. – Per, H, Ap, rare.

* 203. *Peucedanum oreoselinum* (L.) Moench – Per, H, Ap, rare.

204. *Pastinaca sativa* L. – Shl, H, Ap, frequent.

205. *Daucus carota* L. – Shl, H, Ap, rather frequent.

* 206. *Anthriscus sylvestris* (L.) Hoffm. – Per, H, Ap, rare.

* 207. *Torilis japonica* (Houtt.) DC. – Shl, T, Ap, rather frequent.

Primulaceae

208. *Anagalis arvensis* L. – Shl, T, Ar, very rare.

* 209. *Lysimachia vulgaris* L. – Per, H, Ap, rare.

Convolvulaceae

210. *Convolvulus arvensis* L. – Per, G, Ar, common.

* 211. *Calystegia sepium* (L.) R. Br. – Per, G, Ap, very rare.

Boraginaceae

212. *Anchusa officinalis* L. – Shl, H, Ap, rare.

213. *A. arvensis* (L.) M. Bieb. – Shl, T, Ar, rare.

* 214. *Symphytum officinale* L. – Per, H, Ap, very rare.

215. *Echium vulgare* L. – Shl, H, Ap, rather frequent.

216. *Lithospermum arvense* L. – Shl, T, Ar, rather frequent.

217. *Myosotis stricta* Link ex Roem. & Schult. – Shl, T, Ap, rather frequent.

218. *M. arvensis* (L.) Hill – Shl, T, Ar, rare.

Solanaceae

219. *Hyoscyamus niger* L. – Shl, T, Ar, very rare.

220. *Solanum nigrum* L. Emend. Mill. – Shl, T, Ar, very rare.

221. *S. tuberosum* L. – Per, G, Er, very rare.

* 222. *Datura stramonium* L. – Shl, T, Ep, very rare.

* 223. *Nicotiana rustica* L. – Shl, T, Er, very rare.

Scrophulariaceae

224. *Verbascum thapsus* L. – Shl, H, Ap, very rare.

* 225. *V. densiflorum* Bertol. – Shl, H, Ap, very rare.

* 226. *V. nigrum* L. – Shl, H, Ap, frequent.

* 227. *Linaria vulgaris* Mill. – Per, G, Ap, frequent.

228. *Chaenorhinum minus* (L.) Lange – Shl, T, Ap, very rare.

229. *Scrophularia nodosa* L. – Per, G, Ap, very rare.

230. *Veronica chamaedrys* L. – Per, C, Ap, frequent.

* 231. *V. serpyllifolia* L. – Per, H, Ap, rare.

* 232. *V. arvensis* L. – Shl, T, Ar, rather frequent.

* 233. *V. verna* L. – Shl, T, Ap, very rare.

* 234. *V. dillenii* Crantz – Shl, T, Ap, very rare.

235. *V. persica* Poir. – Shl, T, Ep, rare.

* 236. *Euphrasia rostkoviana* Hayne – Shl, T, Ap, very rare.

237. *Odontites serotina* (Lam.) Rchb. – Shl, T, Ap, rare.

* 238. *O. verna* (Bellardi) Dumort. – Shl, T, Ap, rare.

Lamiaceae

* 239. *Glechoma hederacea* L. – Per, H, Ap, rare.

240. *Prunella vulgaris* L. – Per, H, Ap, rare.

241. *Galeopsis angustifolia* (Ehrh.) Hoffm. – Shl, T, Ar, very rare.

* 242. *G. tetrahit* L. – Shl, T, Ap, rather frequent.

* 243. *G. bifida* Boenn. – Shl, T, Ap, frequent.

* 244. *G. pubescens* Besser – Shl, T, Ap, very rare.

245. *Lamium purpureum* L. – Shl, H, Ar, frequent.

246. *L. amplexicaule* L. – Shl, H, Ar, rare.

* 247. *Stachys palustris* L. – Per, G, Ap, rare.

248. *Leonurus cardiaca* L. – Per, H, Ar, rare.

249. *Ballota nigra* L. – Per, H, Ar, rare.

* 250. *Acinos arvensis* (Lam.) Dandy – Shl, T, Ap, rather frequent.

* 251. *Origanum vulgare* L. – Per, G, Ap, very rare.

* 252. *Thymus pulegioides* L. – Per, C, Ap, rare.

253. *T. serpyllum* L. Emend. Fr. – Per, C, Ap, rather frequent.

* 254. *Lycopus europaeus* L. – Per, G, Ap, rare.

* 255. *Mentha arvensis* L. – Per, G, Ap, frequent.

Plantaginaceae

256. *Plantago major* L. – Per, H, Ap, frequent.

257. *P. media* L. – Per, H, Ap, very rare.

258. *P. lanceolata* L. – Per, H, Ap, frequent.

259. *P. arenaria* Waldst. & Kit. – Shl, T, Ap, rare.

Oleaceae

* 260. *Fraxinus excelsior* L. – Per, M, Ap, very rare.

* 261. *Syringa vulgaris* L. – Per, N, Er, very rare.

* 262. *Ligustrum vulgare* L. – Per, N, Er, very rare.

Rubiaceae

263. *Galium verum* L. S. S. – Per, H, Ap, rather frequent.

264. *G. mollugo* L. – Per, H, Ap, frequent.

265. *G. tricornutum* Dandy – Per, G, Ap, very rare.

Caprifoliaceae

* 266. *Sambucus nigra* L. – Per, N, Ap, rare.

* 267. *Viburnum opulus* L. – Per, N, Ap, very rare.

* 268. *Symphoricarpos albus* (L.) S. F. Blake – Per, N, Er, rather frequent.

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Dipsacaceae

* 269. *Scabiosa ochroleuca* L. – Per, H, Ap, very rare.

270. *Knautia arvensis* (L.) J. M. Coult. – Per, H, Ap, rather frequent.

Cucurbitaceae

* 271. *Echinocystis lobata* (F. Michx.) Torr. & a. Gray – Shl, T, Ef, very rare.

Campanulaceae

272. *Jasione montana* L. – Shl, H, Ap, rare.

* 273. *Campanula rapunculoides* L. – Per, G, Ap, very rare.

* 274. *C. patula* L. – Per, H, Ap, rare.

Asteraceae

* 275. *Solidago canadensis* L. – Per, H, He, frequent.

* 276. *S. gigantea* Aiton – Per, H, He, rather frequent.

* 277. *Bellis perennis* L. – Per, H, Ap, very rare.

278. *Conyza canadensis* (L.) Cronquist – Shl, T, Ep, common.

279. *Erigeron acris* L. – Shl, H, Ap, rare.

280. *E. annuus* (L.) Pers. – Per, H, He, rare.

* 281. *Gnaphalium uliginosum* L. – Shl, T, Ap, rare.

282. *Xanthium strumarium* L. – Shl, T Ap, rare.

283. *Helianthus annuus* L. – Shl, T, Er, very rare.

* 284. *Rudbeckia laciniata* L. – Per, H, Ep, very rare.

285. *Bidens tripartita* L. – Shl, T, Ap, rare.

286. *Galinsoga parviflora* Cav. – Shl, T, Ep, frequent.

287. *G. ciliata* (Raf.) S. F. Blake – Shl, T, Ep, rare.

* 288. *Anthemis arvensis* L. – Shl, T, Ar, frequent.

289. *A. ruthenica* M. Bieb. – Shl, T, Ar, very rare.

* 290. *A. cotula* L. – Shl, T, Ar, rare.

* 291. *Achillea ptarmica* L. – Per, H, Ap, very rare.

292. *A. millefolium* L. – Per, H, Ap, common.

293. *Chamomilla recutita* (L.) Rauschert – Shl, T, Ar, rare.

294. *Ch. suaveolens* (Pursh) Rydb. – Shl, T, Ep, frequent.

295. *Matricaria maritima* L. – Shl, T, Ar, rather frequent.

* 296. *Laucanthemum vulgare* Lam. S. S. – Per, H, Ap, rare.
* 297. *Tanacetum parthenium* (L.) Schultz-Bip. – Per, H, Er, very rare.
298. *T. vulgare* L. – Per, H, Ap, frequent.
299. *Artemisia absinthium* L. – Per, Ch, Ap, rare.
300. *A. vulgaris* L. – Per, H, Ap, rather frequent.
301. *A. austriaca* Jacq. – Per, Ch, Ep, very rare.
302. *A. campestris* L. – Per, Ch, Ap, rather frequent.
303. *Tussilago farfara* L. – Per, G, Ap, rare.
304. *Senecio vulgaris* L. – Shl, T, Ar, frequent.
305. *S. viscosus* L. – Shl, T, Ap, rather frequent.
* 306. *S. vernalis* Waldst. & Kit. – Shl, T, Ep, rather frequent.
* 307. *S. jacobaea* L. – Per, H, Ap, frequent.
* 308. *Calendula officinalis* L. – Shl, T, Er, very rare.
309. *Arctium tomentosum* Mill. – Shl, H, Ap, frequent.
310. *A. lappa* L. – Shl, H, Ap, frequent.
311. *A. minus* (Hill) Bernh. – Shl, H, Ap, rare.
312. *Carduus acanthoides* L. – Shl, H, Ar, very rare.
313. *Cirsium vulgare* (Savi) Ten. – Shl, H, Ap, rare.
314. *C. arvense* (L.) Scop. – Per, G, Ap, common.
* 315. *Onopordum acanthium* L. – Shl, H, Ar, very rare.
316. *Centaurea scabiosa* L. – Per, H, Ap, rare.
317. *C. stoebe* L. – Shl, H, Ap, frequent.
* 318. *C. diffusa* Lam. – Per, H, Ep, very rare.
319. *C. cyanus* L. – Shl, T, Ar, very rare.
320. *C. jacea* L. – Per, H, Ap, rare.
321. *Cichorium intybus* L. – Per, H, Ar, rather frequent.
322. *Lapsana communis* L. – Shl, T, Ap, rare.
* 323. *Hypochoeris radicata* L. – Per, H, Ap, rare.
* 324. *H. glabra* L. – Shl, T, Ap, rather frequent.
* 325. *Tragopogon pratensis* L. S. S. – Shl, H, Ap, rare.
326. *T. dubius* Scop. – Shl, H, Ap, very rare.

327. *Leontodon autumnalis* L. – Per, H, Ap, frequent.
* 328. *L. hispidus* L. – Per H, Ap, rare.
329. *Taraxacum officinale* F. H. Wigg. – Per, H, Ap, common.
330. *Sonchus oleraceus* L. – Shl, T, Ar, rare.
331. *S. asper* (L.) Hill – Shl, T, Ar, rare.
332. *S. arvensis* L. – Per, G, Ap, common.
333. *Lactuca serriola* L. – Shl, H, Ar, rare.
* 334. *Crepis biennis* L. – Shl, H, Ap, rare.
* 335. *C. tectorum* L. – Shl, T, Ap, rather frequent.
336. *Hieracium pilosella* L. – Per, H, Ap, frequent.

Liliaceae

* 337. *Allium vineale* L. – Per, H, Ap, rare.

Juncaceae

338. *Juncus bufonius* L. – Shl, T, Ap, rare.
* 339. *J. conglomeratus* L. Emend. Leers – Per, H, Ap, rare.
* 340. *Luzula campestris* (L.) DC. – Per, H, Ap, rare.

Cyperaceae

* 341. *Carex hirta* L. – Per, G, Ap, rather frequent.

Poaceae

342. *Digitaria sanguinalis* (L.) Scop. – Shl, T, Ar, very rare.
343. *D. ischaemum* (Schreb.) H. L. Mühl. – Shl, T, Ar, rather frequent.
344. *Echinochloa crus-galli* (L.) P. Beauv. – Shl, T, Ar, rare
* 345. *Setaria pumila* (Poir.) Roem. & Schult. – Shl, T, Ar, rather frequent.
346. *S. viridis* (L.) P. Beauv. – Shl, T, Ar, rather frequent.
* 347. *Anthoxanthum odoratum* L. – Per, H, Ap, rather frequent.
* 348. *A. aristatum* Boiss. – Shl, T, Er, very rare.
349. *Phleum pratense* L. – Per, H, Ar, frequent.
* 350. *Alopecurus pratensis* L. – Per, H, Ap, rare.
351. *Apera spica-venti* (L.) P. Beauv. – Shl, T, Ar, rare.
352. *Agrostis stolonifera* L. – Per, H, Ap, frequent.
353. *A. capillaris* L. – Per, H, Ap, rare.

354. *Calamagrostis epigejos* (L.) Roth – Per, G, Ap, rare.
* 355. *Holcus mollis* L. – Per, H, Ap, rather frequent.
356. *H. lanatus* L. – Per, H, Ap, rare.
357. *Corynephorus canescens* (L.) Roth – Per, G, Ap, rare.
* 358. *Avena sativa* L. – Shl, T, Er, very rare.
* 359. *Arrhenatherum elatius* (L.) P. Beauv. Ex J. Presl & C. Presl – Per, H, Ap, rare.
* 360. *Phragmites australis* (Cav.) Trin. Ex Steud. – Per, G, Ap, rare.
361. *Eragrostis minor* Host – Shl, T, Ep, very rare.
362. *Cynosurus cristatus* L. – Per, H, Ap, very rare.
363. *Dactylis glomerata* L. – Per, H, Ap, rather frequent.
364. *Poa annua* L. – Shl, T, Ap, frequent.
365. *P. palustris* L. – Per, H, Ap, rare.
366. *P. compressa* L. – Per, G, Ap, rare.
* 367. *P. trivialis* L. – Per, H, Ap, rather frequent.
368. *Puccinellia distans* (Jacq.) Parl. – Per, H, Ap, very rare.
* 369. *Bromus inermis* Leyss. – Per, H, Ap, rather frequent.
* 370. *B. sterilis* L. – Shl, T, Ar, very rare.
371. *B. tectorum* L. – Shl, T, Ar, frequent.
372. *B. secalinus* L. – Shl, T, Ar, very rare.
373. *B. hordeaceus* L. – Shl, T, Ap, frequent.
* 374. *B. carinatus* Hook. & Arn. – Per, H, Ep, rare.
* 375. *Festuca rubra* L. S. S. – Per, H, Ap, rare.
* 376. *F. pratensis* Huds. – Per, H, Ap, rather frequent.
377. *Lolium perenne* L. – Per, H, Ap, common.
* 378. *L. multiflorum* Lam. – Per, H, Ep, rare.
379. *Elymus repens* (L.) Gould – Per, H, Ap, common.
* 380. *Secale cereale* L. – Shl, T, Er, rare.
* 381. *Hordeum murinum* L. – Shl, T, Ar, very rare.
* 382. *Zea mays* L. – Shl, T, Er, very rare.

3. 2. The general characterization of the vascular plants of Pabianice railway grounds

The vascular flora of the railway grounds of Pabianice is rich. At present, it comprises 382 taxa, which belong to 55 families. *Asteraceae* (62 taxa), *Poaceae* (41 taxa), *Fabaceae* (30 taxa), *Brassicaceae* (28` taxa), *Rosaceae* (20 taxa), *Polygonaceae* (18 taxa), *Caryophyllaceae* (17 taxa), *Lamiaceae* (17 taxa), *Scrophulariaceae* (15 taxa), *Apiaceae* (12 taxa) are the families that are richest in taxa. They comprise a total of 270 (70.7%) vascular plants of the investigated flora. In years 2005 and 2006 we recorded 188 new plant species.

The vascular plants of the very rare (116 taxa – 30.4%) and rare (112 taxa – 29.0%) groups were the most frequently recorded. They constituted a total of 228 taxa. The interesting plants of these groups are, e.g. *Rumex maritimus, Reynoutria sachalinensis, Kochia scoparia, Amaranthus blitoides, Eucastrum gallicum, Echinocystis lobata*. The other groups were: rather frequent taxa – 76 (19.9%), frequent taxa – 61 (16.0%), and common taxa – 16 (4.2%) groups. Perennial plants dominated in the vascular flora of the studied area (215 taxa – 56.3%).

As regards life forms, the plants of the groups of therophytes (167 taxa – 43.7%) and hemicryptophytes (129 taxa – 33.8%) dominated. The group of geophytes comprised 33 taxa (8.9%), of nanophanerophytes 22 taxa (5.8%) and of megaphanerophytes 21 taxa (5.5%). Only ten taxa (2.6%) belonged to the other groups: six to herbaceous chamerophytes – (1.6 %) and four to woody chamerophytes – (1.0%).

Plants of native origin (apophytes) constituted the most abundant group (243 taxa – 63.6 %) among the geographic-historical groups. The most common apophytes were: *Equisetum arvense, Polygonum aviculare, Chenopodium album, Berteroa incana, Erodium cicutarium, Cirsium arvense, Taraxacum officinale, Lolium perenne, Elymus repens*. Plants that belonged to the archaeophytes – 68 taxa (17.8%) were frequently and plants that belonged to the epoecophyte – 33 taxa (8.6%) and ergaziophygophyte – 28 taxa (7.3%) groups were rather frequently recorded. Plants of the hemiagriophyte – 7 taxa (1.8%), ephemerophyte – 2 taxa

(0.5%) and holoagriophyte – 1 taxon (0.3%) groups were very rarely and rarely recorded. *Hyoscamus niger, Carduus acanthoides, Onopordum acanthium, Lactuca serriola* from the group of archaeophytes and *Corispermum hyssopifolium, Salsola kali, Amaranthus albus, A. blitoides, Datura stramonium* and *Eragrostis minor* from the group of epoecophytes were those that should be mentioned as interesting in the group of anthropophytes.

4. DISCUSSION

The vascular flora of Pabianice railway grounds is reach. At present, it comprises 382 taxa that belong to 55 families. Its richness is mostly affected by diverse habitat conditions and spatial arrangement and size areas of these habitats, as well as by the vicinity of various communities, mainly ruderal and seminatural.

The characteristic distinguishing features of the investigated flora are attributable to very rare and rare plants (228 taxa – 59.7%). *Corispermum hyssopifolium, Reseda lutea, Hyoscamus niger, Datura stramonium, Scabiosa ochroleuca, Lactuca serriola, Eragrostis minor, Cynosurus cristatus, Puccinellia distans* belong, among others, to the interesting species of these groups. Plants of the common group (16 taxa – 4.2%), e.g. *Equisetum arvense, Polygonum aviculare, Fallopia convolvulus, Chenopodium album, Erodium cicutarium, Convolvulus arvensis, Achillea millefolium, Taraxacum officinale, Lolium perenne, Elymus repens* had the lowest share in the analysed flora.

The plants of native origin (apophytes) constituted the group that was richest in plants (243 taxa – 63.6%). *Agrimonia eupatoria, Trifolium fragiferum, Chaenorhinum minus, Scabiosa ochroleuca, Cynosurus cristatus* should be mentioned among the groups of very rare and rare species.

Results presented in this study may be used in the future as a basis for comparative analyses of railway ground floras in Central Poland, as well as the vascular plants of the Pabianice railway grounds.

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acta universitatis lodziensis
——— 2009 ———
Folia Biologica et Oecologica 5: 43–50
(Acta Univ., Lodz, Folia Biol. et Oecol.)

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THE NEW LOCALITY OF *CHENOPODIUM PUMILIO* R. BR. IN POLAND

Abstract: The clammy goosefoot *Chenopodium pumilio* R. Br. is a rare anthropophyte in the Polish flora. Hitherto, this species was recorded in Gdańsk and Rybnik. The present study describes the newly-discovered locality in Stryków near Łódź (Central Poland), the occurrence of this species in Poland and the general geographical distribution in the world.

Key words: *Chenopodium pumilio*, synanthropic flora, Australian species, alien plants, wool aliens, Poland.

1. INTRODUCTION

In the vicinity of Stryków to the north-east of Łódź, a major transport hub is about to come into existence as the crossing point of A1 and A2 motorways will be located there. The current and predicted changes in the mode of land management in this area provided the incentive for initiation of studies to document the present state of its flora. Already initial floristic exploration brought an unexpected result – the discovery of a site of occurrence of clammy goosefoot *Chenopodium pumilio* R. Br., a synanthropic species rarely recorded in Poland. Correct determination was verified

in the herbarium of the W. Szafer Institute of Botany of the Polish Academy of Sciences in Cracow (KRAM).

Chenopodium pumilio R. Br. (Fig. 1) is an annual plant covered with glandular trichomes; shoots (10-40 cm in length) are reclining and ascending; leaves (1-4 cm in length and 0.5-2 cm in width) sinuously dentate, rhomboid-ovate in shape; flowers in bunches (3-5 mm in diameter), arising in axils of leaves; seeds (0.5-0.8 mm in diameter), reddish-brown in colour, brilliant, laterally flattened (BRENAN 1964; TRZCIŃSKA-TACIK 1992). The study presents the geographical distribution of this species and the location of its new site of occurrence in Poland.

Fig. 1: Habit of *Chenopodium pumilio* R. Br. (after Dostalek *et al.* 1990, modified)

2. GEOGRAPHICAL DISTRIBUTION AND CONDITIONS OF OCCURRENCE

Chenopodium pumilio R. Br. is a native species in Australia and Tasmania. It is most probably an adventive species in New Zealand and New Caledonia. Within

the limits if its natural range it prefers sunny habitats on loam, clay or sand-based soils. It occurs sometimes on salt-containing soils. It grows along shores of rivers and water bodies. It occurs often in synanthropic communities – both ruderal and segetal ones (FLORABASE THE WESTERN AUSTRALIAN FLORA; AELLEN 1960).

As an introduced and partially naturalised species, the clammy goosefoot occurs in Asia (New Zealand, New Caledonia, Papua New Guinea, Korea, China, Japan, Iran), Africa (South Africa, Zimbabwe, Kenya, Ethiopia, Botswana), South America (Argentina), North America (USA) and in numerous European countries (Portugal, Spain, France, England, Scotland, Belgium, Holland, Denmark, Sweden, Norway, Germany, Austria, Czech Republic, Slovakia, Poland, Ukraine, Hungary, Romania) (GLOBAL BIODIVERSITY INFORMATION FACILITY; PROBST 1949; AELLEN 1960; GLEASON & CRONQUIST 1963; BRENAN 1964; HUNZIKER 1965; HEJNÝ & SCHWARZOVÁ 1978; TRZCIŃSKA-TACIK 1992; CHYTRÝ 1993; URBISZ 1996; MOSYAKIN & FEDORONCHUK 1999; HALVORSEN *et. al.* 1998, FERÁKOVÁ 2002; MISIEWICZ & KORCZYŃSKI 2003; RAHIMINEJAD 2004; CHANG-SHAN & SHI-XIN 2006).

Chenopodium pumilio has been introduced to Europe since the late 18th century together with raw wool imported from Australia (PROBST 1949; AELLEN 1960). First records were made in the localities DÖHREN (1889) in Germany (PROBST 1949; AELLEN 1960) and NOSISLAV (1890) in Moravia (HEJNÝ & SCHWARZOVÁ 1978). In Germany, Czech Republic and Slovakia, where it has spread from its initial sites of introduction (wool spinning mills, ports, railway areas) and now occurs in fields, pastures and on river alluvia (AELLEN 1960; LHOTSKA & HEJNY 1979; DOSTALEK *et al.* 1990), it is considered to be a naturalised, but non-invasive species (LHOTSKA & HEJNY 1979; DOSTALEK *et al.* 1990; HAEUPLER & MUER 2000; ROTHMALER 2002; PYŠEK *et. al.* 2002).

The species shows a phytocoenotic optimum in Germany in plant communities from the *Sisymbrion officinalis* and *Chenopodion rubri* alliances (OBERDORFER 1990), while in the Czech Republic its optimum occurs within *Malvion neglectae*, *Polygonion avicularis* and *Sisymbrion officinalis* (DOSTALEK *et al.* 1990).

3. OCCURRENCE IN POLAND

Hitherto, only two localities of *Chenopodium pumilio* had been known:
1) port in Gdańsk – since 1974, the species has persisted along the unloading quay on the depot area and on railway grounds (TRZCIŃSKA-TACIK 1992; MISIEWICZ & KORCZYŃSKI 2003).
2) Rybnik-Piaski – in 1992, 3 individuals were found to occur on a sandy roadside, accompanied by *Polygonum aviculare*, *Plantago major* and *Chenopodium album*. In the subsequent year, the locality was destroyed due to the construction of a concrete sidewalk (URBISZ 1996; ALINA URBISZ personal communication).

A new locality of this species was discovered in 2005 in Stryków, a small town (3000 inhabitants) located ca. 15 km to the north-east of Łódź in ATPOL square DD 67 (ZAJĄC 1978). *Chenopodium pumilio* occurred together with *Digitaria ischaemum* on a strongly trampled strip of land between Stryjkowskiego street and the adjoining sidewalk. The population numbered over a dozen individuals and occupied an area of ca. 1 m^2 (Fig. 2). In 2008, the site of occurrence was partially destroyed when it was buried under a heap of sand used for construction purposes. However, two individuals survived and were able to flower and bear fruit, thus giving hope for preservation of the population of this species in the future. Herbarium documentation of the new locality was deposited in the Herbarium Universitatis Lodziensis (LOD).

4. CONCLUSIONS

It is difficult to unequivocally explain the origin of the *Chenopodium pumilio* population discovered in Stryków. In all probability it is a secondary site of occurrence where the species spread from its initial site of introduction. The strip of ground on which the goosefoot population occurs used to be a lawn in the past. Perhaps, as it was often the case in the past, in the process of its preparation soil was fertilised with wool-cleaning waste material brought from nearby Łódź. However, a doubt is raised by the fact that all wool mills in Łódź ceased their activity already

more than ten years ago and even in their last years of activity the raw material they used was wool previously cleaned elsewhere. It is difficult to presume that the discovered population could have persisted in a locality constantly vulnerable to easy destruction for such a long period of time. Furthermore, occurrence of the clammy goosefoot has never been recorded from Łódź itself despite over 40 years of intensive studies on the urban flora, even though numerous other species customarily introduced with raw wool were found to grow there (WITOSŁAWSKI 2006). Most probably the source of diaspores in this case was different.

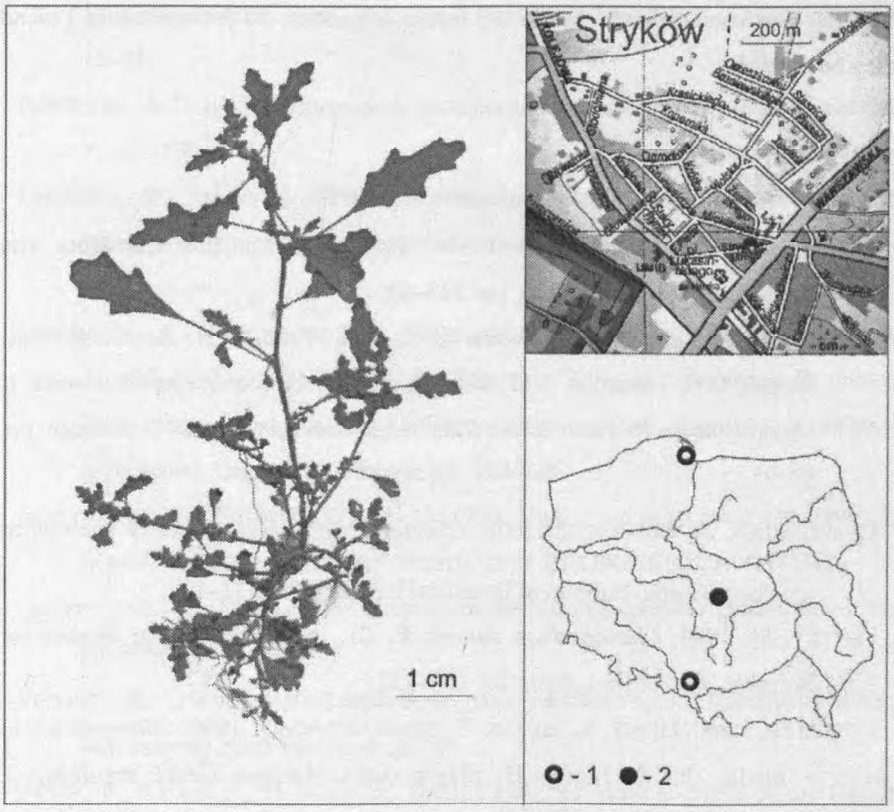

Fig. 2: Herbarium specimen of *Chenopodium pumilio* R. Br. from the locality in Stryków (leg. P. Witosławski, 19 June 2005). Location of the site of (top right) and distribution of the species in Poland (bottom right). 1 – localities known from literature; 2 – new locality of the species

MISIEWICZ and KORCZYŃSKI (2003) suggest that due to its persistent occurrence in Gdańsk *Chenopodium pumilio* should be considered a naturalised species and listed as an epoecophyte. The lack of spreading tendency of this species in Poland is explained by the less propitious climate conditions in comparison to the Czech Republic where the species has undergone expansion for an extended period of time, spreading from industrial centres predominantly along major river valleys (LHOTSKA & HEJNY 1979; TRZCIŃSKA-TACIK 1992).

Naturalisation of *Chenopodium pumilio* in neighbouring countries, its persistent occurrence in Gdańsk and the appearance of secondary sites of occurrence (Rybnik, Stryków) indicate that in the future, expansion of this species in Poland may be possible.

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