The anthropogenic mire communities of the Silesian Upland (S Poland): a case of selected exploitation hollows

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Abstract

In two exploitation hollows i.e. a sandpit and brown coal excavation of the Silesian Upland (Southern Poland) during spring and autumn of 2004, hydrological and phytosociological studies (Tab. 1) on spontaneous mire communities were conducted. It is worth emphasizing that they are an example of primary succession because plants encroached into habitats with a mineral substratum deprived of humus. Hydrological analysis of the exploitation pits, pH and the way in which the water supply does not correspond with the phytosociological diversity of formed plant communities. Numerical analysis (Fig. 1) indicated two different communities *Eriophorum angustifolium-Comarum palustre* in a water body ("Poręba") resembling fens and *Drosera anglica-Oxycoccus palustris* in a water reservoir ("Bory") resembling transitional mires. There are statistical significant differences between the frequency of fens, rush, bog and meadow species (Tab. 2). The objects studied are precious because they are refuges of many rare and protected plants.

Keywords

Mires, wastelands, exploitation hollows, vegetation succession.

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Introduction

Apart from natural factors leading to changes in the environment man's influence on the biotic and abiotic properties of environment also plays the crucial role. Human impact results in the creation of new artificial landscape forms, not only in terms of their modification. These most characteristic elements are waste-tips, dumping sites and ditches, as well as exploitation hollows. Most of these forms are associated with the exploitation of mineral sources and are harmful for environmental, economic and public health reasons (Szczypek 1997). Therefore, some reclamation practices are performed in degraded lands, designed to recover land for economic use. However, classical technical-biological reclamation is very expansive and in many cases fails (Tokarska–Guzik, Rostański 2001). Thus, many degraded areas did not become the subject of land reclamation and vegetation development there is a result of spontaneous succession. In the Polish literature, there are many examples devoted to primary and secondary succession of flora and vegetation, particularly in the following types of habitats: post coal mine heaps (Rostański 1997; Woźniak et al. 2003), lime waste heaps, solvay process tips and calamine heaps (Tokarska-Guzik et al. 1991; Cohn et al. 2001; Wierzbicka, Rostański 2002), sand-pits (Kompała-Bąba et al. 2004; Szymczyk 2000) sedimentation tanks (Woźniak 2001) as well as ditches (Molenda, Chmura 2003). Some case studies highlight the role of anthropogenic habitats as the refuges of rare plant species and stress their function in the maintenance of local biodiversity (Tokarska-Guzik 1996; Woźniak, Kompała 2000; Bzdęga et al. 2004; Bąba, Kompała 2003). The plant communities forming in anthropogenic habitats may resemble those of a semi-natural and even of natural origin. For example on post coal-mine heaps (Woźniak et al. 2003) and sand-pits (Kompała-Bąba et al. 2004), phytocoenoses of mixed coniferous forest *Querco roboris-Pinetum* were found, and in an old ditch resulting from coal mining, patches of *Fraxino-Alnetum* were encountered (Molenda, Chmura 2003). Woźniak and Sierka (2004) in their review work presented a wide array of phytosociologically identified plant communities spontaneously developed in post-exploited and degraded areas. Apart from woodland communities, there are also meadow, rush and aquatic communities. Despite this, not all were classified as plant associations or communities within higher syntaxon in relation to the Braun-Blanquet system, although many of them are precious with regard to the occurrence of rare plant species. The present study was aimed at characterizing and comparing the vegetation and hydrology of anthropogenic mires in areas not transformed by land reclamation.

Methods

The hydrogeographical mapping designed to estimate the water regime of the waste-tip, was carried out after Gutry-Korycka and Werner-Więckowska (1996). The chemical water analyses were conducted using the commonly applied hydrochemical method (Krawczyk 1999). The nitrates (V) were determined potentiometrically using a nitrate ion-selective electrode. The measure of pH and conductivity were determined by means of the Multiline P4 Universal Meter (electrode pH- Sen Tix 97/T) with a standard conductivity cell (Tetra Con 325). In the spring and summer of 2004, nine phytosociological records in plots of 25 m^2, using the commonly applied Braun-Blanquet method, were carried out and hydrological studies were performed. In relation to the small surface of mires and their heterogeneity, only 4 relevés were taken in Poręba and 5 in Sosnowiec Bory. The values of cover-abundance according to the Braun-Blanquet scale, were transformed to medians of percentage intervals according to the following scheme: r = 0.1; + = 0.5; 1 = 5; 2 = 17.5; 3 = 37.5; 4 = 62.5; 5 = 87.5. The similarity of the patches studied was determined through cluster analysis by the average linkage i.e. the unweighted pair-group method using arithmetic averages (UPGMA). Prior to the analysis the data of patches (mean percentage covers of species) were log transformed. The syntaxonomical affiliations of species were adopted after Matuszkiewicz (2001) and plant names were given after Mirek et al. (2002). Due to the small number of samples, only differences in the frequency of species representing different syntaxa were examined using the non-parametric G-test (Sokal, Rohr 1981) and by means of SAS software (SAS 2003). The differences in percentage covers of species were not analyzed. Determining the peat sediments followed Tobolski (2000).

Situation of studied objects

The sedimentation tank "Poręba" is located in the town of Poręba in the Silesian Upland (S Poland). In relation to the geographical division, the studied object is situated in the Tarnogóry Hummock (the Silesian Upland), a region characterized by Triassic dolomites and limestones in the substratum. There are also rich deposits of zinc, lead and silver. In addition there are beds of Jurrasic brown coal and iron ores (Middle Jurrasic period). Such large mineral deposits led to the environmental transformation of the area.

The sedimentation tank "Bory" is located in Sosnowiec Bory, within the Katowice Plateau, a part of the Silesian Upland. In the geological structure, carboniferous sediments, enriched with coal deposits, are covered by a layer of Quaternary sands, gravels and clays with a thickness up to several tens of meters. In the Katowice Upland, sands are a precious mineral source because they are used for hydraulic stowage purposes. Therefore, there are many sandpits in this region and the area of the largest one exceeds 1000 ha.

Results

Hydrology of water bodies

The sedimentation tank "Poręba".

This object formed due to the cessation of brown coal exploitation or fire-clays (Middle Jurrasic Period). The area of the water reservoir covers ca. 2500 m^2, although the maximum depth does not exceed 0.5 m. The exploited mineral must have been situated directly below the surface, because in the neighbourhood there are no waste-tips built by cap rock. Quite numerous are post-exploitation hollows which cover several tens of $m^{2,}$ which are flooded only during spring thaws and strong rainfalls. Some of them are filled with organic deposits. In relation to hydrology this is an interior water body supplied only by rainwater. The infiltration of water is not possible because the bottom of the pit is comprised of clays and silts.

The sedimentation tank "Bory", is a sand-pit in which exploitation of the mineral source probably ceased in the period just prior to the Second World War. During the exploitation period, the water-bearing layer was removed and hence an outflow of underground waters took place. The water was gravitationally removed as is reflected in the presence of the remnants of drainage ditches. After cessation of the exploitation, the conservation of ditches was probably stopped, resulting overgrowth forming, silting up and finally water-logging of the bottom of the hollow. However, it did not result in the creation of a water body because it is a relative shallow open pit and the bottom is hardly covered by the water-table. Taking into account the classification proposed by Żurek and Tomasiewicz (1986), this wetland can be considered as a swamped wetland supplied both with underground waters and rainfalls.

The chemistry of anthropogenic wetlands

The hydrological conditions determine the chemistry of waters in the studied objects. Factors such as type of soil and parent rocks within the direct drainage basin and methods of their use also play a role but are not so crucial. The water supply is very well shown by the electrolytic conductivity of the waters of the objects studied. The conductivity of waters in "Poręba" supplied only by rainfalls, amounted to 94 – 98 uS/cm. As Choiński (2001) reports, conductivity below 100 uS/cm is typical for distrophic water reservoirs. The conductivity of waters in "Bory", supplied both with rainfalls and underground waters, was considerably higher and ranged from 290 to 309 uS/cm. The way water was supplied to the wetlands is reflected by the hardness of their waters. The water hardness in "Poręba" varied between 1.5 – 2 ˚d, as in very smooth waters. The waters of the "Bory" wetland indicated a considerably higher level of hardness ranging from 6 to 7˚d. As far as the pH of waters is concerned, the waters of "Poręba" are a weak acid (6.1 – 6.5 pH). However, the pH range in "Bory" is higher and varied between 6.6-7.1 pH. Also, the nitrate contents are higher, up to 120 mg/dm3.

Analysis of organic sediments

In the excavations after cessation of the exploitation process, the development of the wetlands took place similarly as in natural swamped mires. The minerothrophic vegetation encroaches into the mineral substratum. In "Poręba", a thicker layer of organic material was found. There, the sand is covered by a layer of organic material 10 cm thick. The next interval (10-18 cm) is a weakly decomposed, initial layer of peat of *Sphagnum* origin (H 1). This layer is followed by organic matter (18-30 cm) produced intensively by roots. Above, lies a layer of moss-acrotelm.

Vegetation analysis

The ordination analysis of plant communities in the "Poręba" and "Bory" areas, showed that these two communities are distinctly different, despite both originating from old sand-pits (Fig. 1). These vegetation patches were described using the plant names of dominant species, because no characteristic combinations of species typical for known plant associations were observed. In "Poręba", a stand from the *Eriophorum angustifolium-Comarum palustre* community and from the *Drosera anglica- Oxycoccus palustris* community in "Bory", were used for recognition purposes. In *Eriophorum angustifolium-Comarum palustre,* the number of species ranged from 15 to 29 and the percentage cover of herb

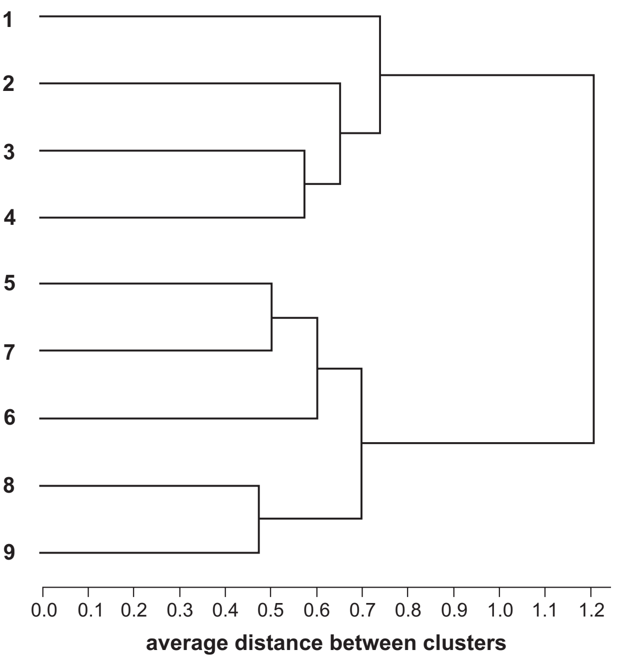

Fig. 1. The UPGMA cluster analysis of vegetation patches of anthropogenic mires. 1-4 relevés from the in exploitation hollow "Poręba", 5-9 relevés from sand-pit "Bory".

species varied from 60 to 70% (tab. 1). The percentage cover of the moss layer comprising mostly of the *Sphagnum*-species, amounted to 70-80%. In *Drosera anglica-Oxycoccus palustris* the herb layer amounted to 50 to 60% and the moss layer ranged from 70-90%.

In the plant community of "Poręba", there is smaller contribution of species representing the fens and transitional fens i.e. *Scheuchzerio-Caricetea nigrae* class, the *Caricetalia nigrae* order and lower syntaxa e.g. the *Caricion nigrae* alliance compared to the vegetation of "Bory" (tab. 2). Moreover, there is higher participation of rush species i.e. tall sedge species such as *Magnocaricion* as well as the representatives of the *Molinio-Arrhenatheretea* class. However, the patches of *Drosera anglica-Oxycoccus palustris* are characterized by a higher contribution of bog species e.g. *Vaccinium uliginosum Ledum palustre* and *Drosera rotundifolia.*

Discussion and conclusions

After cessation of the sand exploitation and stabilization of water relations, the wetlands studied underwent the processes of spontaneous succession. It is worth emphasizing that it is an example of primary

Table 1. Mires of the exploitation hollows studied.

No. of relevé		1	2	3	4	5	6	7	8	9
Area		25	25	25	25	25	25	25	25	25
Shrub cover b (%)		5	-	-	-	-	5	-	-	-
Herb cover c (%)		70	60	60	60	60	50	60	50	50
Moss cover d (%)		80	70	80	80	90	70	90	50	70
Number of species in relevé		29	24	17	19	17	24	12	13	13
		Poręba				Bory				
***Scheuchzerio-Caricetea nigrae* ChCl+*Caricetalia nigrae+Caricion nigrae* Cho,All:**										
Eriophorum angustifolium	c	3	2	2	1		1	+	1	2
Comarum palustre	c	2	2	2	3					
Carex nigra	c	1	+	1	1					
Carex echinata	c	1	1	1	1	1	1	1	+	+
Triglochin palustre	c		+	+						
Agrostis canina	c	+								
Juncus alpino-articulatus	c	+	+		+					
Carex flava	c						1	+		1
Juncus articulatus	c				+		+	+	+	+
Drosera anglica	c					3	2	3	2	2
Tofieldia calyculata	c					1	1	+	+	
Agrostis stolonifera	c						+			+
Viola palustris	c						+		+	
Pinguicula bicolor	c						+			
Parnassia palustris	c						+	+	+	
Rhynchospora alba	c					2	1	2	1	
***Oxycocco-sphagnetea* ChCl**										
Drosera rotundifolia	c	+	1	1	+	1	+	+	+	1
Oxycoccus palustris	c					2	2	2	2	2
Vaccinium uliginosum	c					+	+			
Ledum palustre	c						+			
Aulacomium palustre	d						1			+
***Vaccinio-Piceetea* ChCl**										
Pinus sylvestris	c	+		+		+	+			
Vaccinium vitis-idea	c	+	+							
***Phragmitetea* ChCl:**										
Eleocharis palustre	c	2	2	2	3					
Galium palustre	c	1	+	1						
Peucedanum palustre	c	1	+	1	1					

Phalaris arundinacea	c	+								
Carex vulpina	c	+	+	1	+					
Phragmites australis	c								2	2
***Molinio-Arrhenatheretea* ChCl:**										
Cirsium palustre	c	+		+						
Equisetum palustre	c	3	2	2	2					
Juncus effusus	c	1	+		+					
Juncus conglomeratus	c	1		+						
Molinia caerulea					+				1	
Linum catharticus					1	+				
Sporadic species: *Scirpus sylvaticus* 1(1), *Lysimachia vulgaris* 1(1)										
Accompanying species:										
Betula pubsecens	b	1					1			
Betula pubsecens	c	+	+		+	1	+			+
Salix cinerea	b	1		+						
Frangula alnus	b	1	+							
Frangula alnus	c	+	+			+				
Salix caprea	c	+	+							
Juncus bulbosus	c		+							
Potentilla erecta	c	+	+		+	1	1			
Calluna vulgaris	c					+		+		
Dryopteris carthusiana	c		+			+				
Alnus glutinosa	c					+	+			
Sphagnum fallax	d	5	4	5	4					
Sphagnum denticulatum	d				1	5	4	5	3	4
Calliergon stramineum	d		1	+						
Polytrichum commune	d		1		1					
Sporadic species: *Trientalis europea* 5, *Acer pseudoplatanus* c 6, *Lycopus europeus* 6, *Sparganium minimum* 9										

Table 2. Comparison of statistical probability (P) of no difference between mires studied in relation to average number of occurrences of species from syntaxonomical groups. (* – p<0.05, ** – p<0.01, *** – p<0.001, ns – non significant). Percentage was shown.

	Poręba	Bory	G
Average number of species per relevé	22.25 ± 5,37	15.8 ± 5,0	
Scheuchzerio-Caricetea nigrae (%)	26.7	46.8	7.183**
Oxycocco-sphagnetea (%)	4.7	19.0	8.483**
Phragmitetea (%)	18.6	2.5	12.091***
Molinio-Arrhenatheretea (%)	17.4	2.5	10.874***
Other (%)	30.2	25.3	ns

succession, because plants encroached into habitats with a mineral substratum deprived of humus. The development of anthropogenic wetland along the bank zone of the sandpit hollow "Poręba" is similar to the development of mires of land-formed lakes. Thus, it is an oligothrophic water body; where the water table is covered by a layer of living Sphagna species. There are characteristic species which due to root systems can grow, so forming a "pillow" for the development of moss species. In summarizing the geobotanical studies: these two distinct plant communities differ in the contribution of meadow rush and bog as well fen species. However, they are hard to classify objectively as raised bogs, transitional or fen communities. The mire community in "Bory" resembles a raised bog, but apart from acidophilous plants such as *Drosera rotundifolia* and *Rhynchospora alba,* there are also *Parnassia palustris* and *Tofieldia calciculata,* both calciphilous species. The hydrological analysis of the exploitation hollows, i.e. pH and way of water supply takes, not correspond with the phytosociological differentiation of the communities (Tobolski 2000). However, the genesis of this phytocoenoses is the result of phenomena which do not resemble natural processes. Furthermore, in wastelands and anthropogenic riparian habitats, natural or semi-natural communities, easy classified in a phytosociological way to syntaxa of low rank, are rarely found. Woźniak and Sierka (2004) did it in their review devoted to plant communities of anthropogenic habitats present in mire communities but only in the rank of communities of the Scheuchzerio-Caricetea nigrae class**.**

Moreover, the syntaxonomy of mires, fens and bogs requires further studies (Matuszkiewicz 2001). In spite of syntaxonomical problems, the two exploitation hollows studied are precious because they are refuges of many rare and protected plants. In these objects many protected plant species were found and were the endangered species *Drosera anglica* and two vulnerable species i.e. *Drosera rotundifolia* and *Pinguicula bicolor* (Zarzycki et al. 2002).

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REFERENCES

Bąba W., Kompała A. 2003. Piaskownie jako centra bioróżnorodności (The sandpits as centres of biodiversity). Środowisko i Rozwój 7: 85-101.

Braun-Blanquet J. 1964. Pflanzensoziologie, Grundzuge der Vegetationskunde 3 Aufl. Wien-New York Springer Verl.

Bzdęga K., Pasierbiński A., Chmura D. 2004. Rola hałd pogórniczych w utrzymaniu regionalnej różnorodności florystycznej Górnego Śląska (The role of post-coal mine heaps in the maintenance of regional floristic diversity in the Upper Silesia). Chrońmy Przyr. Ojcz. 60, 2: 17-33.

Choiński A. 2001. Jeziora kuli ziemskiej. (Lakes of Earth). PWN, Warszawa (in Polish).

Cohn V. J., Rostański A., Tokarska-Guzik B., Trueman I.C., Woźniak G. 2001. The flora and vegetation of an old solvay process tip in Jaworzno (Upper Silesia, Poland). Acta Soc. Bot. Pol. 70, 1: 47-60.

Gutry-Korycka M., Werner-Więckowska H. 1996. Przewodnik do hydrograficznych badań terenowych (A guide for hydrological studies). PWN, Warszawa (in Polish).

Kompała-Bąba A., Bąba W., Błońska A. 2004. Forest communities in the „Kuźnica Warężyńska" sandpit. Uniwersytet Zielonogórski, Inżynieria Środowiska, Zesz. Nauk. 131: 197-204.

Krawczyk W.E. 1999. Hydrochemia (Hydrochemistry). Wydawnictwo Univ. Śl, Katowice (in Polish).

Matuszkiewicz W. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski (A guide to plant communities of Poland). PWN, Warszawa (in Polish).

Mirek Z., Piękoś-Mirkowa H., Zając A., Zając M. 2002. Flowering plants and pteridophytes of Poland. A checklist. W. Szafer Institute of Botany, PAS.

Molenda T., Chmura D. 2003. Przykład spontanicznej sukcesji roślinności na terenie starego wykopu w Mikołowie-Gniotku (Example of spontaneous succession of vegetation in the area of old excavation in Mikołów – Gniotek town). Arch. Ochr. Środ. 29, 2: 49-56 (in Polish with an English summary).

Rostański A. 1997. Flora spontaniczna hałd Górnego Śląska (Spontaneous flora of waste heaps of the Upper Silesia). Arch. Ochr. Środ. 23, 3-4: 159-165 (in Polish with an English summary).

SAS 2002–2003. SAS/STAT, Release 9.1. SAS Institute Inc., Cary, NC, USA.

Sokal R. R., Rohlf F. J. 1981. Biometry: The Principles and Practice of Statistics in Biological Research, Second Edition. W.H. Freeman and Company, San Francisco.

Szczypek T. 1997. Warunki naturalne (Environmental conditions). In: K. Rostański (Ed.). Przyroda województwa katowickiego (The nature of Katowice province). Wyd. Kubajak, Krzeszowice: 5-16 (in Polish).

Szymczyk A. 2000. Uwarunkowania siedliskowe sukcesji roślinności na wyrobiskach po eksploatacji piasku (The biotopic causes of vegetation succession in sandpits). PhD thesis, WNoZ, Univ. Śl. Sosnowiec (in Polish).

Tobolski K. 2000. Przewodnik do oznaczania torfów i osadów jeziornych (A guide for determination of peat and lake sediments). PWN, Warszawa (in Polish).

Tokarska-Guzik B. 1996. Rola hałd zasadowych w utrzymaniu lokalnej bioróżnorodności. (The importance of lime waste heaps in maintenance of local biodiversity). Przegląd Przyrodniczy 7, 3-4: 261-266 (in Polish with an English summary).

Tokarska-Guzik B., Rostański A. 2001. Możliwości i ograniczenia przyrodniczego zagospodarowania terenów poprzemysłowych (Prospects and limitations of natural management of post-industrial areas) Natura Silesiae Superioris, Centrum Dziedzictwa Przyrody Górnego Śląska, Katowice: 5-17 (in Polish with an English summary).

Tokarska-Guzik B., Rostański A., Klotz S. 1991. Roślinność hałdy pocynkowej w Katowicach-Wełnowcu. (Vegetation of the zinc smelter spoil heap in Katowice-Wełnowiec). Acta Biol. Siles. 19, 36: 94-102 (in Polish with an English summary).

Wierzbicka M., Rostański A. 2002. Microevolutionary changes in ecotypes of calamine waste heaps vegetation near Olkusz, Poland a review. Acta Biol. Cracov. Ser. Bot. 44: 7-19.

Woźniak G. 2001. Flora roślin naczyniowych osadników ziemnych wód kopalnianych – nieużytków poeksploatacyjnych na terenie Górnego Śląska (Vascular plants flora of the coal mine underground water sedimentation pools - post-industrial wastelands in the Upper Silesia). Centrum Dziedzictwa Przyrody Górnego Śląska. Materiały i Opracowania 6: 1-48. Katowice (in Polish with an English summary).

Woźniak G., Kompała A. 2000. Gatunki chronione i rzadkie na nieużytkach poprzemysłowych (Protected and rare species on post-industrialized wastelands). Problemy środowiska i jego ochrony cz. 8. Centrum Studiów nad Człowiekiem i Środowiskiem Univ. Śl.: 101-109 (in Polish).

Woźniak G., Pasierbiński A., Rostański A. 2003. The diversity of spontaneous woodland vegetation on coals mine heaps of Upper Silesia Region. Arch. Ochr. Środ. 29, 2: 93-105.

Woźniak G., Sierka E. 2004. Importance of spontaneous succession in reclamation processes. Uniwersytet Zielonogórski, Inżynieria Środowiska, Zesz. Nauk. 131: 391-398.

Zarzycki K., Trzcińska-Tacik H., Różański W., Szeląg Z., Wołek J., Korzeniak U. 2002. Ecological indicator values of vascular plant of Poland. W. Szafer Institute of Botany, PAS.

Żurek S., Tomaszewicz H. 1996. Badania bagien (Studies on swamps). In: M Gutry-Korycka., H. Werner-Więckowska. Przewodnik do hydrograficznych badań terenowych, (A guide for field hydrological studies). PWN, Warszawa (in Polish).