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ENVIRONMENTAL EVALUATION FOR REGIONAL PLANNING AND MANAGEMENT: THE UPPER SILESIA CASE STUDY

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Abstract. In this paper authors have presented main methodical criteria which were used to cartographic valorisation of the Silesian Voivodship. Besides, the following environmental components: mining resources, surface and ground waters, and legally protected nature elements, were covered by valorisation. On the base of the impact degree of special threats to the three environment components: anthroposphere, hydrosphere, and biosphere, three anthropopressure maps were constructed. Four classes of conflict areas of various threats degree (A – very high, B – high, C – medium, D – low) were distinguished on these maps. The maps of anthropopressure were compared with the distribution map of the Silesian Voivodship most valuable resources; in that way, the areas requiring special protection against the anthropogenic hazards were delineated..

Key words: valorisation of environment, maps of anthropopressure, Silesian Voivodship.

Abstrakt. W artykule przedstawiono podstawowe założenia metodyczne przyjęte dla przeprowadzenia waloryzacji kartograficznej obszaru województwa śląskiego. Waloryzację przeprowadzono dla następujących komponentów środowiska: kopalin, wód podziemnych i powierzchniowych oraz przyrody prawnie chronionej. Na podstawie stopnia oddziaływania (antropopresji) poszczególnych zagrożeń na trzy sfery środowiska: antroposferę, hydrosferę i biosferę uzyskano trzy mapy sumy negatywnych oddziaływań, które pozwoliły na wyróżnienie czterech klas obszarów o różnym stopniu konfliktowości (A – bardzo wysoki, B – wysoki, C – średni, D – niski). Porównanie tych map z mapą rozmieszczenia najcenniejszych zasobów przyrody w województwie śląskim pozwoliło na wskazanie terenów wymagających szczególnej ochrony ze względu na występujące tam zagrożenia pochodzenia antropogenicznego.

Słowa kluczowe: waloryzacja środowiska, mapy antropopresji, województwo śląskie.

INTRODUCTION

The Upper Silesian Conurbation (5,555 km^2) has more than 3 million inhabitants. Since medieval times, shallow deposits of zinc and lead ores, with silver content, were mined here, and since the 1700s, there began intense exploitation of very rich coal beds. In the 20th century, the Upper Silesian Coal Basin was among the largest European mining and industrial centres. At the peak of the industrial development, in the 1970s, the annual coal output reached 200 million tons while that of zinc and lead ores exceeded 3 million tons. Earlier, also iron ores were exploited north of the Basin, as were huge quantities of rock material, e.g. sands for mining and carbonates for metallurgy. Over 30% of the national electric power was produced there, and iron and non-ferrous metallurgy as well as various branches of metal and chemical industries developed.

About 15 years ago, a socially difficult process of restructuring the Upper Silesian mining and industry began. Dozens of coal mines were closed down, and the annual coal output dropped to about 100 million tons. Within the next five years, the coal production will be reduced by further 10% to 15%. Zinc and lead ores mining is in decline, and the last Zn–Pb ores mine is to be decommissioned by 2008–2010, in the eastern part of the Basin. Major restructuring of steel metallurgy

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is under way, and new industrial branches, like car industry, are being developed.

The past and still continuing extremely intense exploitation of the Upper Silesian natural environment has led to its drastic transformation and, in many cases, resulted in its heavy degradation. The landscape as well as surface and ground waters were the most affected environmental elements by man's pressure. The regional parliament of the Silesian Voivodship (Province), established in its current shape in 1999, after the territorial reform of Poland, has to consider the principles of the sustainable development when restructuring the area. Major aspects to be taken into account in regional planning are: protection of biotic and abiotic natural environment, improvement of the population's living conditions, and revitalising degraded areas.

Throughout the Upper Silesia, dozens inventories of environmentally hazardous objects were assembled, various monitoring projects yielded thousands of data on the conditions of particular environmental components (ground and surface waters, air, soil, vegetation, and so on), dozens of specific environmental assessments were made, but an overall analysis and complex synthesis dealing with the Upper Silesian region was still lacking. Most regional geoenvironmental assessments stopped at the inventory stage or, at most, included an evaluation carried out in accordance with the binding legal standards. There are a few cartographic studies, only, especially in digital formats.

The main objective of the former authors was to evaluate the environmental resources, estimate the anthropopressure on their particular components, and then identify the conflict areas. Due to local specificity, the main attention was paid to the impact of mining and related processing industry. An important consideration was that the final results of the study were fully useful for the regional authorities, fitting their requirements both in scope and in technical aspects (software, scale of study, database update procedures, etc.), and were available for regional developmental planners of the province (Sikorska-Maykowska *et al.*, 2001; Sikorska-Maykowska ed., 2001).

METHODS OF THE ENVIRONMENT VALORISATION

As the basis for further analyses, the following environmental components were evaluated: mining resources, surface and ground waters, and legally protected nature elements (national parks, landscape parks, nature reserves, areas of protected landscape, nature monuments, and ecological lands). For the critical re-evaluation of mineral resources, an extensive experience of the Polish Geological Institute was applied, especially as far as the assessment of coal resources in Poland was concerned (Kwarciński *et al.*, 2001). Analyses of the Silesian Voivodship water resources were performed in co-operation with the Faculty of Earth Sciences, University of Silesia.

Surface waters posed a major problem during the environment evaluation. Other components were assessed using clear criteria, repeatedly discussed in the literature, and applied in practice; the weight scales for particular characteristics had to be decided, only. With surface waters the proper assessment was not so simple. The easiest way would be to restrict the project to presentation of the rivers water quality in accordance with the national monitoring system. However, the surface waters deserved a special treatment due to the Upper Silesian specific conditions connected with centuries of strong impact of mining and associated industry, and intense human settlement. Thus, in the Upper Silesia several special aspects had to be taken into account, as well. They were as follows:

- abundance of catchments,
- long distance water transfers,
- sewerage extent,
- participation of other regions water in the surface flows,
- artificial reduction of flows,
- impact of the terrain subsidence caused by mining on the regime and directions of surface water flows changes.

The analyses of existing data revealed a clear tripartite hydrological division of the Silesian Voivodship, allowing to discern three regions. Their specificity was taken into account when collision zones were identified, and in the final synthesis for the identification of the most environmentally valuable areas. Additionally, land use analyses were performed on the base of Landsat TM satellite scenes. They were performed with the ERMapper 5.5 software, and the least distance method was used, as well. The study enabled evaluation of the afforestation degree, and direction of the development and expansion of urban-industrial agglomerations.

The following categories of land use were included in the maps:

- surface waters,
- marshes and wetlands,
- meadows,
- farmland (cultivated fields, fallow fields, wasteland),
- sandy areas without vegetation cover,
- shrubs (areas with dispersed bushes and deciduous trees),
- coppices — mostly birch (mainly along forest edges and in areas destroyed by forest fires),
- forests: deciduous, mixed, conifer,
- built-up areas and infrastructure,
- mine waste dumps.

To estimate chemical pollution of soils and grounds, results of soil content determinations for more than 20 elements, made by the Polish Geological Institute during the years 1991–1995, were used. Samples were collected from the depth of 0–20 cm below surface, in a 5x5 km grid. For the 6,290 km^2 area of the Upper Silesian Coal Basin, a finer sampling grid was used (2x2 km). The cartographic picture of soil pollution based upon these data was sufficient for a regional study (1:200,000) of the Upper Silesian Conurbation, while for the rest of the province, it has been treated as an indication, only.

Higher concentrations of many elements in the Silesian Voivodship soils are both a heritage of many centuries of mining exploitation and processing, especially of zinc and lead ores, and an effect of the geological structure of the area, especially sub-Quaternary outcrops of the Middle Triassic carbonate rocks enriched in zinc, lead, cadmium, and silver.

To estimate the degrees of anthropopressure on the environment, a matrix of studied impacts of analysed threats on selected environmental components has been constructed (Table 1) with arbitrarily attributed weights, i.e. intensity of impact. The analyses of pressures acting on particular environmental components were related to the three basic realms: the anthroposphere (impact on human comfort and life quality), hydrosphere (impact on surface waters) and biosphere (impact on living nature).

A classification of the Silesian Voivodship groundwater into classes A to D (Sikorska-Maykowska ed., 2001) based on methods proposed by Paczyński (1996), later developed and adapted to the Upper Silesian specific conditions (Różkowski, Kowalczyk, 1997; Witkowski *et al.*, 1998, 2000). It was performed with the use of the previously prepared characteristics, serving as evaluation criteria, presented in Table 2:

- degree of the aquifer hazard risk (a),
- module of available resources (b),

Table 1

Matrix of environmental impacts

ENVIRONMENTAL COMPONENTS		ENVIRONMENTAL HAZARDS																	
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
National park		+	+	++	+++	++	++	++	+++	++	++	++	+++	++	+++	++	++	+++	++	+
Nature reserve			+	+++	+++	+++	+++	+++	+++	+++	+++	++	+++	+++	+++	+++	++	+++	+++	+
Landscape park				+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
Area of protected landscape				+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
Park protection zone				+	+	+	+	+	+	+			+		+	+		+		
CORINE refuge		+	+	++	+++	++	++	++	+++	++	++	++	+++	++	+++	++	++	+++	++	+
Nodes of ECONET	I		+	++	++	+	+	+	++	+	+	+	+	+	+	+	+			
	N		+	+	+	+	+	+	+			+		+	+		+			
ECONET corridors	I		+	++	++	+	+	+	++	+	+	+	+	+	+	+	+			
	N		+	+	+	+	+	+	+			+		+	+		+			
Ground water	Class A			++	+++	+++	+++	+++	+++	+++	++	++	+++	++	++		++	+	+	+
	Class B				++	++	++	++	++	++	++	+	++	+	++		+			
	Class C				+	+	+	+	+	+	+		+							
	Class D				+		+	+	+	+			+							
Rivers head-streams areas				+	++		++	++	+++	+++	+	+++	+	+	+		+	++		
Protected soils				+	++	+	+	+	++	+					+			++		
Other farmland				+	+	+	+	+	+	+					+			+		
Forests				+	+	+	+	+	+	+					+			+		
Cities		+++	+++	+++	+++		+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+	+++	+++
Other built up areas		+++	+++	+++	+++		+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+	+++	+++
Prospective areas for mineral resources					++				++	++			++	++			+			

Column no.: 2 – subsidence, 3 – mining shocks, 4 – flooding, 5 – mines waste dumps, 6 – depression sinks, 7 – abandoned shallow mines, 8 – open cast mining, 9 – industrial waste sites, 10 – municipal landfills, 11 – industrial treatment plants, 12 – sewage treatment plants, 13 – industrial plants hazardous to environment, 14 – potentially polluting plants, 15 – dust and gas emissions 16 – noise, 17 – transportation impact, 18 – soil pollution, 19 – impact of accidental wave, 20 – impact of flood wave

I – international; N – national; + – low impact; + + – high impact; + + + – very high impact

Table 2

Groundwater valuation criteria for the first usable aquifer

Factor	Score points	Weight (w)
1. Hazard risk (**a**)		$w_1 = 2$
high	1	
medium	2	
low and very low	3	
2. Module of available resources (**b**) [m^3/d]		$w_2 = 1$
<100	1	
100–200	2	
200–300	3	
300–400	4	
3. Valuation class of MGWR (**c**)		w_3
A – highest		2
B – high		1.75
C – medium		1.5
D – low		1.25
Outside MGWR		1
4. Water quality (**d**)	no points	no points
satisfactory		+
unsatisfactory		–

• water quality with regard to their consumption and the value of Major Groundwater Reservoir (MGWR; Polish: GZWP) (c).

The evaluation involved superimposing of susceptibility maps and maps of module of available resources in aquifers. This allowed delineating overlapped areas for which point scores were assigned, for both elements. The value of a discerned aquifer fragment was attributed using the following formula:

$$W= (aw_1 + bw_2)c$$

A factor c >1 was employed to strengthen the weight of those aquifer fragments that have an MGWR status, which is higher than that of ordinary usable aquifers. The evaluation of an aquifer with this formula yields scores ranging from 3 to 20 points. The obtained scores served as a basis for dividing the usable aquifers (and the MGWRs) into four value classes:

>15 points Class A – highest value,
10–15 points Class B – high value,
5–10 points Class C – medium value,
<5 points Class D – low value.

An additional criterion, decisive for the final evaluation of a given aquifer fragment, was its water quality presented in the water quality map. When the water quality measured at monitoring sites was satisfactory, i.e. fulfilled the standards for potable waters, then the value class was assigned according to the point score. When, however, the water quality was unsatisfactory, the aquifer was given a class lower by one rank from that calculated as point score. The results of valuation of the first usable aquifer are presented in the Figure 1. These detailed analyses allowed for a rational evaluation of the Upper Silesian Voivodship groundwater and determination of the degree of anthropogenic factors threats.

MAPS OF CONFLICT AREAS

Three maps were subsequently produced presenting the total anthropopressure impacts on various environmental components, and then these maps were compared with a map showing distribution of the province most valuable natural resources, current land use, and land management plans delineating functional-spatial areas. This synthesis allowed to establish the following four classes for areas differing in the conflict intensity degree:

A — very high,
B — high,
C — medium,
D — low.

Class A — area of very high anthropopressure on the anthroposphere and hydrosphere, and high pressure on biosphere, mainly as an effect of exploitation and processing of coal and zinc-lead ores. Here the negative impact of industry on water catchments is strongest: in surface watercourses over 75% of flows are allochthonous, discharged mainly from mines. Also the environmental impact of shallow mining of zinc and lead ores is most pronounced here, out of the whole Upper Silesian Coal Basin. Very strong impact by the underground coal mining results in the presence of numerous industrial waste dumps, groundwater inundation and flooding, as well as in terrain subsidence. Exploitation of coal and zinc-lead ores, involving prolonged drainage of mines, created for instance, extensive regional depression sinks in Carboniferous and Triassic strata. Together, the aforementioned negative impacts have caused very heavy soil pollution: about 90% of soils fit no standards and can only be recultivated.

Class B — areas of high and very high anthropopressure, mainly due to the operation of coal mines and numerous industrial plants, as well as to the still very intense environmental impact of former shallow coal mining (exploitation down to 80 m depth).

Centuries of mining in Carboniferous strata caused the formation of two major depression sinks extending over the whole Upper Silesian Industrial District (USID) and the Rybnik Coal District (RCD). In these areas, strong anthropopressure has its impacts also on flows in surface watercourses, with allochthonous waters exceeding 50% there. Soil condition in these areas is varied. Large majority of soils (over 70%) will be manageable after recultivation, only, while the less polluted soils would be suitable mainly for housing development and parks.

Class C — areas surrounding the USID with predominantly medium and high anthropopressure, mainly due to coal mining and numerous industrial plants. The negative impact of coal mining is lower here than in the central and northern

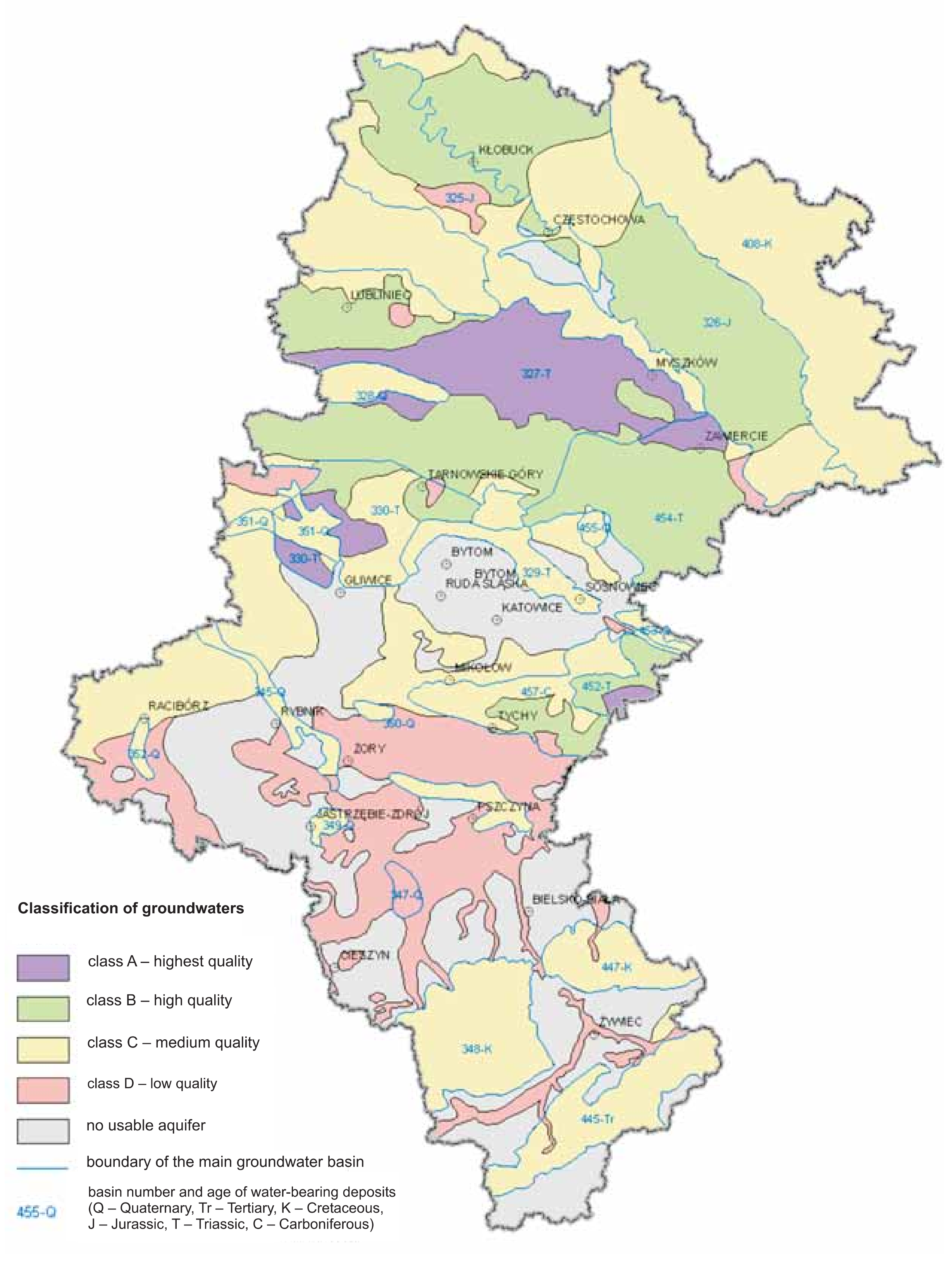

Fig. 1. Valorization of groundwaters

parts of the USID because there are fewer active mines there. However, there are many unexploited coal resources there which should be regarded as the potential reserves for future exploitation. The effects of underground mining cause in the area especially the subsidence risk, and to a lesser degree, inundation and flooding. The presence of numerous industrial and municipal waste storage sites has also its impact. Post-mining anthropopressure is visible also in modified flows in surface watercourses, with 25–75% share of allochthonous waters.

In areas with medium conflict severity, situated farther from the USID, the anthropopressure is local and related to the individual pollution sources, such as industrial waste sites resulted from exploitation and processing of coal and zinc-lead ores and the operation of industrial plants, especially extremely arduous for the environment cement works. Within the area of former exploitation of iron ores, the negative consequences of that mining are still felt, with predominantly medium and low level of anthropopressure.

Class D — mostly small areas with low and medium intensity of anthropopressure caused by indirect impact of the general infrastructure of coal and zinc-lead ores mining industry, of individual industrial plants, and of waste storage sites, especially the industrial ones. Most areas recognised as those of low conflict are located within the extent of aquifers of highest (Class A) and high (Class B) values. According to the applied classification, vast majority of soils in the discussed areas is suitable for housing development, parks, and for agricultural purposes.

To further characterise, and consequently, evaluate the local environment, areas of the Silesian Voivodship with the most valuable natural resources were determined. The criteria included presence of best quality groundwater, necessity of surface waters protection, occurrence of the most valuable mineral resources (coal, zinc and lead ores, dolomites), and nature protection areas selected for the CORINE and NATURA 2000 programs. The analyses allowed to identify, except for areas requiring special treatment due to anthropogenic hazards, also areas needed protection because of their natural values.

RESULTS

The study resulted in creation of a huge digital geoenvironmental database, supplemented by in-depth analyses and synthesis of natural environment and industrial-mining influences. The major covered topics included:

- assessment and evaluation of mineral resources,
- assessment and evaluation of the surface and ground waters resources,
- legally protected nature resources, systems CORINE and NATURA 2000,
- the most valuable environmental resources of the province,
- land use mapping (satellite scenes interpretation),
- geochemical conditions of soils (interpretation aimed at possibilities of land management),
- identification of the areas most influenced by mining and industry,
- delineating conflict areas.

The study results have been included into the Regional System of Spatial Information (RSIP) of the Silesian Voivodship. They allow local authorities to give answers to many environmental questions, and to help in strategic decision making. The conclusions of the environmental evaluation and assessment of the anthropopressure degree will be taken into account in economic policy, spatial planning, or more generally, in environmental and spatial management of the province. The study was run in a GIS system, using ARCINFO software (as preferred by the intended users), with a complex relational database.

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