

**POST-MINING LANDSCAPE ECOLOGY - ANALYSIS OF  
SELECTED PROBLEMS, THE CASE OF ADAMÓW  
BROWN COAL BASIN**

Katarzyna FAGIEWICZ\*

Faculty of Geographical and Geological Science

Department of Integrated Geography, Adam Mickiewicz University in Poznań

The paper presents the main problems of the development of post-mining area landscapes, which are due to the ignoring or including, to a small extent, the environmental criteria in the process of reclamation. It refers to the newly shaped elements (forests, meadows, reservoirs, arable land), which create the ecological structure of post-mining landscape, and in particular their spatial distribution, structural and functional integrity with the areas not transformed by mining. On this basis, the principles of shaping the ecological structure of post-mining areas were formulated, which should become a code for good reclamation practice.

Keywords: post- mining landsapes, landscape ecology, reclamation

## **1. INTRODUCTION**

The natural environment is a system which combines two basic categories of geographical space: the natural environmental system and anthropogenic environmental system which is formed as a result of human activity. In the precincts of Turku, anthroposphere is mainly the result of processes related to the opencast exploitation of lignite, and the post-mining landscape with its distinctive character (external and internal dump, final excavation) is their visualization. Its structure and functioning depend on the direction and strength of the interaction between post-mining geosystems and system of natural environment. Therefore, the post-mining areas are the element of the system of natural environment and require a systematic approach at all stages of their development. For the geographic space, the stage of reclamation and development is the most important, as it restores the environment bringing

---

\* Corresponding author. E-mail: [kfag@amu.edu.pl](mailto:kfag@amu.edu.pl)

round the areas which were temporarily out of use and degraded due to exploitation. The policy of reclamation directions defines the types of new elements of landscape structure, which determines the shape and character of the post-mining areas. Mutual relations between the new elements of the structure as well as the relationship between the new elements of the structure and the environment decide how quickly the post-mining area should reach a new secondary equilibrium and take up new environmental, economic and social functions.

Observation of the processes of reclamation and development of post-mining areas in Poland, which have been taking place in recent decades, indicates a high level of adopted solutions of technical and biological reclamation. Optimization of reclamation methods focuses primarily on the criterion of the quality delivered in land use. The result is a full-fledged land, characterized by beneficial physico-chemical properties that create good conditions for the development of crops as well as forests. In the process of reclamation, however, the ecological criteria, to a certain extent, are ignored or taken into account. It refers to the principles of the spatial distribution of the newly emerging structures, their structural and functional integrity. This is particularly important in the case of multi-open-cast mines (KWB "Adams", KWB "Konin"), where the exploitation of lignite is carried out within a few, distributed spatially mining areas.

The purpose of this study is to identify the problems in the development of post-mining areas and an indication on the basis of the principles of the planning system; taking into account the ecological conditions of post-mining landscapes. This issue shall be illustrated by case study examples of reclamation of the post-mining areas of Adamowski Brown Coal Basin, where mining activity has been carried out for more than 50 years now. Opencast lignite exploitation is being carried out within the two mining areas "Adamów", and "Kozmin" while exploitation has been completed in "Bogdałów" and "Władysławów" open-cast mines. Since the beginning of mining until the year 2009, 928 hectares of land were reclaimed for forestry, 2185.00 for farming and 514 hectares for water or other resources [5]. The post-mining area in the precincts of Turek is 3627 hectares (36.27 km<sup>2</sup>).

## **2. THE PROBLEMS OF DEVELOPING POST-MINING AREAS FROM THE POINT OF VIEW OF LANDSCAPE ECOLOGY**

Landscape Ecology is a science that studies the components of the landscape and the ongoing relationship between them [8] and in particular spatial relations. Ecology of the landscape assumes that the spatial structure and configuration of the landscape play an important role in the conservation of

biological diversity as they determine the possibilities for survival and spread of particular species [9, 4, 2]. Thus, the landscape ecology research focuses on the natural elements of the landscape, and in particular on their size (area), quality, distribution in space and the spatial cohesion resulting from this distribution. Analysis of the structure and configuration of the reclaimed post-mining areas, taking into account the above mentioned features, provides a basis for identifying problems that affect the functioning of post-mining landscapes. The most important ones are the following:

### **2.1. Limiting the concept of reclamation and management to the degraded areas through the process of exploitation**

Post-mining areas with natural structures created by the process of reclamation, with internal and external relationships determining their functioning, are specific post-mining geoecosystems. Post-mining geosystem, even though it is man-made from the "terra nova" point of view, is not to be seen as an individual spatial unit, but as part of a greater whole, a component of the natural environment. In such a system approach, where the relations between particular elements are important, the reclamation plans should be linked with the environment and the spatial structure which surrounds the reclaimed area ("background environment") taken into account. That is because the environment affects various elements of post-mining geosystems and, furthermore, it has impact on the environment. The projects of reclamation of the open-pit mines clearly highlights the problem. The paths of reclamation are outlined within the borders of post-mining areas, while the information on the surrounding is limited to the presentation of situational elements in the form of roads or waterways. Thus, ignoring land cover types important for the functioning of the environment in particular, the elements forming the ecological structure of the area. Such an approach towards the reclamation process of the areas permanently altered by the process of exploitation is not conducive for adaptation in the natural environment, but emphasizes alienation and distinct new forms. It also contradicts the idea of temporary exclusion of the areas from being used and their re-inclusion into the functioning of the natural environment.

### **2.2. Lack of spatial connectivity of post-mining geoecosystems and the presence of natural geoecosystems in their surroundings**

Spatial connectivity of the landscape is defined as the completeness of the natural resources that build ecological structure, enabling the maintenance of functional relationships between particular elements of that structure.

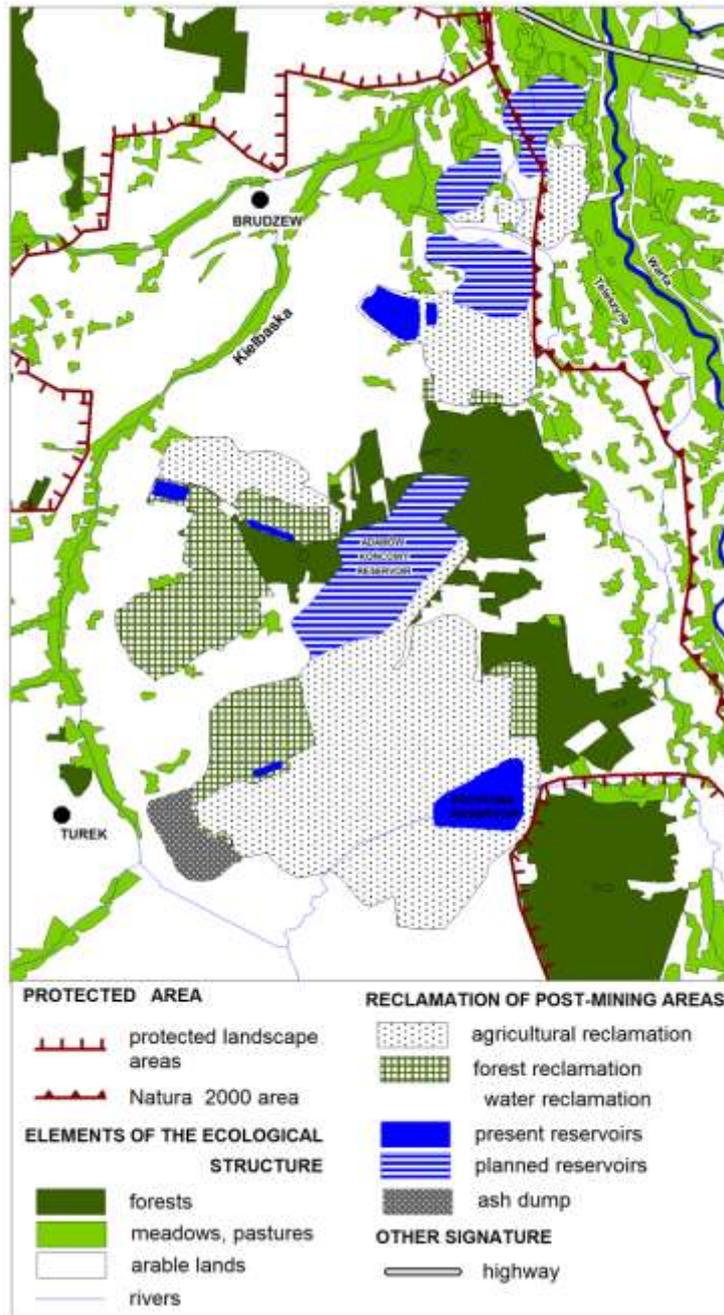


Fig. 1. Spatial distribution of post-mining geosystems against the ecological structure of the Adamów mining area (source: own work)

In the assessment of spatial connectivity of post-mining landscapes it is particularly important to assess the ecological relationships (continuity and discontinuity) between the post-mining geosystems created as a result of reclamation and natural geosystems located in their surroundings.

The basis for this assessment is the analysis of the spatial distribution of post-mining geosystems against the basic forms of land use, particularly important for the preservation of the ecological balance and biodiversity: forests, meadows and pastures, river valleys, reservoirs, protected areas (Fig. 1), occurring in the vicinity of open-pit mines. It allows for the identification of areas that need reshaping in order to restore, or maintain the spatial coherence of the natural system of pre-and post-mining areas. While shaping the post-mining landscapes, one should strive to protect main natural structures (large stands, the major ecological axis). However, if the conditions of deposit exploitation require elimination of such structures, one should, at the stage of reclamation place priority on rebuilding the lost land and its relations, as a result of the exploitation. Not taking into account these principles may result in the deepening of the problem of degradation of habitats and fragmentation of the natural matrix within the post-mining areas. The principles of reclamation of post-mining areas which take into account the issue of reconstruction of the ecological structure and development of ecological connections will be discussed under the example of the "Adamów" open-pit mine in the final part of the paper (Fig. 2).

### **2.3. The shaping of the structure of using the catchment of newly constructed reservoirs, which is unfavorable for water protection**

Reclamation plans for the post-mining area of "Adamów" mine imply water reclamation of about 26% of the excavation area [5]. Three reservoirs Bogdałów, Przykona and Janiszew were given out to be used, and there are plans to build other five reservoirs until the end of exploitation period in this area (2023). For the sake of protecting them, it is important to develop, in the process of multi-direction reclamation, the most favorable structure of catchment use, particularly in the immediate vicinity of the reservoir. Biological reconstruction of the river bank zone by planting herbaceous vegetation, shrubs (willow scrub - alder, willow - poplar) and trees (reforestation) in a system depending on the functions carried out by the particular reservoir will prevent water erosion, which is the cause of the movement of the slime material in the catchment. Foliage around the reservoir creates the so-called biogeochemical barrier, which limits the flow of mineral matter (NPK-fertilizers, plant protection chemicals) into water, which supports its protection against pollution and eutrophication [6, 7].

Around the completed Przykona and Janiszew reservoirs no buffer zones were created. Surrounding the reservoirs is an open space, partly covered by sod of the synanthropic character, and partly devoid of vegetation, where one can observe the intensification of the processes of wind and water erosion. It also applies to the southern part of the Przykona reservoir which is intended for recreational use, where the sandy-grass sunbathing zone goes directly into a zone of allotment gardens and recreational buildings. Subsequent reclamation projects of the built reservoirs (Głowy, Koźmin, Koźmin-końcowy, Adamów) indicate that in their surrounding there will be agricultural land. Neither afforestation nor the creation of buffer zones is planned around the reservoirs. The implementation of water reclamation without taking comprehensive solutions into consideration, does not only have adverse effects on the functioning of the reservoirs, but also on the aspect of the landscape.

#### **2.4. Lack of biological reconstruction of the river valleys, rivers and canals**

One of the reasons for the change related to water in the post-mining areas is the transformation of the network of surface waters associated with the necessity of elimination of watercourses, relocation of the river troughs and construction of a number of drainage canals as well as the channels which are the arteries of water transfers (Warta–Kiełbaska Channel). For example, within the “Adamów” open-pit mine, part of the Teleszyn trough was closed-down. The progress of mining activities within the Koźmin deposit forced the replacement of 3.5 km section of the Struga Janiszewska on the eastern edge of the pit and the in-take of the waters by a so called Passive Canal. The need for the water management within the catchment and regulating water relations within its borders, requires technical reconstruction of the water courses and reservoirs in the form of distribution structures (weirs, embankment locks), estuaries (culverts, pipes) and dams. However, no attention is paid to the fact that the watercourses as linear structures, in the natural landscape, serve as ecological corridors, which are migration paths of matter, energy and organisms in the landscape. Moreover, they are also habitats for specific groups of species act as filter (barriers) and they have enriching and regulating (biotic and abiotic) impact on the environment. As a result of mining activities, many of these functions have been lost. Rebuilding of the ecological potential of the watercourses is possible at the stage of reclamation by introducing canals along the river, and biological recovery in the form of shrubs and tree plantings, which will strengthen and enrich the ecological structure. Observation of a new system of hydrographic network in the “Adamów” open-pit mine shows that the issue of renaturalization of the transformed watercourses and built canals as well as the forms of their natural enrichment are marginalized in reclamation project.

### **2.5. The landscape monotony of the large-scale internal spoil tips reclaimed for farming**

Since the beginning of the "Adamów" open-pit mine, 2185 ha of agricultural land has been reclaimed. After the reclamation and agro technical activities the soils reach higher quality classes (III, IV) than the ones occupied for the purpose of mining - poor, sandy soils typical for the region. As a result of reclamation, a valuable land was created, which was efficient for the development of crop and dairy farming. However, while developing these areas, the ecological principles of shaping the agricultural landscape were ignored. As a result, the landscape was dominated by vast sheets of monotonous agricultural land devoid of ecological structure. The ecological structure of agricultural land is created by rows of mid-field woodlots along balks, watercourses and roads. They not only increase the aesthetic value of the landscape, but most of all, they stimulate geodiversity and biodiversity. They are a refuge for plants and animals, acting as a link between patches of forest and, thereby, reducing their isolation. The basic functions of mid-field woodlots are: reduction of wind erosion and water erosion of soil (windproof and waterproof function), shaping the microclimate and water protection [1, 10, 6, 7]. The introduction of mid-field woodlots in the reclamation of areas for agriculture is the most effective tool supporting water management by increasing the retention capacity of the environment (reducing evaporation from the soil surface, facilitating the infiltration of snow accumulation), increasing evapotranspiration, reducing run-off and increasing precipitation. These processes intensify water flow and increase the amount of water recirculating in an agricultural environment contributing to the favorable shaping of the water balance. In the post-mining areas where, after the stage of transition of water relations (dehydration), the reconstruction of water-bearing horizons is inevitable; and the support of this process by the properly shaping the structure of large areas reclaimed towards agriculture, is particularly important.

### **2.6. Geometric shapes of landscape borders**

The borders of natural geosystems are developed (winding) and have a mild course. They form transitional zones called ecotones, within which the characteristic features for one system of components are gradually disappearing, while some typical features for the new system show up [8]. For example, the "full" border of the forest covers forest phytocoenoses – climber – bushes – herbaceous plants and moves into non-forest community (arable land). The borders of the post-mining ecosystems, in accordance with the borders of open-pit excavations, stand out characteristically from its surroundings with straight and sharp lines. They are formed, for instance, by a wall of monoculture forest and arable land. If correction of the shape of borders of post-mining complexes

is difficult due to the technology of mining or land ownership, insomuch as the shaping of the borders is possible in the process of reclamation and justified from an environmental point of view, taking into account their spatial development (which is, creating transition zones between anthropogenic and natural geosystems). This is especially true in case of the borders between the land reclaimed into forest and other forms of land use (agricultural land), which ought to be densified with enduring bushy, herb-like vegetation. A well-developed vegetation of forest marginal zone encourages a faster formation of characteristic conditions for the interior of the forest (e.g. microclimate) and creates a barrier to protect the interior of the forest against the ingress of foreign species.

### 3. CONCLUSIONS

With regard to the above formulated problems and indications a concept for the reclamation of "Adamów" open-pit has been developed, which presents the idea of comprehensive shaping of post-mining landscape on environmental grounds (Fig. 2).

In the surrounding of the Adamów and Bogdałów open-pit mines, the fragments of two areas of protected landscape were listed (Złotogórski Protected Landscape Area and Uniejowski Protected Landscape Area) as well as the area of Natura 2000 "The Valley of the Central Warta." The dominant element in the system of ecological structure is the valley of Warta and Teleszyna as well as Kielbaska rivers. The valleys of the meridional courses define the main axes of the structure creating ecological corridors which are essential (at regional and local levels) in the implementation of the ecological relationships as they constitute a pathway of migration of substances, energy and organisms in the landscape. The vast majority are a series of meadow-peatbog, forested in small sections. The structure is completed by large forest complexes. In the north, we have woods, which cover an area of 1166 ha (located in the foreland of the open-pit mine and are partly intended for logging) while in the east and south-east there are forest patches covering areas of 371 ha and 2542 ha respectively, which surround the reclaimed parts of the open-pit mine. The complex shaping of this area, which takes into account the environmental conditions, should include:

- harmonious combination of elements of the natural structure of the post-mining areas and the natural areas occurring in their environment
- reconstruction of the forest complex in the northern part of the Adamów open-pit mine. In particular, the creation of greenways along the eastern edge of the Final Adamów Reservoir, which would be a link between the

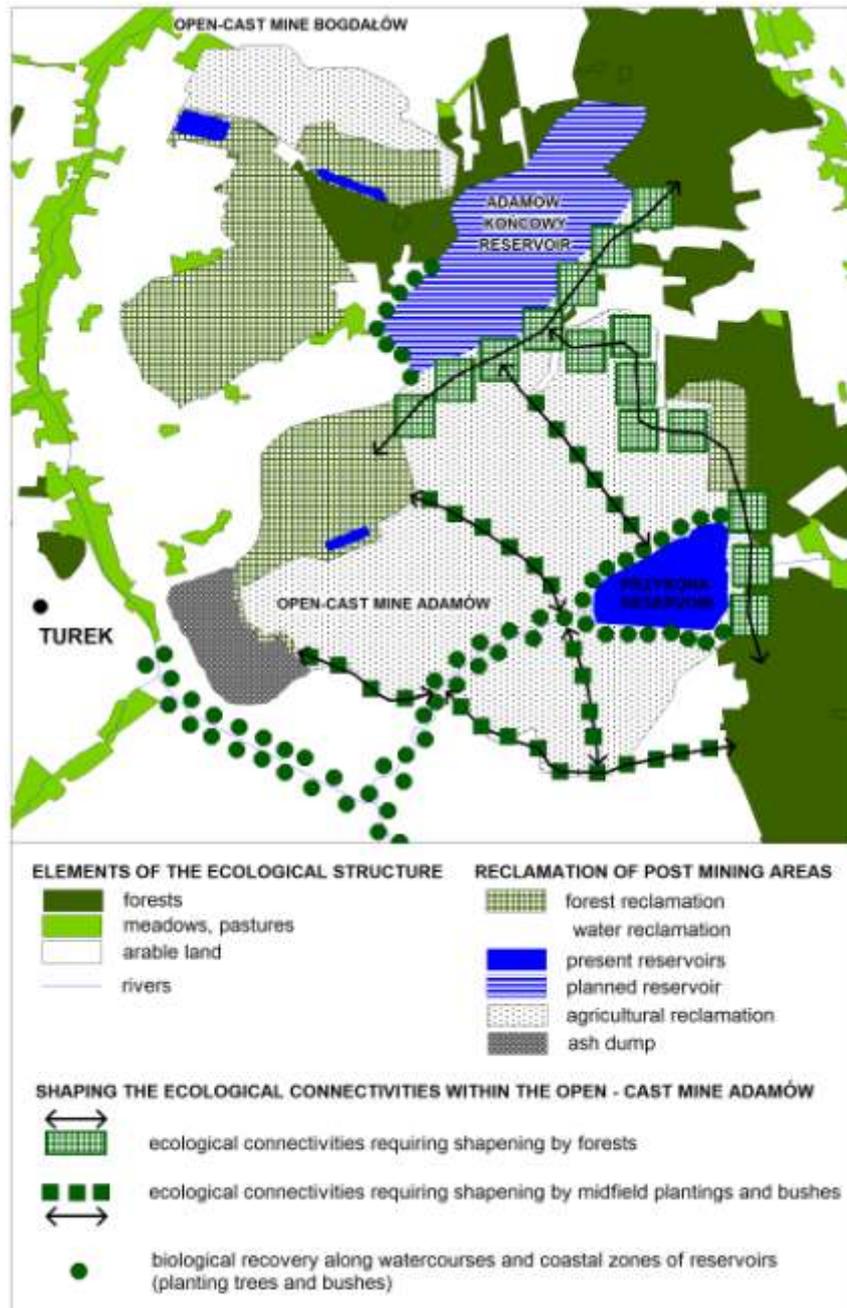


Fig. 2. The concept of shaping the post-mining landscape of Adamów and Bogdałów open-pit mine (source: own work)

reclaimed parts of the internal spoil tip towards the forest and primary forests in the western and eastern part of the open-pit mine. The plantings along the eastern edge of the Przykona reservoir should be the continuation of the greenway, which implements the ecological relationships with a large forest complex surrounding the external spoil tip from the south-east.

- creation, in the form of a network, of links between the existing nodal forest areas and the river valleys of Kielbaska and Teleszyna by introducing ecological microstructure in the form of midfield plantings and bushes in the area of reclaimed internal spoil tip into agricultural land
- protection of the valleys of Kielbaska and Teleszyna as well as the Przykona and Adamów reservoirs by introducing biological recovery along the watercourses and coastal zones of the reservoirs (i.e. planting trees and bushes).

#### **4. SUMMARY**

The aim of this study was to present the issue of shaping the landscape of post-mining areas in terms of landscape ecology. The basic recommendation resulting from the research is that the planning of reclamation activities cannot be limited to areas degraded by the reclamation process but it must take into account its relationship with the environment. However, the presented principles for shaping the ecological structure of post-mining areas are a kind of code of good practice of reclamation. Reclamation of post-mining areas is a statutory obligation for a mining entrepreneur, who is obliged to secure funds for this purpose (mine closure fund) and carry out the reclamation process. Taking into account that, in the reclamation plans, plantings necessary to fill up or strengthen the natural structure, are therefore not additional financial or executional burden, but has a dimension of ideas, the introduction of which will involve a qualitative change of the reclamation process. Landscaping in the post-mining reclamation process, that harmonizes nature and open-cast mining is now a necessity in the light of requirements of the National Environmental Policy and towards the increasingly environmentally conscious society. It should also be a fundamental factor in the discussions on the design of the exploitation of new deposits.

#### **REFERENCES**

1. Chłapowski D.: *O rolnictwie*, Poznań, Druk Walentego Stefańskiego 1843.
2. Doerr V.A., Doerr E.D., Davies M.J.: *Systematic Review 44: Does Structural Connectivity Facilitate Dispersal of Native Species in Australia's*

- Fragmented Terrestrial Landscapes? Collaboration for Environmental Evidence*, Bangor 2010.
3. Forman R.T., Dordon M.: *Landscape ecology*, New York, Wiley 1986.
  4. Kasztelewicz Z.: *Rekultywacja terenów pogórnich w polskich kopalniach odkrywkowych*, Kraków, Fundacja Nauka i Tradycje Górnicze, Akademia Górniczo – Hutnicza, 2010.
  5. Kędziora A., Ryszkowski L., *Ocena wpływu struktury krajobrazu na bilans cieplny i wodny zlewni wraz z określeniem jej modyfikującej roli dla efektów zmian klimatycznych*, Funkcjonowanie geosystemów w zróżnicowanych warunkach morfo klimatycznych – monitoring, ochrona, edukacja, red. A. Karczewski, Z. Zwoliński, Poznań, Stowarzyszenie Geomorfologów Polskich 2001, 202-223.
  6. Nowak M.: *Zadrzewienia śródpolne jako stymulator georóżnorodności i różnorodności biologicznej*, *Czasopismo Geograficzne*, **82**, 3 (2011) 271-283.
  7. Richling A., Solon J.: *Ekologia krajobrazu*, Warszawa, PWN, 2011.
  8. Solon J.: *Zastosowanie koncepcji potencjałów krajobrazowych dla oceny stopnia spójności krajobrazu*, *Problemy Ekologii Krajobrazu* **14** (2004) 29-43.
  9. Zajączkowski K.: *Zadrzewienia w planowaniu przestrzennym*, Znaczenie zadrzewień w krajobrazie rolniczym oraz aktualne problemy ich rozwoju w przyrodniczo – gospodarczych warunkach Polski, Płock 1997, 111 – 121.

EKOLOGIA KRAJOBRAZU POGÓRNICZEGO – ANALIZA WYBRANYCH  
PROBLEMÓW NA PRZYKŁADZIE KOPALNI WĘGLA BRUNATNEGO  
„ADAMÓW”

Streszczenie

W opracowaniu przedstawiono problemy kształtowania krajobrazu obszarów pogórnich, wynikające z pomijania w procesie rekultywacji, lub uwzględniania w niewielkim zakresie, kryteriów ekologicznych. Dotyczy to kształtowanych w procesie rekultywacji nowych elementów (lasy, łąki, zbiorniki wodne, grunty orne) tworzących strukturę ekologiczną krajobrazu pogórnich, a w szczególności ich rozkładu przestrzennego, spójności strukturalnej i funkcjonalnej z obszarami nie przekształconymi przez górnictwo. Analiza dokonana na przykładzie Adamowskiego Zagłębia Węgla Brunatnego wskazuje, że głównym problemem jest ograniczanie prac rekultywacyjnych do przestrzeni zdegradowanej przez proces eksploatacji, bez uwzględniania jej relacji z otoczeniem. Efektem jest brak spójności przestrzennej pomiędzy geosystemami i postępujący proces fragmentacji osnowy przyrodniczej w obrębie obszarów górniczych. Brak wykształconej struktury ekologicznej (obudowa biologiczna zbiorników, cieków,

kanałów, zadrzewienia śródpolne) nie sprzyja funkcjonowaniu geokompleksów pogórnicych i opóźnia proces dochodzenia tych obszarów do nowej, wtórnej równowagi. Wpływa również na fizjonomię krajobrazu podkreślając jej antropogeniczny charakter. Na tej podstawie sformułowano zasady kształtowania struktury obszarów pogórnicych z uwzględnieniem przesłanek ekologicznych, które powinny stać się kodeksem dobrej praktyki rekultywacyjnej. W odniesieniu do nich opracowano koncepcję rekultywacji odkrywki Adamów, która przedstawia ideę kompleksowego kształtowania krajobrazu pogórnicych.