Engineering of GIS for environmental monitoring of mining landscapes

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Abstract. Features of GIS design, designed to monitor the state of disturbed lands at open mining facilities, natural and climatic conditions in the mining area, are considered in order to inform the adoption of administrative and management decisions. The introduction of such systems will make it possible to carry out operational environmental monitoring of lands subject to technological violations, reduce the time for preparing reporting and technical documentation when designing and conducting measures aimed at land reclamation, make decisions on the technology and timing of reclamation of subsoil use facilities, and also reduce the time for making such decisions.

1. Introduction
In view of the rapid development of industry, it is becoming increasingly important to assess the man-made impact of human activities, especially in places of mining, building materials and peat, as well as in places of their enrichment and processing [1]. Open mining activities, which disturb natural ecosystems, cause significant damage to the natural environment. The area of disturbed land by coal mines as of 2016-2017 years amounted to about 180 thousand hectares [2], iron ore quarries – more than 43 thousand hectares [3], in addition, non-mineral deposits are being developed.

Despite the obligation to restore ecosystems on disturbed lands, reclamation work in most cases is not carried out on time, not in full, leaving large areas for self-restoration. The climate, hydrological regime, composition of overburden can lead to the effect of a slow rate of land restoration, so there is a high probability that the restoration process will go on for a long period of time or will not occur at all. Recultivation of disturbed land is carried out with the aim of further use in forest, agriculture, water farms, for construction, recreational, environmental and sanitation measures. It is not possible to assess the effectiveness of the work performed and determine the prospects for the further use of such lands without comprehensive monitoring studies. Studies of the ecological status and level of restoration of natural components on mining landscapes are carried out effectively on the basis of analysis of remote sensing data [1, 2].

2. Objectives and opportunities of the projected GIS
The projected geoinformation system is designed to provide information on the state of disturbed lands at open mining facilities, natural and climatic conditions in the mining area, with the aim of informational support for the adoption of administrative and management decisions.

The projected opportunities:
1) record keeping of registered users in the system;  
2) 24-hour access to the system;  
3) maintenance of structural parts of mining enterprises geobase, their condition throughout the life cycle, as well as elements of assessment of natural and climatic characteristics of the region;  
4) providing access to the necessary information and functionality to the user for making a decision on reclamation, drawing up land restoration forecasts;  
5) implement interactions with other data sources necessary for decision-making;  
6) preparation of reporting documents in the form of graphs, charts, maps and reports on the results of the carried out reclamation, rate of vegetation restoration, statistics on administrative units and other indicators depending on user requests.

The designed GIS should provide access to information through the Internet through a web interface. Input data loaded by the geodatabase administrator can be represented by raster and vector models, the attribute table must meet the requirements of the subject area. The output is user-set scale maps, reports, and charts based on user requests.

In accordance with the subject area, purpose and tasks, the following thematic layers can be identified: administrative-territorial division; relief; hydrography; road routes; hydrometeorological data; geology of the monitoring area; disturbed land.

3. Design of GIS

On the basis of the selected thematic layers, the geodatabase is designed, which is fully integrated into the GIS of environmental monitoring of mining landscapes.

The projected geographic information system will be presented to users as a geoportal based on the multi-user client-server architecture (figure 1)

![GIS Architecture Diagram](image)

**Figure 1.** GIS architecture of ecological monitoring of mining landscapes.

An independent model of client interaction with the Web server may be used to improve GIS efficiency. Each operation will be performed asynchronously in a separate thread, allowing the client to perform other actions at that time.
A conceptual model has been developed to represent the geodatabase structure (figure 2), reflecting the internal relationships. A distinctive feature of the geodatabase from databases is that tables do not always have a tabular relationship by primary code, often attribute tables of spatial objects have a spatial relationship with other attribute tables. For example, by means of a spatial query, the user can find all enterprises located in the region. The development of a conceptual model of the geodatabase determines which data is related to each other. Thus, by defining these links, the user can search for objects from one table by the attributes of another table.

![Geodatabase conceptual model](image)

**Figure 2.** Geodatabase conceptual model.

The next step is logical design. The purpose of this step is to convert a conceptual model based on the selected data model into a logical model.

The structure of the tables and the attributes of the coatings must be defined to develop a logical geodatabase model. Based on the developed conceptual model and structure of attribute data tables, a logical model can be developed. (figure 3).

Thus, this GIS will allow to remotely receive information through Internet access using a web browser, export materials in the form of maps, reports, charts and graphs. For the further implementation of GIS, functional and non-functional requirements were formulated, a geodata database was designed, a system for encoding and classifying objects and their attributes in accordance with the subject area was developed.
Figure 3. ER-model of geodatabase tables linked by primary and secondary codes.

As a further development of the system, one can consider: the addition of new layers of objects of disturbed land and other characteristics that allow more detailed analysis of the ecological state of disturbed land.

4. Conclusion
In general, the introduction of this GIS will reduce the time for making administrative and managerial decisions, carry out operational environmental monitoring of lands subject to technological violations and make decisions on the technology and timing of reclamation of subsoil use facilities. In addition, GIS will reduce the time to prepare reporting and technical documentation for the design and implementation of measures aimed at land reclamation.

References
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