DOI 10.52209/1609-1825_2021_3_140 UDC 528.88

# Analysis of the Environmental Situation in Coal-Mining Areas Using Satellite Data

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***Abstract.*** *The development of coal deposits has a negative impact on the ecological situation of natural water objects. For the timely elimination of the consequences of pollution of natural water objects, it becomes necessary to obtain relevant environmental information as soon as possible. The article presents an analysis of the possibility of using space survey data to assess the environmental situation in coal-mining regions. To solve this problem, based on the analysis of literature sources, the AMWI index, was chosen, which characterizes the spectral properties of acidic mine waters. The research was carried out on the example of the territory of the Pavlodar region, where the mining industry is widely developed. The images were taken from the Landsat-8 spacecraft. The results of the assessment of surface water pollution, obtained based on the analysis of long-term series of satellite images for 2015-2019 by comparing multispectral data, are confirmed by information from the reports of ecologists for this period.*

***Keywords:*** *remote sensing, ecology, coal mine, Landsat, Qgis.*

**Introduction**

Getting up-to-date information about the environment is one of the significant problems in environmental monitoring. In addition, obtaining the necessary information in a fairly short time is also very important. To date, one of the methods of obtaining data that meets these requirements is the use of satellite data. This method allows you to conduct research not only on the surface of the planet Earth, but also the study of the Earth's atmosphere. The application of this method is relevant for the vast expanses of Kazakhstan, located on the continent of Eurasia and covering an area of 2724.9 thousand km$^2$.

It is known that the pollution of natural water bodies occurs during the development of coal field. Mine water emissions have a significant negative impact on mining equipment. This negatively affects the conduct of mining operations and, as a result, it leads to a deterioration in the properties of the extracted coal. Contamination of chemical, bacterial and mechanical properties occurs during the opening of coal seams, which are rich in pyrite, and infiltration waters containing oxygen, during the interaction of which sulfuric acid is formed. Acid mine waters contain: calcium, sodium, potassium, magnesium and aluminum sulfates, as well as suspensions and the colloidal phase of carbonate and sulfate precipitation containing a high percentage of sulfate ion (including free sulfuric acid), iron, aluminum, etc. metals [1].

**Research results**

The current stage of development of digital technologies leads to a gradual transition from traditional methods of environmental monitoring of territories to innovative methods – remote methods of Earth sensing. Currently, remote Earth sensing methods are widely and actively used at mining companies in urban areas, at hydraulic structures, when servicing open-pit mining operations and performing surveys, mapping and assessing the condition of objects.

The reasons for the development of remote sensing at the present time are the following: firstly, the availability of software for processing satellite data; secondly, everyone can get access to images, both free of charge and on a commercial basis. This allows doing such research not only for professors, but also for schoolchildren, under the guidance of an experienced mentor and the presence of good equipment. For example, satellite data from the NOAA, Terra, Aqua, etc. space programs (KP) of low and medium resolution can be downloaded for free on the server, moreover high and ultra-high resolution data from other space satellites can be obtained from distributors of space data for remote sensing of the Earth.

The American satellite of the Landsat-8 series was launched into outer space in 2013. It is used for remote sensing of the planet Earth. The Landsat-8 spacecraft is equipped with a multi-channel scanning radiometer OLI (Operational Ground Recorder), which operates in 9 spectral ranges together with the Thermal InfraRed Sensor (TIRS) instrument, which uses 4 lenses. The Multichannel Scanning Radiometer (OLI) was created by Ball Aerospace & Technologies Corporation. The multichannel scanning radiometer (OLI) measures in the visible, near-infrared and short-wave infrared parts of the spectrum. The images obtained by the OLI multichannel scanning radiometer have 15-meter (49 ft) panchromatic and 30-meter multispectral spatial resolution in a 185 km (115 mi) wide viewing band. These images cover vast areas of the Earth's landscape. In addition, the mentioned above images provide sufficient resolution that allows you to distinguish between objects such as urban centers, farms, forests and other types of land use. The presence of infrared radiometers TIRS allows you to obtain a «thermal» image of the earth's surface with a resolution of 100 m [2].

The images from the Landsat-8 spacecraft were used to perform an analysis during the assessment of the environmental situation in the coal-mining region of Kazakhstan. The images from the Landsat-8 spacecraft were chosen for the following reasons: firstly, it is the availability of data; secondly, a wide range of tasks to be solved and the coverage of the studied territory (more than 400 scenes). Moreover, the received data is stored in the database of the US Geological Survey and the data is ready for use 24 hours after receipt and they are not limited in the number of copies. Using the US Geological Survey database gives access to satellite images for a significant period of time (50 years). Third, the preservation of geometry, calibration, coverage, spectral characteristics, image quality and data availability is provided at a level similar to previous Landsat satellites [2].

You can learn about the negative impact of coal mining on the state of natural water bodies by analyzing multispectral satellite data for a certain period of time. Various combinations of spectral channels make it possible to detect the presence of various impurities and mechanical suspensions in the object under study. The deterioration of water properties as a result of anthropogenic interference is an urgent problem for most water bodies. The presence of this process can be detected by comparing the spectral characteristics on a series of multispectral images [3].

The purpose of the study is to determine the possibility of using long-term satellite data series for spectral analysis and assessment of the current environmental situation in Kazakhstan on the example of the coal field.

The research was carried out for the territory of Pavlodar region, which has a developed mining industry. The selection of images was carried out for the period from 2015 to 2019 by visual decryption and assessment of cloud cover on the territory of the object (Figure 1).

The following algorithm was used for processing satellite data:

- binding of geographical coordinates;
- pansharpening (increasing the image resolution);
- atmospheric correction.

These processes are performed using a semi-automatic plug-in classifier module in the Qgis 3.6 software package (Figure 2).

Based on the data of the ArcGIS Pro service, there are several indexes for analyzing the state of natural

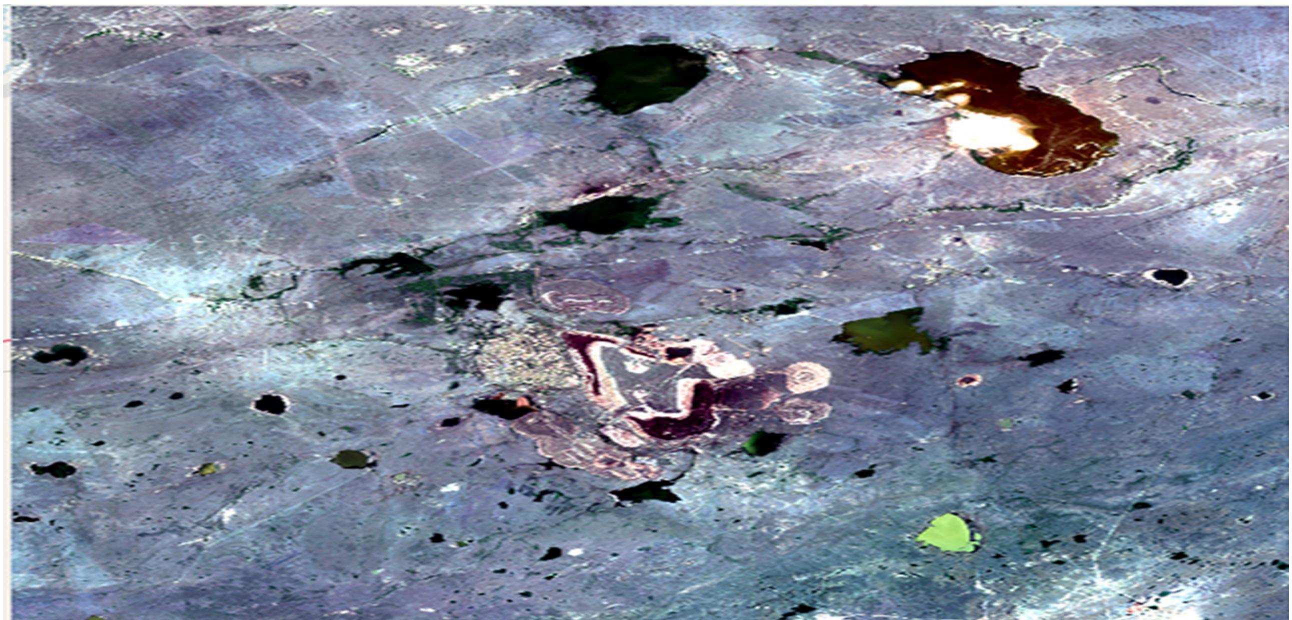


Figure 1 – The territory of the coal field under study

water bodies today [4]:

- MNDWI-water difference index (modified);
- NDSI-standardized index of differences in snow cover;
- NDMI-standardized index of differences in the moisture content of the territory;
- NDTI – normalized turbidity index.

To calculate the indices, taking into account the spectral features, the formulas are derived. The MNDWI index is calculated as follows:

$$MNDWI = \frac{GREEN - SWIR2}{GREEN + SWIR2},$$

where GREEN is the spectral brightness coefficient (QX) in the green channel (the wavelength for Landsat data is from 0.52 to 0.6 microns);

and SWIR 2 is the spectral brightness coefficient (KX) of the short-wave infrared channel (the wavelength for Landsat data is from 1.56 to 1.66 microns).

This index is effective and makes it possible to select a water object most accurately, if the coastline is located near any structure.

NDSI is a standardized index of differences in snow cover. The index was developed specifically for the analysis of satellite data of the MODIS series (channels 4 and 6) and Landsat (channels 2 and 5).

This index allows the identification of snow cover with a decrease in the influence of atmospheric effects, without the influence and interference of clouds. The NDSI index is calculated using the following formula:

$$NDSI = \frac{GREEN - SWIR}{GREEN + SWIR},$$

where SWIR is the spectral brightness coefficient (KX) of the short-wave infrared channel (the wavelength for Landsat data is from 1.36 to 1.39 microns);

GREEN is the KX in the green channel (the wavelength for Landsat data is from 0.52 to 0.6 microns).

NDMI is a standardized index of differences in the moisture content of the territory. The index is calculated for tracking and analyzing droughts, fixing the level of combustible materials in fire-hazardous areas. The NDMI index is calculated using the following formula:

$$NDSI = \frac{NIR - SWIR1}{NIR + SWIR1},$$

where NIR is the spectral brightness coefficient (KX) of the near infrared channel (the wavelength for Landsat data is from 0.845 to 0.88 microns);

SWIR1 is the spectral brightness coefficient (KX) of the short-wave infrared channel 1 (the wavelength for Landsat data is from 1.36 to 1.39 microns).

NDTI – normalized algorithm – turbidity index. This index is characterized by the fact that it allows you to calculate the turbidity index of water, as well as to record a decrease in water transparency associated with an increase in the number of inorganic and organic ligatures.

The NDTI index is calculated using the following formula:

$$NDTI = \frac{RED - GREEN}{RED + GREEN},$$

where RED is the spectral brightness coefficient

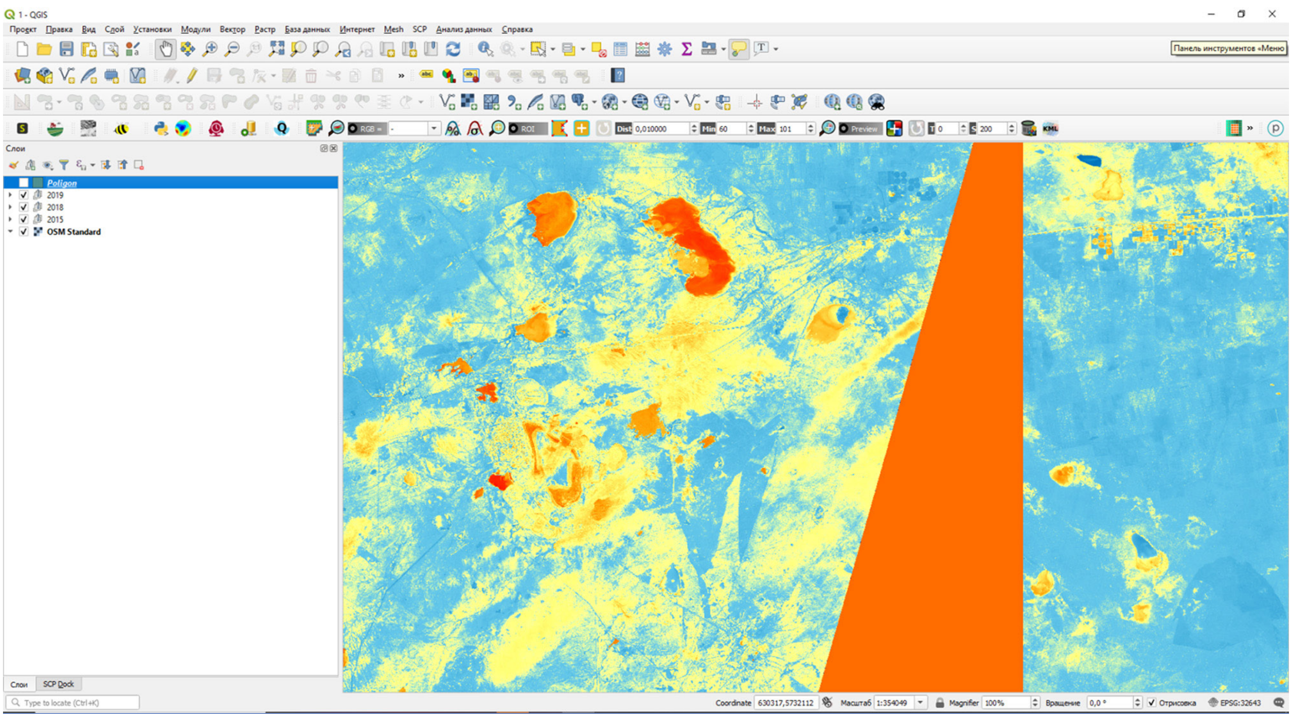


**Figure 2 – Image processing in the Qgis 3.6 software package**

(QX) in the red channel (the wavelength for Landsat data is from 0.63 to 0.69 microns);

GREEN – the spectral brightness coefficient (QX) in the green channel (the wavelength for Landsat data is from 0.52 to 0.6 microns) [4].

An important task is the correct choice of the most suitable index.

The authors O.A. Berezina, A.N. Shikhov, R.K. Abdullin in their scientific work [5] (on the use of space data for assessing the environmental situation in coal-mining areas) suggest using the AMWI index: «Since a distinctive feature of river water that was exposed to pollution by acid mine waters (AMW) is a sharp jump in the spectral brightness coefficient (SBC) in the ranges from blue to red».

The following formula was developed for calculating the index, when processing satellite data, on the presence of spectral changes characteristic of reservoirs contaminated with acid Mine water (Acid Mine Water Index, AMWI):

$$AMVI = \frac{RED - BLUE}{RED + BLUE},$$

where RED is the spectral brightness coefficient (SBC) in the red channel (the wavelength for Landsat data is from 0.63 to 0.69 microns);

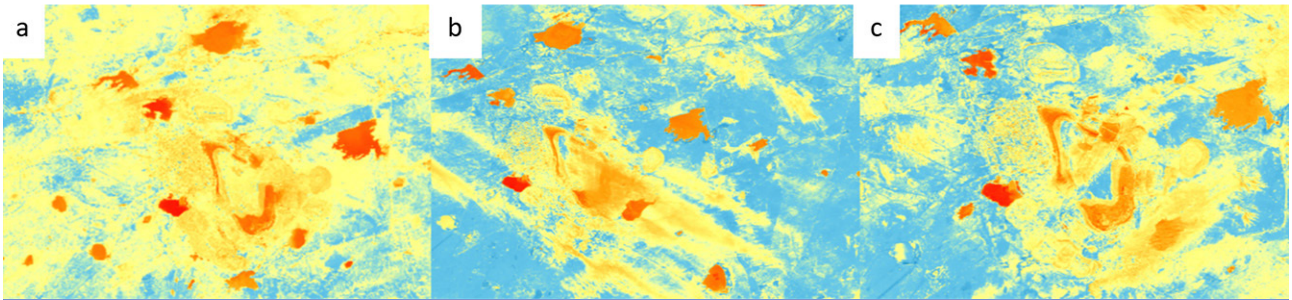
where BLUE is the spectral brightness coefficient (SBC) in the blue channel (the wavelength for Landsat data is from 0.45 to 0.52 microns) [5].

When processing satellite data on the coal-mining area in the Pavlodar region, the AMWI indices were calculated for 2015, 2018 and 2019 (Figure 3).

Graphs of changes in the brightness of the studied area in the red range were obtained based on a visual study of the data obtained in the Qgis 3.6 software package (Figure 4).

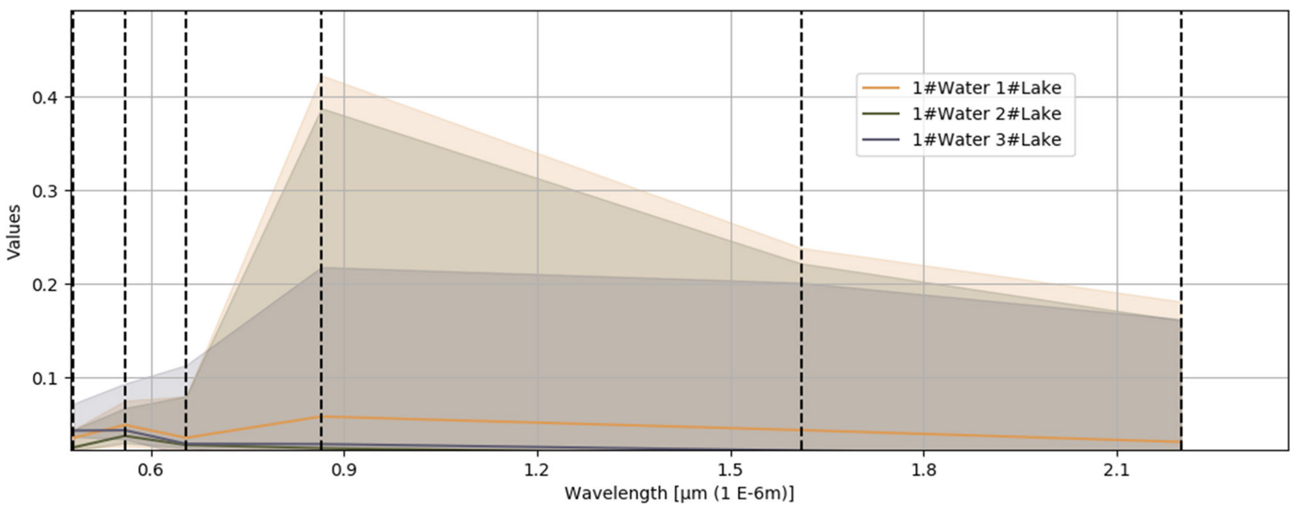
The graphs show the dynamics of changes in the brightness indicator in the red range, depending on the year. These data are confirmed by information from the reports of environmentalists.

Ecologists conducted an assessment of the quality of surface water in the Pavlodar region for the period from 2015 to 2019. This assessment demonstrates the dynamics of exceeding the maximum permissible concentrations (MPC) for substances from the group of biogenic substances (iron) and heavy metals (copper), as well as an increase in the BOC indicator 5 (biological oxygen consumption) (Figure 5).




a) the year 2015; b) the year 2018; c) the year 2019;

Figure 3 – The territory of the coal field




1#Lake – 2019 year; 2#Lake – 2018 year; 3#Lake – 2015 year

Figure 4 – Graphs of changes in the brightness of the studied area

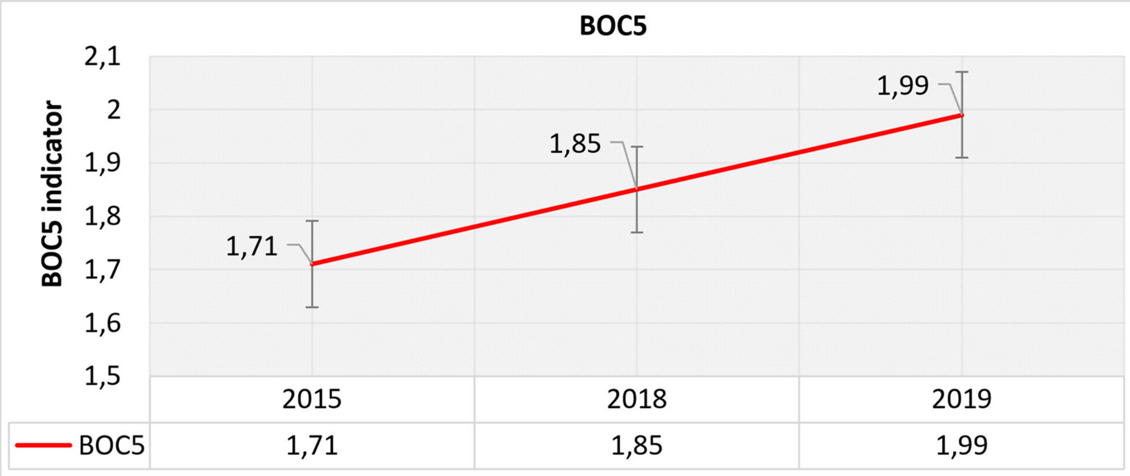



Figure 5 – Graph of changes in the level of the BOC indicator 5

The analysis of the value of the complex index of water pollution (CIWP) was performed to assess the level of surface water pollution. This index was based on the comparison and identification of the dynamics of changes in water quality [6].

Various technologies for the purification of suspended substances from mine (quarry) waters and water waste from coal-processing plants exist in the world. These technologies are used as measures to protect the environment, to neutralize the acidic mine waters of coal fields.

The disadvantages of most of them are the high cost and duration of the neutralization process. The effectiveness of most methods is no more than 40%. Buffer ponds, storage ponds, horizontal settling tanks and their combination are most often cleaned. The content of suspended substances in purified water can be from 30 mg/l or more [1].

Carrying out cleaning in the winter is a very time-consuming and expensive work, so this is the key moment, because getting up-to-date information in a fairly short time makes it possible to pay attention to the emerging problem in time.

## Conclusion

The results of the assessment of surface water pollution, obtained based on the analysis of long-term satellite data series for 2015-2019 by comparing the brightness in the blue and red spectral ranges, are confirmed by information from ecologists' reports for this period of time. Therefore, it can be argued that the use of satellite data to assess environmental pollution by acid mine waters and land degradation is an urgent issue of environmental protection today.

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***Ғарыштық түсіру деректерін қолдана отырып, көмір өндіретін аудандардағы экологиялық жағдайды бағалау***

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***Аңдатпа.*** *Көмір кен орындарын игеру табиғи су объектілерінің экологиялық жағдайына теріс әсер етеді. Табиғи су объектілерінің ластануының салдарын уақтылы жою үшін мүмкіндігінше тезірек тиісті экологиялық ақпарат алу қажет болады. Мақалада көмір өндіретін аудандардағы экологиялық жағдайды бағалау үшін ғарыштық түсіру деректерін пайдалану мүмкіндігіне талдау ұсынылған. Бұл мәселені шешу үшін әдебиет көздерін талдау негізінде AMWI индексі таңдалды, ол қышқыл кеніш суларының спектрлік қасиеттерін сипаттайды. Зерттеулер тау-кен өнеркәсібі кеңінен дамыған Павлодар облысының аумағы мысалында жүргізілді. Суреттерді іріктеу Landsat-8 ғарыш аппаратынан жүргізілді. Мультиспектралды деректерді салыстыру арқылы 2015-2019 жылдардағы спутниктік суреттердің ұзақ мерзімді серияларын талдау негізінде алынған жер үсті суларының ластануын бағалау нәтижелері осы уақыт кезеңіндегі экологтардың есептерінен алынған мәліметтермен расталады.*

***Кілт сөздер:*** *қашықтықтан зондтау, экология, көмір разрезі, Landsat, Qgis.*

### *Оценка экологической ситуации в угледобывающих районах с применением данных космической съемки*

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***Аннотация.*** *Разработка угольных месторождений оказывает негативное воздействие на экологическую ситуацию природных водных объектов. Для своевременного устранения последствий загрязнения природных водных объектов возникает необходимость получения актуальной экологической информации в наиболее короткие сроки. В статье представлен анализ возможности применения данных космической съемки для оценки экологической обстановки в угледобывающих районах. Для решения поставленной задачи на основе анализа литературных источников сделан выбор индекса AMWI, характеризующего спектральные свойства кислых шахтных вод. Исследования выполнялись на примере территории Павлодарской области, где широко развита горнодобывающая промышленность. Отбор снимков проводился с космического аппарата Landsat-8. Результаты оценки загрязнения поверхностных вод, полученные на основании анализа долгосрочных серий спутниковых снимков за 2015-2019 годы путем сравнения мультиспектральных данных, подтверждаются сведениями из отчетов экологов за данный период времени.*

***Ключевые слова:*** *дистанционное зондирование, экология, угольный разрез, Landsat, Qgis.*

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