Predictive assessment of damage to vegetation at the Krapivinsky reservoir and directions for its minimisation

Irina Kalacheva, Elena Fedulova, Artem Rada

1Kemerovo State University, Department of Accounting, Taxation and Finance, 650000 Kemerovo, Russia

Abstract. The Krapivinsky hydroelectric complex is a project that was a complex of more than 40 events. Their full-scale implementation could prevent those environmental problems that are especially acute for Kuzbass today. The production of electricity at the Krapivinsky HPS was supposed to be an incidental process accompanying the environmental project to a greater extent. However, in order to make a decision on the future fate of this object, it is necessary to assess the impact on the environment, including flora within the territorial boundaries of the Krapivinsky reservoir, assessing the possible damage to vegetation in the water protection zone and in the flood zone. This is especially true for rare plant species listed in the Red Book of the Russian Federation and the Kemerovo region - Kuzbass. For this purpose, an analysis of the vegetation on the territory of the object under consideration was carried out, the species of the presented plants were studied and examined, it was determined whether they were classified as rare species, and ways were also proposed to minimize possible harmful or irreversible damage to the flora in the zone of the Krapivinsky HPS.

1 Introduction

The construction and operation of large industrial facilities, including a reservoir, always represent a source of certain hazards and risks for the environment. First of all, the flora and fauna of the area under operation are at risk. In this regard, the first priority is to assess the environmental impact and damage to the territory where such facilities are located. For the implementation of the project, an area of 61,000 hectares, which includes the lands of natural reserves of regional significance, will fall within the flood zone. The Bunargarapsko-Azhendarovsky and Saltymakovsky nature reserves are included in the estimated flood zone, but their boundaries will be extended after construction is completed. As a result, conditions for the conservation and restoration of populations of rare plant and animal species will be created in full, and conditions for the conservation and breeding of aquatic and biological resources will be organised.
In this regard, the purpose of the study is a forecast assessment of damage to rare protected plants listed in the Red Book of Russia and the Kemerovo Region-Kuzbass [1], as well as proposals to minimise possible damage.

2 Materials and Methods

- analysis of stock materials, published research materials, data of controlling bodies on the state of biological resources (vegetation) and use of biological resources (collection of wild fruits);
- assessment of the current state of vegetation in the areas affected by the creation of the Krapivinsky reservoir;
- damage assessment of rare protected plant species upon completion of construction of the Krapivinsky reservoir.

The Krapivinsky hydroelectric power station, which includes the Krapivinsky HPS and the Krapivinsky Reservoir, has been constructed on the Tom River between the cities of Novokuznetsk and Kemerovo since 1977. The main goal of the project was to provide settlements and enterprises of Kuzbass with clean water in sufficient quantity [2]. By 1989, the Krapivinsky hydroelectric complex could block the river channel by more than 70%, but the work was forcibly stopped, and in 1993 the construction was frozen for an indefinite period. By that time, 264.9 billion rubles had been spent on the construction of the Krapivinsky HPS, which was 48.7% of the total project cost. A lot of preparatory work was carried out: 42 thousand hectares of forest were cut down for the reservoir bed, cemeteries and cattle burial grounds were moved outside the developed territory, all agricultural producers were paid monetary compensation if their lands were also withdrawn, more than three thousand people were resettled from the area of supposed flooding, and the village of Zelenogorsky was formed near the hydroelectric complex for the residence of Krapivinsky HPS builders. Due to the difficult economic situation during this period, it was supposed to mothball the hydroelectric power plant for some time, but the financing was sufficient to fulfil 21% of the work. The issue of unfreezing the facility and completion of construction was repeatedly raised by regional authorities. In 2007-2008, the possibility of privatising the hydroelectric complex and putting it on the balance sheet of a large Russian engineering company was discussed. In 2012, the reinforced concrete frame of the dam was inspected, and experts concluded that with certain financial investments the structure could be restored to a serviceable condition. In 2015, a potential investor appeared at Krapivinsky HPS, but no further action was taken. At the end of 2020, the issue of construction completion was again raised during the project presentation by the Governor of Kuzbass S. Ye. Tsivilev. According to the data provided, 45 billion roubles will be required to complete the construction of the Krapivinsky HPS. To this end, a cooperation agreement has been concluded with RusHydro, which has updated the project and increased the HPS capacity from 300 to 345 MW. In January 2022, the Lengidroproject design institute, which is part of RusHydro, submitted a preliminary environmental impact assessment (EIA) of the procedure for completing the construction of the hydropower plant. The construction is planned to be completed within the next five years [3].

According to the assessment of flora on the territory of the Krapivinsky hydroelectric power plant, it was noted that the vegetation is rather monotonous. This is especially characteristic for the territory of the reservoir bed over the entire area it occupies (Figure 1). The uncomplicated type of vegetation cover in the inundation zone was formed as a result of forest clearance and clearing in the process of preparation for flooding at the early stages of construction of the hydroscheme. At the time of cessation of works, the area under development was undergoing a process of natural overgrowth due to the absence of forestry measures, which resulted in swampy areas in the floodplains of tributaries.
Meadow communities also developed naturally in open areas of space. In the absence of cultural and technical conditions, weedy eurythropic species also prevailed here and tree and shrub species were massively introduced and spread, spreading to new and new territories. In former arable lands, weed species have massively spread. Along the bank of the Tom River, where settlements have remained or where areas for temporary or permanent residence are being redeveloped on open spaces used for hayfields, true meadow communities of mesophilic appearance have been preserved or are forming. Willow thickets are abundant and dense in the former settlement areas, making access to water bodies difficult. Natural water bodies in the river floodplain are also surrounded by shrubbery alternating with wetlands.

Commissioning of the Krapivinsky reservoir will result in direct elimination impacts as-sociated with the inundation of historical terrestrial plant habitats on an area ranging from 54132.63 ha (NPL 175 m) to 59143.4 ha (NPL 177.5 m). On the territory of the Krapivinsky hydroelectric complex in the zone of flodding and direct impact 29 protected species of plants and fungi have been identified, 17 of them are covered-seed species, rare species of algae and fungi are represented. In addition, there are direct threats of species extinction and habitat destruction during reworking of the reservoir's bedrock banks and changes in plant growing conditions in places where the water table rises. Complete data on the composition of the flora of these areas is currently not available. The main reason is the difficult accessibility of the territory for biological surveys.

Table 1 provides data only for the habitats of the flood zone and the water protection zone within the boundaries of no more than 200 metres from the water edge of the water body under construction. However, it should be noted here that the data for habitats in the water protection zone are also incomplete and additional research is required. For example, for many years the coastal strip in the territories of special contingent placement was not available for research.

<table>
<thead>
<tr>
<th>No.</th>
<th>Species name</th>
<th>Rarity status category</th>
<th>Endangered status category</th>
<th>Category of degree and priority of measures to be taken and planned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nymphoides peltata (S.G. Gmel.) O. Kuntze</td>
<td>DD</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Gypsophila patrinii</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Nuphar pumila (Timm) DC.</td>
<td>VU</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Nymphaea tetragona Georgi</td>
<td>VU</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Nymphaea candida J. Presl</td>
<td>VU</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Scientific Name</td>
<td>IUCN Status</td>
<td>Conservation Status</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------</td>
<td>-------------</td>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Erythronium sibiricum (Fisch. et C.A. Mey.) Kryl.</td>
<td>VU</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Buttercup Family – Ranunculaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ranunculus lingua L.</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Orchid Family – Orchidaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cypripedium guttatum Sw.</td>
<td>LC</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cypripedium macranthon Sw.</td>
<td>LC</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Herminium monorchis (L.) R. Br.</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Gymnadenia conopsea (L.) R. Br.</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Liparis loeselii (L.) R. Ric.</td>
<td>VU</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Apiaceae Family – Apiaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Osmorhiza aristata (Thunb.) Rydb.</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Sanicula europaea L.</td>
<td>VU</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Violet Family – Violaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Viola dissecta Ledeb.</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Section III. Filiciform – Polypodiophyta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Moonfern Family – Botrychiaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Botrychium multifidum S. G. Gmel. Rupr.</td>
<td>I</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Botrychium lunaria L.</td>
<td>VU</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Polypody Family – Polypodiaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Polypodium vulgare L.</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Salvinia Family – Salviniaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Salvinia natans (L.) All.</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Shield Fern Family – Dryopteridaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Polystichum braunii (Spenner) Fée</td>
<td>NT</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Section IV. Bryophytic – Bryophyta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Brachythecia Family – Brachytheciaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Rhynchostegium rotundifolium (Scop. exBrid.) Bruchetal.</td>
<td>DD</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Eurhynchium angustirete (Broth.) T.J.Kop.</td>
<td>VU</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Algae - Characeae Family – Characeae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Chara virgata Kütz.</td>
<td>VU</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Fungi (Mycota) – Agaricaceae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Leucoagaricus nymphaenum (Kalchbr.) Bon</td>
<td>LC</td>
<td>III</td>
<td></td>
</tr>
</tbody>
</table>
27. Calvatia gigantea (Batsch) Lloyd

28. Phallus impudicus L.

29. Ealaphomyces granulatus Fr.

Note. Rarity status categories:
0 - Probably extinct,
1 - Endangered,
2 - Declining in number and/or distribution,
3 - Rare,
4 - Uncertain in status,
5 - Recovering and recovering.

3 Results and Discussion

The results of the research provide a preliminary assessment of the resource significance of the territory. Some species of vegetation, the reserves of which are mostly represented in the study area, are of industrial importance for the region [4]. For example, the biological potential of St. John's wort has a certain significance, the resources of which in the area of the Krapivinsky hydroelectric complex are quite high, while in other areas of the Kemerovo region its availability and accessibility are sharply decreasing.

When determining the amount of damage only for species listed in the Red Data Book of the Russian Federation and the Red Data Book of Kuzbass on the basis of qualitative characteristics of species recorded in the flood zone, the following results were obtained.

Species growing in the water protection zone defined by the NPL 177.5 m mark will not be significantly affected. With the exception of subsequent years of reservoir operation, e.g.,
in the case of permanent recreation, agricultural development, forestry. At NPL 175 m the probability of direct elimination effects on rare species is further reduced and it is not appropriate to adopt these characteristics for the water protection zone in further calculations.

In the event of construction cancellation in any of the decision-making options, there will be no adverse impact on rare protected species. A damage calculation is not required.

As a regulatory and legal basis for calculation of damage to rare protected plant species growing in the area of direct impact in case of habitat destruction in the reservoir flooding zone the following are accepted: Federal Law "On Environmental Protection" dated 10.01.2002 No. 7-FZ; Federal Law "On Environmental Expertise" dated 23.11.1995 No. 174-FZ; Order of the Ministry of Natural Resources and Ecology of the Russian Federation dated 23.05.2016 No. 306 "On Approval of the Procedure for Maintaining the Red Data Book of the Russian Federation".

Taking into account the requirements of the Law of the Kemerovo region from 03.08.2000 № 56 "On the Red Book of the Kemerovo region", recommendations of the "Strategy for the conservation of rare and endangered species of animals, plants and fungi" (Order of the Ministry of Natural Resources of Russia from 06.04.2004. No. 323) and "Methodological Guidelines for Keeping the Red Data Book of the Subject of the Russian Federation" (Ministry of Natural Resources of the Russian Federation - Moscow, 2004, as amended on 15.02.2008), we collected data and formed a system of qualitative indicators for plant species listed in the Red Data Book of the Russian Federation and the Kemerovo Oblast.

As a result of the research, 29 species of rare plants and fungi, which are in danger of extinction and are represented in the zone of direct destruction of their habitat, were identified. A full calculation of the amount of damage is not possible at this stage of the assessment, as there are no quantitative characteristics for each rare species.

If the Krapivinsky Reservoir is commissioned, it will also result in the transformation of bedrock banks, which will result in the flooding of a significant area of coastal territories. These processes will also have either a direct destructive impact on the habitats of rare species or an indirect impact by altering the living conditions and normal functioning of organisms.

According to the original technical design, 308 km of coastal strip with a width of 10 to 350 metres will be subjected to coastal destruction. The total length of waterlogged areas along the hydro-isobath of 2 metres will be 319 km, the width of the waterlogged zone varies from 45 to 3500 metres [2]. In case of modern technical solutions (NPL 175), the localization, configuration and area of such territories will change significantly. There are no design conclusions about the quantitative parameters of these territories at the current stage, but they should also be included in the corrective indicators of damage in the future.

For an independent assessment of the amount of damage caused to the objects of flora listed in the Red Book of the Russian Federation and Kemerovo region-Kuzbass, it is necessary to carry out additional special route and stationary studies in accordance with the regulations of paragraph 8 "Engineering and environmental surveys" of the Code of Regulations SP 47.13330.2016.  "Engineering surveys for construction. Basic Provisions" [5].

The composition of field work should include monitoring studies of rare species' cenopopulations in order to record absolute numbers, determine the reproductive core of cenopopulations and calculate the "insurance" core of each species for a specific habitat. The composition of the above-mentioned relevant baseline data is necessary to specify the basic probabilistic damage during construction of water reservoirs in the zones of direct destruction and subsequent impact.

From the point of view of preservation of a component of regional biodiversity, refusal from construction of the Krapivinsky reservoir under any of the proposed scenarios (4 such options are considered, including the option proposed according to the results of the development of the main technical solutions in 2021) is a radical way of preserving all elements of the flooding biozone, adjacent natural systems in the zones of direct and indirect impact.
From the point of view of rational nature management, involvement in the development of biological resources and water bodies, this mechanistic approach is not always absolutely correct. The complete cessation of economic activity, which happened in the Krapivinsky reservoir zone after the construction and conservation of the facility was terminated, leads to the degradation of the soil and vegetation cover, which even under the conditions of managed nature management will take many years to restore. Conservation of forests is not possible at all without forestry on the exploited territories. In the conditions of modern logistic chains, accessibility of remote forest tracts, and the regular need to control the fire hazard of forest lands, complete abandonment of construction cannot be considered an optimal solution.

The first way of minimising damage to all natural complexes of the reservoir zone is already being considered and will most likely be adopted. Lowering the NPL to 175 m will reduce the flooding area by 5,010.77 ha of natural areas covered with vegetation, which in most cases are forest communities on sloping areas of bedrock banks that are in satisfactory functional condition.

In order to preserve rare plants of the Red Data Books of all levels, project decisions most often provide for compensation payments. The value of the objects to be destroyed and their habitat destroyed is calculated. This technique reflects the current extensive approach in solving the problems of preserving natural environment objects, as the payment of compensation does not actually save plant species from direct destruction, change of gene pools and disappearance of price funds.

We calculate probabilistic damage to vegetation, objects of which are listed in the Red Book of the Russian Federation and the Red Book of Kuzbass and their habitat in the flooded territory of the Krapivinsky reservoir should assume direct compensation payments to budgets of all levels [6]. Application of the mechanism of compensation payments will not lead to the preservation of gene and cenofonds of rare protected species and will not provide the possibility of their further existence.

This technique reflects the current extensive approach in solving the problems of preservation of natural environment objects, as the payment of compensations does not really save plant and animal species from direct destruction, change of gene pools and disappearance of gene pools.

In this situation, it is necessary to take into account the explanations contained in the Letter of the Ministry of Natural Resources of the Russian Federation dated 15 July 2013 No. 15-47/13183 "On Application of Methods", where it is indicated that the Resolution of the Government of the Russian Federation dated 16 February 2008 No. 87 "On the Composition of Project Documentation and Requirements to Their Content" approved the "Regulations on the Composition of Sections of Project Documentation and Requirements to Their Content".

Clauses 25 and 40 of the Regulations contain requirements for inclusion in the sections "List of Environmental Protection Measures" and "Environmental Protection Measures" of conditions for protection of flora and fauna objects and their habitats. These clauses also provide for the inclusion in the sections of the said List and Measures of the calculation of costs for the implementation of environmental protection measures and compensation payments. But the Letter further specifies: "... Compensation payments in respect of flora and fauna objects are not provided for by the current legislation of the Russian Federation. In relation to the objects of flora and fauna, the necessary element for inclusion in the project documentation are measures for their protection and calculation of costs for the implementation of the relevant measures".

Consequently, the estimated amount of probable damage to rare species of plants and mushrooms living in the flood zone of the reservoir under construction has informational values and states the real amount of damage that may be received in case of ignoring and not taking measures and activities to preserve biological objects and their habitat.
Current regulatory documents governing the conservation of regional biodiversity and the functioning of specially protected natural areas, unified methodological recommendations suggest several ways to reduce negative impacts on natural systems in the areas of projected industrial activity [7].

In the practice of implementing the provisions of the Convention on Biological Diversity there are two main directions of conservation of biological species: "in situ" - conservation in natural habitats, as well as maintenance and restoration of viable populations of species in their natural environment and "ex situ" - conservation of species outside their natural habitats [8].

In "ex situ" conditions, gene pool resources are removed from the natural environment and kept separately from their original habitat as components of biodiversity. In general, this provides an opportunity to maintain the integrity of the gene pool of wild flora representatives. The limiting factor of "ex situ" measures is considered to be the limited resource of areas (botanical gardens, dendroparks, experimental farms, laboratories) for the placement of biological material, and the conditions in them do not always meet the biological needs of species-introducers.

A more effective and nature-saving mechanism may be the "eviction" and "resettlement" of vulnerable components of regional biodiversity from places of obvious threats and indirect impacts to natural habitats with conditions peculiar to them. In the current realities, this is the most pragmatic measure for the conservation of organisms "in situ". In addition, it is economically more favourable to implement measures to relocate plant species within their native habitats than to make compensation payments for the expected damage, which include a number of coefficients that increase the amount of payments. Consequently, the implementation of such actions will be less costly for nature management organisations and will show a good quality indicator.

4 Conclusions

As part of the construction of the Krapivinsky hydroelectric complex, a comprehensive solution is proposed for the conservation of rare, unique protected plants from the Red Book of the Russian Federation and the Red Book of Kuzbass is proposed.

1. Transportation of the "insurance core" valuable populations of rare plants from disturbed habitats to new territories in the "in situ" system by creating a new type of natural reserve on the territory of the Krapivinsky water reservoir. To supplement the categories of specially protected natural territories of the Kemerovo Oblast of regional and local importance with the concept of "recipient reserves".

Let us explain that a recipient reserve is a certain natural complex that can accept related biological objects without disturbing the established biogeocenotic relations.

Conditions for the formation and location of recipient reserves:
- the zone of the recipient reserve is not delimited by the administrative-territorial division of the region, i.e., it is completely natural;
- the area should contain the main structural units of the landscape of the region, i.e., be representative;
- the network of recipient reserves should consist of elements of all typical or predominant landscape groups or communities, ecosystems characteristic for the territory of the region;
- the function of recipiency with indication of qualitative and quantitative characteristics of the biological objects to be introduced should be emphasised in the policy documents.

Under these conditions, the main group of vegetation species from the Red Book, which grows in the flood zone and the influence of the reservoir, will be preserved.
2. In the KemSU land plots of the Botanical Gardens and Kuzbass Botanical Garden of the Federal Centre of Scientific and Technical Research of the Siberian Branch of the Russian Academy of Sciences, it is possible to preserve the rarest and few plant species in the "ex situ" system with the organisation of further monitoring and genetic research.

3. Conservation of seed material and compensatory measures for objects whose conservation measures cannot be realised in "in situ" and "ex situ" conditions.

The problem of fresh water supply to the region, creation of conditions for resumption of navigation on the Tom River, availability of an additional source of clean, carbon-free electricity—these are a number of changes that will be facilitated by the completion of the Krapivinsky hydroelectric project. Settlements will be restored, jobs will be created at the hydroelectric plant, and related sectors of the economy will develop. Thus, in particular, it is planned to organise a fish farm for cultivation of some fish breeds, which will create 40 jobs.

The Saltymakovsky nature reserve will be expanded by more than 20 thousand hectares. Its zone—territory will include the water area of the future Taydon bay with the adjacent water protection zone up to Medvezhka settlement, as well as the water area of the bays of the Kuchumanda and Ulumanda rivers, as well as the lands of the forest fund located in the zone of this interfluve, the territory of the Taydon river from Medvezhka settlement and the river valley of the Alzas, Bayanzas, and Sa-Yanzas rivers. As a result, an integral nature protection and water conservation system will be formed, which will allow to preserve the headwaters and channel sections of the main main tributaries of the Taydon River with water of natural quality. This, in its turn, will increase the diversity of habitats for plants and animals of the specially protected natural area.

The Bungarapsko-Azhendarovsky reserve will also increase its area due to the inclusion of the water area of Bungarapsky Bay. Additionally, this territory will form a separate group in the form of a protected natural reserve within the boundaries of the water area of Nizhne-Tersin Bay and its water protection zone.

Thus, the above results of the work represent one of the main components of a comprehensive environmental impact assessment for the completion of construction of the Krapivinsky HPS on the Tom River and can be used to make subsequent management decisions on the creation of the Krapivinsky reservoir on the territory of the Kemerovo region—Kuzbass from the position of minimising the loss of vegetation growing on this territory.

The authors of the article confirm that there is no conflict of interest in the investigation. This article does not contain studies involving humans or animals as research subjects.

5 Acknowledgements

The research was conducted on the equipment of the Research Equipment Sharing Center of Kemerovo State University, agreement No. 075-15-2021-694 dated August 5, 2021, between the Ministry of Science and Higher Education of the Russian Federation (Minobrnauka) and Kemerovo State University (KemSU).

References


9. E3S Web of Conferences 462, 02044 (2023) AFE-2023 https://doi.org/10.1051/e3sconf/202346202044