**REVIEW**

**by official reviewer Appazov Nurbol Orynbassaruly for Kunarbekova Mahabbat Seit-Zadaevna's dissertation on "Obtaining modified carbon materials for removing radionuclides from contaminated water", submitted for the degree of Doctor of Philosophy (PhD) in the specialty "8D07109 – Innovative technologies and new inorganic materials"**

| № p/p | Criteria | Meeting the criteria (underline one of the possible answers) | Justification of the official reviewer's position (italicized remarks) |
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| 1. | The topic of the dissertation (as of the date of its approval) corresponds to the directions of scientific development and/or state programs. | 1.1 Compliance with the scientific priority areas of development or government programs:<br>**1) the dissertation was completed within the framework of a project or target program funded from the state budget (specify the name and number of the project or program);**<br>2) the dissertation was completed within the framework of another state program (specify the name of the program);<br>3) the dissertation corresponds to the priority area of science development approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (specify the direction). | The dissertation work has been carried out in accordance with the Resolution of the Government of the Republic of Kazakhstan No. 248 dated March 28, 2023, "On the Approval of the Concept for the Development of Higher Education and Science in the Republic of Kazakhstan for 2023–2029," and within the framework of the project AP19577049 "Synthesis, characterization and physico-chemical study of sorbents of biomass origin for industrial water purification from radionuclides."<br>This work is aimed at addressing environmental pollution issues caused by radionuclides. The conducted research corresponds to one of the priority areas for scientific development for 2021–2023, as approved by the Protocol of the meeting of the Higher Scientific and Technical Commission of the Republic of Kazakhstan on April 29, 2020: "Rational use of water resources, flora and fauna, ecology." |
| 2. | Importance for science | The work **makes**/does not make a significant contribution to science, and its importance is well **disclosed** / not disclosed. | The study makes a significant contribution to science, and its importance is well-articulated. The work is focused on the development of a technological protocol and modified biomass-based sorbents for the effective adsorption of radionuclides $Cs^+$ and $I_3^-$. |
| 3. | The principle of independence | The level of independence:<br>**1) high;**<br>2) Average;<br>3) Low;<br>4) there is no independence. | The level of independence is high. The author of this dissertation actively participated in formulating the research objectives, conducting scientific experiments, analyzing literature data, selecting analytical methods and applications, setting theoretical and practical tasks, discussing the obtained results, and substantiating conclusions. |
| 4. | The principle of internal unity | 4.1 Substantiation of the relevance of the dissertation:<br>**1) justified;**<br>2) partially justified;<br>3) is not justified. | The relevance of the research conducted in the dissertation is well substantiated, with a strong emphasis on the study of the chemical composition of modified sorbents and the impact of composition on their structure and sorption capacity. Factors influencing the sorption capacity of both non-radioactive and radioactive isotopes were identified in ideal solutions as well as in industrial water samples, reflecting natural matrix conditions and actual levels of cesium and iodine. |
| | | 4.2 The content of the dissertation reflects the topic of the dissertation:<br>**1) reflects;**<br>2) partially reflects;<br>3) does not reflect. | The content of the dissertation accurately reflects its topic, as it is devoted to experimental studies of modified sorbents based on activated carbon derived from rice husk, buckwheat husk, and walnut shell biomass, and their sorption activity towards cesium and iodine radionuclides. |

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| | | 4.3. The purpose and objectives correspond to the topic of the dissertation:<br>**1) corresponds;**<br>2) partially corresponds;<br>3) they don't match. | The dissertation is distinguished by the coherence and logical structure of its aims, objectives, and the proposed methods for their realization. The objectives are logically derived from the comprehensive literature review. |
| | | 4.4 All sections and provisions of the dissertation are logically interrelated:<br>**1) completely interconnected;**<br>2) the relationship is partial;<br>3) there is no relationship. | All sections and elements of the dissertation are logically interconnected. The literature review provides background for the research, its goals, and objectives. The experimental part gives exhaustive information on the research methods and equipment used. The discussion is grounded in experimental data. |
| | | 4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions:<br>**1) there is a critical analysis;**<br>2) partial analysis;<br>3) the analysis is not your own opinions, but quotes from other authors.;<br>4) There is no analysis. | The author has developed methods for obtaining modified carbon sorbents from low-cost biomass, studied the mechanisms of interaction between carbon and target cesium and triiodide ions, and created new, highly effective modified carbon sorbents designed for the sorption of radionuclides from various types of water.<br><br>The high scientific level of the research is confirmed by publications in Kazakh journals ("Combustion and Plasmochemistry Journal," "NNC RK Bulletin") and international journals ("Journal of Water Process Engineering," "ES Materials and Manufacturing," "International Journal of Environmental Research and Public Health"), as well as the presentation of results at international conferences. |
| 5. | The principle of scientific novelty | 5.1 Are the scientific results and provisions new?<br>**1) Completely new;**<br>2) partially new (25-75% are new);<br>3) not new (less than 25% are new). | The scientific results and findings of the dissertation are entirely novel. |
| | | 5.2 Are the conclusions of the dissertation new?<br>**1) Completely new;**<br>2) partially new (25-75% are new);<br>3) not new (less than 25% are new). | The conclusions of the dissertation are completely original, as confirmed by the author's publications in peer-reviewed international journals. |
| | | 5.3 Technical, technological, economic or managerial decisions are new and justified:<br>**1) Completely new;**<br>2) partially new (25-75% are new);<br>3) not new (less than 25% are new). | All technical solutions are aimed at achieving the stated objectives, which include the development of methods for producing carbon sorbents doped with ferrocyanide and urea via hydrothermal treatment, and their application in the adsorption of various ions, including radionuclides. The obtained sorbents were tested on real radioactive isotopes and contaminated water from a nuclear test site, effectively bridging the gap between laboratory research and practical application. |
| 6. | Validity of the main conclusions | All the main conclusions are based/not based on scientifically significant evidence or are well-founded enough (qualitative research) and areas of study in the arts and humanities. | All major conclusions are based on reliable experimental data. A wide range of modern instruments and analytical techniques were applied in the research. |
| 7. | The main provisions | It is necessary to answer the following questions for each provision separately:<br>7.1 Has the position been proven? | Finding 1 – Hydrothermal modification of biomass-based activated carbons using urea (surface area: 1600–2200 $m^2/g$) significantly enhances nitrogen functionalization and improves sorption capacity by 30% (buckwheat husk-based AC) and 35% (rice husk- |

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| | submitted for defense | **1) Has it been proven;**<br>2) rather proven;<br>3) rather not proven;<br>4) not proven;<br>5) in the current formulation, it is impossible to verify the validity of the provision.<br>7.2 Is it trivial?<br>1) yes;<br>**2) no;**<br>3) in the current formulation, it is impossible to verify the triviality of the position.<br>7.3 Is it new?<br>**1) yes;**<br>2) no;<br>3) in the current formulation, it is impossible to verify the novelty of the provision.<br>7.4 Application level:<br>1) narrow;<br>2) Average;<br>**3) Wide;**<br>4) in the current wording, it is impossible to verify the level of application of the provision.<br>7.5 Is it proved in the article?<br>**1) yes;**<br>2) no;<br>3) in the current formulation, it is impossible to verify the evidence of the provision in the article. | based AC). This was proven in the dissertation and published in the following scientific article:<br>- M.S. Kunarbekova, I.O. Sapargali, L.N. Seymukhanova, K.K. Kudaibergenov, S. Azat. "Synthesis of nanofiber composite doped with nitrogen groups from biomass by chemical activation." Combustion and Plasmochemistry Journal, 22(1), 3–11. https://doi.org/10.18321/cpc22(1)3-11<br>Finding 1 is novel, non-trivial, and has broad applicability.<br><br>Finding 2 – Activated carbons modified with Prussian blue demonstrate high selectivity for $Cs^{+}$, reducing overall activity from 120 to <5 Bq/L in multi-ion systems ($Sr^{2+}$, $Ca^{2+}$, $Na^{+}$) using water from the Degelen site. This was validated in the dissertation and published in scientific articles, conference proceedings, and a patent:<br>- M. Kunarbekova et al. "Carbon adsorbents for the uptake of radioactive iodine from contaminated water effluents: A systematic review." *Journal of Water Process Engineering* (Q1, 92% percentile);<br>- M. Kunarbekova et al. "Synthesis and characterization of activated carbon from biomass for the sorption of radioactive iodine." *Combustion and Plasmochemistry Journal*, 22(4), 331–341. https://doi.org/10.18321/cpc22(4)331-341;<br>- 2nd International Conference on High Energy Physics, Materials Science and Nanotechnology (ICHEPMS-2024);<br>- X International Conference "Semipalatinsk Research Forum" (STS-2023), Kurchatov, Kazakhstan;<br>- Patent No. 9470 – "Method of obtaining sorption material for water purification from radionuclides".<br>Finding 2 is novel, non-trivial, and has broad applicability.<br><br>Finding 3 – Sorption mechanisms were elucidated using Gaussian modeling via NADA based on FTIR and SEM-EDX data, revealing fragment structures and quantifying physical sorption, chemisorption, and electrostatic contributions. This was demonstrated in the dissertation and presented in the following conference materials:<br>- VIII Kazakhstan Student Scientific and Practical Conference "Chemical Physics and Nanomaterials", Almaty, 2024;<br>- 4th International Russian-Kazakh Scientific and Practical Conference "Chemical Technologies of Functional Materials", Almaty, April 2024;<br>- Advanced Engineering Science Symposium and the 2nd International Symposium on New Materials and Devices, June 2024.<br>Finding 3 is novel, non-trivial, and has broad applicability. |
| 8. | The principle of reliability. Reliability of sources and | 8.1 The choice of methodology is justified or the methodology is described in sufficient detail:<br>**1) yes;**<br>2) No. | The methodology is well-detailed in the experimental section, including protocols for obtaining modified activated carbon sorbents, with special focus on structural features and sorption efficiency. |

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| | information provided | 8.2 The results of the dissertation work were obtained using modern scientific research methods and methods of data processing and interpretation using computer technology:<br>**1) yes;**<br>2) No. | All applied analytical methods are considered sufficient for this type of research. |
| | | 8.3 Theoretical conclusions, models, identified relationships and patterns have been proven and confirmed by experimental research (for areas of training in pedagogical sciences, the results have been proven on the basis of a pedagogical experiment):<br>**1) yes;**<br>2) No. | Theoretical conclusions, identified relationships, and patterns are confirmed through experimental studies. |
| | | 8.4 Important statements are **confirmed**/partially confirmed/not confirmed by references to relevant and reliable scientific literature. | Key statements are supported by references to credible scientific literature. References include domestic and international sources indexed in Scopus and Web of Science. |
| | | 8.5 The literature sources used are **sufficient**/not sufficient for a literary review. | The dissertation includes 199 sources, which are sufficient for solving the stated tasks. |
| 9 | The principle of practical value | 9.1 The thesis has theoretical significance:<br>**1) yes;**<br>2) No. | This work is a scientific study addressing both theoretical and applied challenges. |
| | | 9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice:<br>**1) yes;**<br>2) No. | The dissertation has practical relevance and a high potential for real-world application in purifying radionuclide-contaminated water. |
| | | 9.3 Suggestions for practice are new:<br>**1) Completely new;**<br>2) partially new (25-75% are new);<br>3) not new (less than 25% are new). | The proposals for practical implementation of the results obtained in the dissertation are partially novel and can be used in the treatment of radioactive wastewater. |
| 10. | Quality of writing and design | The quality of academic writing:<br>**1) High;**<br>2) Average;<br>3) below average;<br>4) Low. | The academic writing quality is high. The dissertation is formatted in accordance with the requirements for dissertation works. |
| 11. | Review comments on the dissertation | 1. Some sections, such as the synthesis protocols and characterization procedures, could be more detailed. For instance, the exact conditions (e.g., temperature, time, pressure) for hydrothermal treatments and KOH activation should be explicitly stated to ensure reproducibility;<br>2. The long-term stability and regeneration efficiency of the sorbents are not thoroughly addressed;<br>3. The scalability of the synthesis methods, particularly the hydrothermal and autoclave processes, could pose practical challenges;<br>4. The economic and environmental costs of chemical activators (e.g., KOH) should be considered; | |

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| | | 5. The thesis mentions experimental errors (e.g., ±2.8% for BET measurements) but does not consistently discuss the reproducibility of results across multiple batches or experiments. |
| 12. | The scientific level of the doctoral student's articles on the research topic (in the case of a dissertation defense in the form of a series of articles, official reviewers comment on the scientific level of each doctoral student's article on the research topic) | The doctoral candidate presents three publications indexed in Scopus/Web of Science databases, including two review articles and one original research paper:<br>1. The review titled "The State of the Art of the Mining and Metallurgical Industry in Kazakhstan and Future Perspectives: A Systematic Review", published in *ES Materials and Manufacturing* in September 2024, outlines the current state of Kazakhstan's mining and metallurgical industries, highlights their potential and existing challenges, and analyzes the country's rich mineral resources such as copper, gold, iron, lead, and uranium. It also discusses the environmental and social implications of mining activities. This review is considered relevant to the dissertation topic, as the data provided were later used to define the objectives for the treatment of wastewater using newly developed modified sorbents;<br>2. The review titled "Carbon adsorbents for the uptake of radioactive iodine from contaminated water effluents: A systematic review", published in *Journal of Water Process Engineering* in November 2024, addresses the removal of radioactive iodine from contaminated wastewater using activated carbons derived from various raw materials. This review is directly aligned with the theme of the dissertation;<br>3. The article "Health Risk Assessment of Nitrate in Drinking Water with Potential Source Identification: A Case Study in Almaty, Kazakhstan", published in *International Journal of Environmental Research and Public Health* in January 2024, presents an assessment of drinking water samples from the water distribution network in eight districts of Almaty and their health risks for infants, children, adolescents, and adults. This article is not directly relevant to the topic of the dissertation, as it does not involve modified carbon sorbents or the removal of radionuclides from contaminated water;<br>4. Two articles published in Combustion and Plasmochemistry Journal are relevant to the dissertation topic. However, one article published in NNC RK Bulletin concerns the production of nanocellulose and its application for dye removal from water, which is not directly related to the dissertation's focus;<br>5. Five conference proceedings and one utility model patent are devoted to the synthesis of biomass-derived sorbents and their application for radionuclide removal from wastewater. All of these contributions are relevant and correspond well to the dissertation topic. |
| 13. | The decision of the official reviewer | To award a Doctor of Philosophy (PhD) degree. |

**Official Reviewer:**
Candidate of Chemical Sciences,
Research Professor of Educational Programs
in "Engineering Technologies"
of Korkyt Ata Kyzylorda University

(signature) N.O. Appazov