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Non-Commercial Joint-Stock Company
"K.I. Satbayev Kazakh National Research Technical University"
_____ E.I. Kuldeyev
"_____" _____ 2026

EXTRACT FROM MINUTES № 9
Baikonurov Mining and Metallurgical Institute
Extended Meeting of the Department of Chemical Processes and Industrial Ecology
April 24, 2026, 14:00

Chairperson: Sh.N. Kubekova – Head of the Department of Chemical Processes and Industrial Ecology, Candidate of Technical Sciences, Associate Professor.

Secretary: D.T. Kurmanalieva – Engineer.

ATTENDEES: Sh.N. Kubekova – Head of Department; A.S. Berkinbayeva – PhD, Associate Professor; G.K. Bishimbayeva – Doctor of Technical Sciences, Professor (online); A. Dalbanbay – Master, Senior Lecturer (online); B.K. Yelikbayev – Doctor of Biological Sciences, Professor; A.S. Zhumagulov – PhD, Lecturer (online); N.M. Zhunusbekova – Candidate of Chemical Sciences, Associate Professor (online); M.B. Zhursinbayeva – Candidate of Chemical Sciences, Associate Professor; T.K. Iskakova – Doctor of Chemical Sciences, Professor; S.K. Kabdrakhmanova – Candidate of Technical Sciences, Professor; A.S. Kalenova – Candidate of Chemical Sciences, Associate Professor; D.M. Akubayeva – Candidate of Technical Sciences, Senior Lecturer; A.K. Abildina – PhD, Associate Professor; G.K. Kusainova – Senior Lecturer, Master; B.K. Mustafimov – Candidate of Technical Sciences, Associate Professor (online); S.M. Nurmakova – Candidate of Technical Sciences, Associate Professor (online); A.S. Raiymbekova – PhD, Associate Professor; G.B. Kezembayeva – DBA, Senior Lecturer (online); S.O. Sarsenbayev – Master, Senior Lecturer; A.K. Kalymbet – Master, Senior Lecturer; G.T. Ibraimova – Master, Senior Lecturer; Sh.B. Yegemova – PhD, Senior Lecturer; N.K. Satybaldyeva – Candidate of Chemical Sciences, Senior Lecturer (online); N.Zh. Seitkaliyeva – Candidate of Chemical Sciences, Associate Professor (online); U.K. Sarsembein – PhD, Senior Lecturer; N.A. Yesdauletova – Lead Engineer; G.E. Zheksenbiyeva – Lead Engineer; D.T. Kurmanalieva – Engineer (online); Sh.U. Myrzabekova – Engineer.

ABSENT: A.L. Kozlovsky – PhD, Research Professor; R.E. Nurlybayev – PhD, Research Professor; A.T. Yerzhanova – Senior Lecturer; K.Zh. Abdiyev – Doctor of Chemical Sciences, Professor; Z.K. Uskembayeva – Senior Lecturer; Zh.N. Yessenbayeva – PhD, Senior Lecturer; V.I. Kapralova – Doctor of Technical Sciences, Professor; Sh.K. Nauryzbayeva – Master, Senior Lecturer; M.S. Kunarbekova – PhD, Senior Lecturer; A.E. Isakyn – Master, Assistant.

Total: 29 persons.

INVITED: Gita Sh. Sultanbayeva – Candidate of Technical Sciences, Associate Professor, A.B. Bekturov Institute of Chemical Technologies.

AGENDA

1. Preliminary defense of the dissertation by **Arailym Kairoldakyzy Kalymbet**, submitted for the degree of Doctor of Philosophy (PhD) under the educational program group D097 –

1. "Chemical Engineering and Processes", specialty 8D07109 – "Innovative Technologies and New Inorganic Materials", entitled: *"Research of Properties and Development of Technology for Obtaining Sorption-Filtering Materials from Domestic Raw Materials."*

HEARD:

Chairperson of the meeting, Head of the Department of Chemical Processes and Industrial Ecology, Candidate of Technical Sciences, Associate Professor **Sh.N. Kubekova**: "A quorum is present to hold the extended meeting of the department. I propose to proceed with today's agenda; if there are any comments, I am ready to hear them. Those in favor of approving the agenda, please vote."

VOTING RESULTS:

"For" – unanimous,
"Against" – none,
"Abstained" – none.

Chairperson **Sh.N. Kubekova**:

"Dear colleagues, I declare the extended meeting of the department open. The dissertation of **Arailym Kairoldakyzy Kalymbet**, prepared within the framework of the educational program 8D07109 – 'Innovative Technologies and New Inorganic Materials', is submitted for preliminary defense for the degree of Doctor of Philosophy (PhD).

The dissertation topic is: *'Research of Properties and Development of Technology for Obtaining Sorption-Filtering Materials from Domestic Raw Materials.'*

The preliminary defense will be conducted in English."

Scientific Supervisors:

1. **Domestic supervisor:** Sholpan Nakishbekovna Kubekova – Candidate of Technical Sciences, Associate Professor, Head of the Department of Chemical Processes and Industrial Ecology, Non-Commercial Joint-Stock Company "K.I. Satbayev Kazakh National Research Technical University".
2. **Foreign supervisor:** Silviya Lavrova-Popova – PhD, Associate Professor, Department of Environmental Engineering, University of Chemical Technology and Metallurgy (Sofia, Bulgaria).

Reviewers:

1. **Internal reviewer:** Makhabbat Seit-Zadayevna Kunarbekova – PhD, Senior Lecturer, Department of Chemical Processes and Industrial Ecology, Non-Commercial Joint-Stock Company "K.I. Satbayev Kazakh National Research Technical University".
2. **External reviewer:** Gita Sh. Sultanbayeva – Candidate of Technical Sciences, Associate Professor, Leading Researcher of the Laboratory of Fertilizers and Salt Chemistry, A.B. Bekturov Institute of Chemical Technologies.

The language of the preliminary defense is **English**. The doctoral candidate's personal file contains the following documents: an anti-plagiarism report, a list of scientific publications, and reviews from the reviewers and scientific supervisors.

To present the content of the dissertation and its main provisions, the floor is given to doctoral candidate A.K. Kalymbet. The presentation time is 20 minutes.

SPOKE:

Doctoral candidate A.K. Kalymbet presented the essence and main provisions of the dissertation. The presentation is attached.

Chairperson of the meeting: "Thank you, the presentation is concluded. You may now proceed with questions to the candidate."

QUESTIONS WERE ASKED BY:

A.S. Kalenova – Candidate of Chemical Sciences, Associate Professor of the Department of Chemical Processes and Industrial Ecology:

Question: "Are the publications sufficient for admission to the defense?"

Answer: "Thank you for your question. Yes, the list of publications is sufficient for admission to the defense and has been verified by the Department of Postgraduate Education."

Question: "What is the practical significance of your work?"

Answer: "From a practical perspective, the developed sorbent is characterized by low solubility (~1%) and high mechanical strength (~91%), which ensures stable and long-term operation in filtration systems. It demonstrates efficient removal of Cu^{2+} ions: over 97% under static conditions and over 83% under dynamic conditions, while maintaining a residual concentration below 0.2 mg/L, which meets water quality standards. Due to these properties, the material is suitable as a polishing sorbent at the final stage of water treatment and exhibits higher stability and lower solubility compared to bentonite."

Question: "Was the economic aspect also considered?"

Answer: "Yes, the economic aspect was also considered. An approximate cost evaluation of the sorbent was carried out in the literature review. The results indicate that the developed sorbents obtained from technogenic raw materials are economically advantageous compared to conventional materials. In particular, the production of activated carbon requires significantly higher costs (raw materials, energy, activation processes), whereas the proposed sorbent is derived from mining waste, resulting in lower production costs while maintaining high efficiency at the water polishing stage."

S.K. Kabdrakhmanova – Candidate of Technical Sciences, Professor of the Department of Chemical Processes and Industrial Ecology

Question: "You obtained six different sorbents, and Sample 3 was identified as optimal. Why, given that their compositions do not differ significantly?"

Answer: "Thank you for your question. The selection of Sample 3 as optimal is primarily related not to its chemical composition, but to its structural–morphological and surface properties. SEM analysis showed that at 600 °C, microcracks and pore elements are formed on the particle surface, facilitating ion diffusion and increasing the accessibility of active sites. In addition, this sample exhibited the most negative ζ-potential, indicating a high degree of surface functionalization and the presence of negatively charged groups ($P–O^-$, –OH). As a result, positively charged heavy metal ions (e.g., Cu^{2+}) are effectively adsorbed through electrostatic attraction. Thus, despite similar compositions, the superior performance of Sample 3 is attributed to its morphology, microcrack formation, and enhanced surface charge."

Question: "Is this a model solution?"

Answer: "Yes, this is a model solution, not industrial wastewater. Studies with real industrial waters are planned for future research, including investigations of cadmium and cobalt cations."

Question: "During synthesis, did temperature play the main role, or did acid concentration also influence the process?"

Answer: "Both factors are important. In this study, phosphoric acid concentrations of 20% and 35% were used. Temperature (400–800 °C) governs structural transformations, microcrack formation, and pore development, while acid concentration controls the formation of surface phosphate groups and chemically active sites. The combined effect of these parameters increases the negative surface charge and enhances the sorption of heavy metal cations."

Question: "Was BET analysis conducted? What differences were observed between samples, and how did temperature affect textural properties?"

Answer: "Yes, BET analysis was performed. All samples exhibited relatively low specific surface area (approximately 2–6 m^2/g), indicating that sorption performance cannot be explained by this parameter alone. The main differences arise from the combined influence of temperature and acid concentration on textural and surface properties. Increasing temperature (400 → 600 → 800 °C) leads to structural reorganization: at ~600 °C, microcracks and additional pores form, improving accessibility of active sites, whereas at 800 °C, pore enlargement and partial densification occur, which may reduce surface area. The sorption mechanism is mixed, involving both physical adsorption and chemisorption, including complexation and ion exchange with phosphate ($P–O^-$) and hydroxyl groups. Therefore, performance is governed primarily by morphology, functional groups, and ζ-potential rather than BET surface area."

Question: "What is the origin of the negative surface charge in Sample 3?"

Answer: "The negative charge arises from changes in surface chemistry due to phosphoric acid modification. Phosphate groups (Si–O–P bonds) are introduced into the silicate matrix, forming negatively charged functional groups ($P–O^-$, $≡Si–O^-$). At 20% acid concentration, this process is more effective due to sufficient water content, which promotes hydroxylation and surface hydration. Partial dissociation of these groups leads to increased negative charge. At higher acid concentration (35%), excessive condensation and structural densification may reduce the accessibility of active sites. Therefore, Sample 3 (20% H_3PO_4, 600 °C) exhibits the highest negative ζ-potential and enhanced sorption of Cu^{2+} ions."

Question: "Was the chemical mechanism (chemism) presented in the dissertation?"

Answer: "Yes, the chemical aspects of sorption were addressed. The mechanism is discussed in detail in the literature review, including ion exchange, complex formation, and interactions with surface functional groups ($P–O^-$, ≡Si–OH). In the experimental section, these mechanisms are supported indirectly by kinetic data, ζ-potential, and FTIR results, confirming that sorption has both physical and chemical nature. The formation of additional pores is explained by gas release during thermal treatment (dehydration of –OH groups, decomposition of carbonates with CO_2 evolution) combined with the action of phosphoric acid, which promotes structural rearrangement and formation of Si–O–P bonds, stabilizing the porous structure."

Question: "The comparison with bentonite—was it a commercial product?"

Answer: "Yes, the bentonite used for comparison is a commercial product complying with technical specifications TU 2164-004-00204493-2009. Although it is widely used and has a silicate composition (~50–60% SiO_2), it exhibits high solubility and dispersion, which reduce its stability under dynamic conditions. In contrast, the developed optimal sorbent (Sample 3) demonstrates lower solubility and higher mechanical strength, ensuring more stable performance in filtration systems."

Question: "What type of water treatment is the sorbent intended for? Did you consider drinking water?"

Answer: "The developed sorbent is primarily intended for the polishing stage of industrial and natural water treatment, i.e., for reducing residual concentrations after primary treatment steps. Its application for drinking water is not excluded; however, it is considered only for the final purification stage, as drinking water treatment requires strict standards and multi-stage processing."

A.S. Berkinbayeva – PhD, Associate Professor of the Department of Chemical Processes and Industrial Ecology:

Question: "Is there any influence of time between the samples?"

Answer: "No, time was not considered as a variable factor in this study. All samples were synthesized and analyzed under identical time conditions; therefore, the differences between them are explained not by time, but primarily by the effects of thermal treatment temperature and phosphoric acid concentration. The main distinction is related to acid concentration: at 20% H_3PO_4, the higher liquid phase content promotes more effective interaction with the raw material, resulting in enhanced surface functionalization."

Question: "Why was bentonite thermally treated at 600 °C?"

Answer: "Bentonite was thermally treated at 600 °C to ensure a valid comparative analysis. At this temperature, significant structural changes occur: interlayer water is removed, organic and weakly bound components decompose, and the mechanical strength of the material increases. Additionally, such treatment reduces its dispersibility and allows for a more reliable evaluation of its stability under static conditions. Thus, this temperature was selected to place bentonite under conditions comparable to those used for the synthesized sorbents, enabling a consistent comparison of their properties."

G.T. Ibraimova – Master, Senior Lecturer of the Department of Chemical Processes and Industrial Ecology:

Question: "You mentioned that lower phosphoric acid concentration improves surface characteristics. Did you consider even lower concentrations?"

Answer: "No, in this study only 20% and 35% phosphoric acid concentrations were investigated, with 20% showing the optimal performance. Lower concentrations were not examined; however, theoretically, further reduction may negatively affect surface functionalization and the incorporation of phosphate groups. Therefore, the 20% concentration represents an optimal balance between efficiency and structural stability, although the outcome may also depend on the composition of the raw material and the type of acid used."

S.K. Kabdrakhmanova – Candidate of Technical Sciences, Professor of the Department of Chemical Processes and Industrial Ecology:

Question: "During acid–thermal synthesis using Akbakay mining waste, did the volume of acid vary?"

Answer: "Yes, the interaction with acid varies depending on the mineral phases present in the raw material. For example, dolomite ($CaMg(CO_3)_2$) readily reacts with phosphoric acid, dissolving with CO_2 evolution and contributing to pore formation. In contrast, silica (SiO_2) is relatively inert, but under acid–thermal conditions, its surface undergoes restructuring with possible formation of Si–O–P bonds. Therefore, the degree of interaction depends on the mineral composition, which in turn influences acid consumption and structural transformations."

Question: "Did you verify the composition after synthesis?"

Answer: "Yes, the composition of the synthesized sorbents was analyzed using XRD and EPMA. The results showed changes in mineral phases and elemental composition after acid–thermal treatment: while the silicate matrix was preserved, the incorporation of phosphate groups and the presence of phosphorus confirmed successful modification. Although compositional differences were not substantial, the sorption properties were found to be primarily governed by surface functional groups, morphology, and negative ζ-potential."

Question: "You state that a synthesis technology was developed, but no technological flow diagram is presented. Why?"

Answer: "The main stages of the synthesis technology are fully described in the dissertation; however, a separate technological flow diagram was not included. The primary objective of the

work was to investigate material properties and substantiate synthesis conditions; therefore, the process was described step-by-step in text form (raw material preparation, acid treatment, thermal treatment, washing, and drying). If necessary, this process can be represented as a technological scheme, which may be further developed for scale-up at the industrial level."

Question: "Will you submit the work for a patent?"

Answer: "Yes, this is planned for the future."

Question: "Was the sorbent tested for selectivity? Also, the novelty and statements require stylistic revision."

Answer: "The selectivity of the sorbent was not comprehensively studied in this work, as the main focus was on Cu^{2+} ion removal. However, the literature review discusses selectivity of silicophosphate sorbents toward heavy metal cations, considering factors such as charge, ionic radius, hydration energy, and interactions with surface functional groups. Since the sorption mechanism involves both physical and chemical processes (complexation and ion exchange), a certain degree of selectivity can be inferred. This aspect represents a promising direction for future research. Stylistic comments will be addressed before the defense, thank you."

T.K. Iskakova – Doctor of Chemical Sciences, Professor of the Department of Chemical Processes and Industrial Ecology:

Question: "What is the reproducibility of results when using waste materials for sorbent synthesis?"

Answer: "Reproducibility was ensured through proper preparation of the technogenic raw material (sampling, grinding, and homogenization), as well as maintaining constant synthesis parameters (temperature, acid concentration, and solid-to-liquid ratio). Experiments were repeated multiple times, and no significant differences were observed in sorption capacity or removal efficiency, indicating good reproducibility. Although natural variability of raw materials exists, it was minimized through sample preparation, and deviations remained within acceptable error limits without affecting the main conclusions."

Question: "You conducted experiments with copper solutions three times. Were errors taken into account?"

Answer: "Yes, sorption experiments with Cu^{2+} ions were performed in triplicate. Average values were calculated, and errors were taken into account. The results presented in graphs and tables include standard deviation/error values, demonstrating the reproducibility and reliability of the experimental data."

Sh.U. Myrzabekova – Engineer of the Department of Chemical Processes and Industrial Ecology:

Question: "What instrumental analysis methods did you use in this study?"

Answer: "In this work, a complex of instrumental analysis methods was applied to comprehensively evaluate the composition, structure, and properties of the sorbents. These included X-ray diffraction (XRD) for phase composition, electron probe microanalysis (EPMA) for elemental composition, Fourier-transform infrared spectroscopy (FTIR) for identification of functional groups, scanning electron microscopy (SEM) for morphological analysis, ζ-potential measurements for surface charge evaluation, and the BET method for determination of textural characteristics."

Question: "Have you considered implementing this work in industry?"

Answer: "Yes, the potential for industrial implementation has been considered. The developed sorbent is based on readily available technogenic waste, and the synthesis technology is relatively simple (acid treatment followed by thermal treatment), which makes it suitable for scaling up. In addition, the high stability and efficiency of the material make it promising for application in industrial wastewater treatment at the polishing stage.

The relevance of this direction is also associated with the current shortage of qualified chemical specialists in industry, highlighting the need to strengthen collaboration between universities and industrial enterprises. Integration of scientific research with industrial practice will facilitate technology transfer, workforce training, and the solution of real environmental problems."

Chairperson of the meeting, Sh.N. Kubekova – Head of the Department of Chemical Processes and Industrial Ecology, Candidate of Technical Sciences, Associate Professor: "Dear colleagues, are there any further questions? If there are no more questions, the floor is given to the external reviewer – Gita Sh. Sultanbayeva, Candidate of Technical Sciences, Associate Professor, Leading Researcher of the Laboratory of Fertilizers and Salt Chemistry, A.B. Bekturov Institute of Chemical Technologies."

SPOKE:

Gita Sh. Sultanbayeva – Candidate of Technical Sciences, Associate Professor, Leading Researcher of the Laboratory of Fertilizers and Salt Chemistry, A.B. Bekturov Institute of Chemical Technologies:

The relevance of the research topic lies in the development of sorption–filtering materials based on technogenic waste for the removal of heavy metal ions from water, which represents one of the key directions in modern environmental and materials science. Under conditions of increasing anthropogenic impact on water resources and the necessity for rational use of mineral raw materials, the search for efficient and accessible materials for water treatment is of particular importance. The use of mining and beneficiation waste as raw material is consistent with the principles of sustainable development and the "green economy," emphasizing the applied significance of the study.

The scientific novelty of the work includes: a comparative study of various types of domestic mining waste as raw materials for sorbent synthesis; substantiation of the selection of Akbakay flotation tailings as the most promising precursor; development of a method for producing silicophosphate sorbents using phosphoric acid and thermal treatment; establishment of relationships between synthesis conditions and physicochemical properties of the obtained materials; and identification of sorption features of Cu^{2+} ions under both static and dynamic conditions. The obtained results contribute to the advancement of approaches for creating functional materials based on technogenic raw materials.

The practical significance of the work is reflected in the development of an accessible and effective sorbent suitable for water purification from heavy metal ions. The obtained materials are characterized by high removal efficiency of Cu^{2+} ions over a wide concentration range, low solubility in water, and sufficient mechanical strength for application in flow systems. The research results can be applied in advanced wastewater treatment technologies and water treatment systems.

The validity and reliability of the results are confirmed by the use of a comprehensive set of modern physicochemical analysis methods, including XRD, SEM, FTIR, BET, zeta potential measurements, and atomic absorption spectroscopy. The experimental studies were carried out at an adequate level, and the results are consistent and in agreement with literature data.

The dissertation is logically structured, contains all necessary sections, and is performed at a high scientific level. The material is presented systematically and clearly, supported by appropriate illustrations and their analysis. Particular attention is given to the comparative evaluation of sorbent properties and performance under different conditions. The work demonstrates a high level of independence of the author and proficiency in modern research methods.

As remarks, it is recommended to further consider issues related to sorbent regeneration and to expand the range of studied heavy metal ions in future research. These comments are advisory in nature and do not diminish the scientific value of the work.

In conclusion, the dissertation entitled *" Research of Properties and Development of Technology for Obtaining Sorption-Filtering Materials from Domestic Raw Materials "* represents a completed scientific qualification work that addresses a relevant scientific and technical problem. In terms of content, scientific novelty, and practical significance, the work meets the requirements for the degree of Doctor of Philosophy (PhD).

Chairperson of the meeting, Sh.N. Kubekova: "The floor is given to doctoral candidate A.K. Kalymbet to respond to the reviewer's comments and recommendations."

Doctoral candidate A.K. Kalymbet: "I would like to express my sincere gratitude to Ms. Gita Sh. Sultanbayeva for the careful review and comprehensive evaluation of my dissertation work. I agree with all the comments. The indicated remarks will be taken into account, and appropriate revisions will be made."

Chairperson Sh.N. Kubekova: "The next floor is given to the second reviewer — Makhabbat Seit-Zadayevna Kunarbekova, PhD, Senior Lecturer of the Department of Chemical Processes and Industrial Ecology. As she is unable to attend for valid reasons, her review will be read."

The relevance of the dissertation lies in addressing one of the pressing environmental problems related to water contamination by heavy metal ions, particularly copper ions originating from mining and metallurgical industries. The accumulation of heavy metals in aquatic environments poses significant risks due to their toxicity, persistence, and bioaccumulation capacity. In this context, the development of cost-effective and mechanically stable sorption–filtering materials based on domestic technogenic raw materials is of high importance. The use of mining waste aligns with the principles of circular economy and sustainable resource management, confirming the scientific and practical relevance of the study.

Within the framework of the dissertation requirements, the work comprehensively achieves its objectives: silicophosphate sorption–filtering materials were synthesized based on domestic mining waste; their physicochemical properties were thoroughly characterized; equilibrium and kinetic parameters of Cu^{2+} sorption were determined; dynamic behavior was studied in fixed-bed column conditions; relationships between synthesis conditions, structure, and sorption performance were established; and comparative evaluation with conventional mineral sorbents was conducted.

The validity and reliability of the results are supported by seven scientific publications, including four articles in peer-reviewed journals, one publication in a journal recommended by the Committee for Quality Assurance in Science and Higher Education of the Republic of Kazakhstan, and two publications in international conference proceedings.

The scientific novelty lies in the development of structurally stable silicophosphate sorption–filtering materials obtained via phosphoric acid modification followed by thermal treatment. The materials are characterized by low solubility and high mechanical strength, ensuring stable performance under filtration conditions. Sorption characteristics of Cu^{2+} ions were comprehensively studied under equilibrium, kinetic, and dynamic conditions, including fixed-bed column experiments. Relationships between mineral composition, synthesis parameters, structural transformations, and sorption efficiency were established. The developed sorbents demonstrate high removal efficiency of copper ions (>97% under static and >83% under dynamic conditions), with residual concentrations below 0.2 mg/L. Compared to traditional sorbents such as bentonite, the materials exhibit improved structural stability and operational reliability. Despite moderate sorption capacity, their stability and low-cost raw material base make them promising for water polishing applications.

The practical significance of the work is demonstrated by the development of structurally stable sorption–filtering materials with low solubility and high mechanical strength, suitable for water purification from copper ions under both static and dynamic conditions. The results confirm the feasibility of applying these materials at the polishing stage of water treatment and highlight their potential for industrial wastewater purification.

The main results of the dissertation are sufficiently reflected in the author's publications, which adequately represent the content of the work.

As remarks, it is recommended to expand the study to other heavy metal ions, provide additional discussion of the relatively low specific surface area, further investigate sorbent regeneration and reuse, and include experiments with real industrial wastewater. These comments are not fundamental and do not reduce the scientific value of the work.

In conclusion, the dissertation entitled *"Research of Properties and Development of Technology for Obtaining Sorption-Filtering Materials from Domestic Raw Materials"*, carried out by Arailym Kairoldakyzy Kalymbet within the educational program 8D07109 – "Innovative Technologies and New Inorganic Materials," meets the requirements for the degree of Doctor of Philosophy (PhD) and is recommended for defense.

Chairperson of the meeting, Sh.N. Kubekova: "The floor is given to doctoral candidate A.K. Kalymbet to respond to the reviewer's comments and recommendations."

Doctoral candidate A.K. Kalymbet: "Dear Makhabbat Seit-Zadayevna, I would like to express my gratitude for your careful review and valuable feedback on my dissertation work. I agree with all the comments. The identified shortcomings will be fully addressed in due course."

Head of the Department, PhD, Associate Professor Sh.N. Kubekova: "The next floor is given to the foreign scientific supervisor — Silviya Lavrova-Popova. As she is unable to attend for valid reasons, her review will be read."

"I had great pleasure and professional satisfaction serving as the foreign scientific supervisor of Ms. Arailym Kalymbet during her doctoral studies. Throughout her studies, she consistently demonstrated a high level of responsibility, perseverance, and dedication. Despite challenges encountered during the research process, she remained strongly motivated and focused on successfully completing her work.

Her dissertation addresses a topic of clear scientific and practical significance. The research is devoted to the development and study of silicophosphate sorbents obtained from mining waste via acid and thermal treatment, as well as the evaluation of their sorption capacity for wastewater purification. This topic is highly relevant in the context of developing efficient and economically feasible water treatment methods and aligns with the principles of circular economy.

In the summer of 2023, Ms. Kalymbet completed a research internship at the University of Chemical Technology and Metallurgy (Sofia, Bulgaria), where she carried out part of the planned experimental work on the sorption properties of the synthesized materials. During this period, she demonstrated excellent organizational skills, accuracy, and discipline in laboratory work, as well as a high level of theoretical knowledge and well-developed practical skills.

Her personal and professional qualities also deserve high recognition. She is a responsible, reliable, and diligent young researcher who quickly masters new methods and effectively applies them in practice. She has shown a strong ability to adapt to new working environments and integrate new knowledge into her scientific activity.

An important indicator of the quality and significance of her doctoral research is her publication activity based on experimental results. Our joint work resulted in four scientific publications, reflecting both the scientific value of the results and her active contribution to their dissemination within the scientific community.

In my opinion, Ms. Arailym Kalymbet has fully achieved the level of scientific maturity, research competence, and academic preparation required of a doctoral candidate. Her dissertation contains scientifically novel results, is performed at a high methodological level, and has both scientific and practical significance.

Based on the quality of the completed dissertation, the obtained results, and my direct supervision of her research and laboratory work, I fully support her dissertation and recommend awarding her the degree of Doctor of Philosophy (PhD)."

Head of the Department, PhD, Associate Professor Sh.N. Kubekova: "The next floor is given to the internal scientific supervisor — Sholpan Nakishbekovna Kubekova, Candidate of Technical Sciences, Associate Professor, Head of the Department of Chemical Processes and Industrial Ecology."

Sh.N. Kubekova: "The dissertation of Arailym Kairoldakyzy Kalymbet is devoted to a relevant scientific and technical problem—development of effective sorption–filtering materials based on technogenic waste for the removal of heavy metal ions from water. The work includes an analysis of the mineral resource base of Kazakhstan and substantiates the selection of Akbakay flotation tailings as a promising raw material.

The author proposed a method of acid–thermal modification using phosphoric acid and determined the influence of acid concentration and temperature on material properties. The structure and properties of the sorbents were comprehensively studied using XRD, FTIR, SEM, BET, and ζ-potential methods. Despite relatively low specific surface area, high sorption activity was demonstrated due to the formation of phosphate groups.

Sorption of Cu^{2+} ions was investigated in terms of kinetics, isotherms, and dynamic behavior, showing that the process follows a pseudo-second-order model. The effectiveness under dynamic conditions was confirmed, and the applicability of the material for the polishing stage of water treatment was demonstrated.

The scientific novelty lies in the development of an approach for transforming mineral waste into targeted silicophosphate sorbents. The dissertation is performed at a high scientific level, the results are published, and the author is deserving of the PhD degree."

Chairperson Sh.N. Kubekova:

"Dear colleagues, we have heard the opinions of the reviewers, scientific supervisors, and invited participants. We will now proceed to voting. Only members of the Department of Chemical Processes and Industrial Ecology have the right to vote. Currently, the department has 34 members; a quorum is present.

I put to vote the proposal to recommend the dissertation of Arailym Kairoldakyzy Kalymbet entitled *'Research of Properties and Development of Technology for Obtaining Sorption-Filtering Materials from Domestic Raw Materials'* for defense before the Dissertation Council under the educational program 8D07109 – 'Innovative Technologies and New Inorganic Materials' for the degree of PhD.

Those in favor, please raise your hands. Those against? Abstentions?"

VOTING RESULTS:

"For" – unanimous,
"Against" – none,
"Abstained" – none.

A total of 29 department members participated in the extended meeting. The decision was supported unanimously.

Chairperson of the meeting, Head of the Department of Chemical Processes and Industrial Ecology, PhD, Associate Professor Sh.N. Kubekova:

"Thank you all for your comments and active participation in the discussion. Thus, we consider that the dissertation of Arailym Kairoldakyzy Kalymbet entitled *'Research of Properties and Development of Technology for Obtaining Sorption-Filtering Materials from Domestic Raw Materials'* should be recommended for defense before the Dissertation Council for the degree of Doctor of Philosophy (PhD)."

RESOLVED:

The dissertation of Arailym Kairoldakyzy Kalymbet entitled *"Research of Properties and Development of Technology for Obtaining Sorption-Filtering Materials from Domestic Raw Materials"*, submitted for the degree of Doctor of Philosophy (PhD) under the educational program 8D07109 – "Innovative Technologies and New Inorganic Materials," is recommended for defense before the Dissertation Council.

Chairperson: _____ **Sh. Kubekova**

Secretary: _____ **D. Kurmanalieva**