Brief information about the project

Title	AP23490113 «Establishing a scientific and technical foundation for developing a consortium of aquatic plants and microalgae, effective for phytoremediation of water with the associated production of raw materials for biofuel»
Relevance	For much of the world, the issue of heavy metal (HM) discharge from industrial operations into domestic waters and wastewater remains a difficult challenge to overcome. Aquatic ecosystems continue to be exposed to contaminants despite the use of various water treatment technologies. Pollutants such as heavy metals pose a serious threat to the environment due to their resistance to degradation and their toxic effects on human health and aquatic biodiversity. The need to find more effective and innovative purification methods is becoming increasingly urgent to ensure the sustainability of water resources and the preservation of ecosystems as a whole. A leading method in environmental biotechnology that uses living organisms to clean up environmental pollutants is bioremediation. Among all the strategies, phytoremediation stands out for its effectiveness, efficiency, cost accessibility, and minimal environmental impact. To enhance the effectiveness of purification technologies, it is advisable to utilize a community of organisms that coexist in a specific natural system, interact with each other, and possess diverse biochemical properties. Thus, the formation of a consortium of higher aquatic plants (HAPs) and microalgae resistant to heavy metals opens new opportunities in environmental biotechnology for the treatment of domestic and industrial wastewater. The use of HAPs as natural water filtration agents has long been practiced, whereas microalgae have only begun to receive significant research attention in recent decades for their potential in bioremediation.
Goal	Study of the cellular and physiological-biochemical mechanisms of resistance the association of higher aquatic plants and microalgae to heavy metals, for of developing a scientifically based, effective technology for phytoremediation of water while simultaneously producing valuable green biomass as a raw material for biofuels.
Tasks	1. Selection of microalgae strains that are resistant to heavy metals (Cd, Cu, Zn, Cr, Pb). 2. Study of the ability of selected microalgae strains to bioaccumulate heavy metal ions. 3. Study of cellular and physiological-biochemical mechanisms of resistance of active strains of microalgae to heavy metals. 4. Isolation of higher aquatic plants (HAP) from aquatic ecosystems of the Republic of Kazakhstan contaminated with heavy metals and study of the mechanisms of their resistance to toxicants. 5. Study of the ability of selected species of higher aquatic plants (HAP) for sustainable bioaccumulation of heavy metals. 6. Study of cellular mechanisms of heavy metal detoxification in isolated resistant species of aquatic plants. 7. Construction of a consortium of higher aquatic plants (HAP) and microalgae with a high sorption capacity for

	heavy metals. 8. Study of the bioenergy potential of the biomass of the HAP consortium and microalgae obtained incidentally during the phytoremediation of water contaminated with heavy metals and organic substances. 9. Development of scientifically based technological regulations for the phytoremediation of water from heavy metal ions based on a consortium of HAP and phototrophic microorganisms with the subsequent use of the resulting green biomass as a valuable raw material for the production of biofuel.
Expected and Achieved Results	1. Collectible strains of microalgae with high resistance to heavy metals (Cd, Cu, Zn, Cr, Pb) will be selected. 2. The ability of selected microalgae strains to bioaccumulate heavy metal ions will be investigated. 3. The main cellular and physiological-biochemical mechanisms of resistance of active microalgae strains to heavy metals will be determined. Changes in cell ultrastructure, changes in biochemical parameters (level of enzymes (SOD, catalase, peroxidase, glutathione reductase, etc.), proteins, carbohydrates, pigments (carotenoids, chlorophyll)) will be detected. 4. The highest aquatic plants from the aquatic ecosystems of the Republic of Kazakhstan contaminated with heavy metals will be selected and their stability and sorption capacity against heavy metals will be studied. 5. Higher aquatic plant (HAP) accumulation capacity for heavy metals will be investigated. 6. The main cellular mechanisms of heavy metal detoxification in isolated resistant aquatic plant species will be determined. Changes in cell ultrastructure, changes in biochemical parameters (level of enzymes (SOD, catalase, peroxidase, glutathione reductase, etc.), proteins, carbohydrates, pigments (carotenoids, chlorophyll)) will be detected. 7. A consortium of higher aquatic plants (HAP) and microalgae with a high sorption capacity for heavy metals will be obtained. 8. The bioenergetic potential of the biomass from the consortium of HAP and microalgae will be studied, in particular the biochemical composition of the biomass (polysaccharides (yield of reducing sugars and glucose under different conditions of biomass hydrolysis), proteins, lipids, fatty acid composition) will be determined in order to assess the prospects for obtaining biobutanol and biodiesel. 9. A scientifically based technological regulations will be developed for the phytoremediation of water from heavy metal ions using a consortium of HAP and phototrophic microorganisms, followed by the use of the resulting green biomass as a valuable raw material for biofuels.

Names and Surnames of Research Group Members with Their Identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and Links to Corresponding Profiles	1. Sadvakasova Assemgul ResearcherID – X-6084-2019 Scopus Author ID – 55978114100, https://orcid.org/0000-0003-1456-5320 https://www.scopus.com/authid/detail.uri?authorId=55978114100 https://www.webofscience.com/wos/author/record/1865165 2. Bauenova Meruyert Researcher ID: ABD-6906-2021 Scopus Author ID: 57201014777ORCID https://orcid.org/0000-0003-4117-8449 https://www.scopus.com/authid/detail.uri?authorId=57201014777 https://www.webofscience.com/wos/author/record/2418336 3. Kossalbayev Bekzhan ResearcherID: Q-6587-2017 Scopus Author ID: 57205673698 https://orcid.org/0000-0003-3892-7920 https://www.scopus.com/authid/detail.uri?authorId=57205673698 4. Sarsekeyeva Fariza ResearcherID: E-4491-2015. Scopus Author ID: 56524602300 https://orcid.org/0000-0001-9119-2279 https://www.scopus.com/authid/detail.uri?authorId=56524602300 https://www.webofscience.com/wos/author/record/801305 5. Zaletova Dilnaz Scopus ID: 58698487800 https://orcid.org/0009-0000-1604-4241 https://www.scopus.com/authid/detail.uri?authorId=58698487800
Publications list with links to them	1. Meruyert O. Bauenova, Assemgul K. Sadvakasova, Bekzhan D. Kossalbayev, Girayhan Yilmaz, Zhiyong Huang, Jingjing Wang, Huma Balouch, Dilnaz E. Zaletova, Mariya A. Lyaguta, Hesham F. Alharby, Suleyman I. Allakhverdiev Optimising microalgae-derived butanol yield // International Journal of Hydrogen Energy. 2023. https://www.sciencedirect.com/science/article/pii/S0360319923057488?dgcid=coauthor Импак-фактор 2020: 5.816. H-Index - 215, Q-1, CiteScore-9.0. Процентиль: ##22/224: 90-й. 2. Bauenova, M.O., Sadvakasova, A.K., Mustapayeva, Z.O., Kokociński M., Zayadan B.K., Wojciechowicz M.K., Balouch H., Akmukhanova N.R., .Alwasel, S., Allakhverdiev, S.I. Potential of microalgae *Parachlorella kessleri* Bh-2 as bioremediation agent of heavy metals cadmium and chromium, Algal Research, Volume 59, 2021. https://doi.org/10.1016/j.algal.2021.102463. Импак-фактор 2020-2021: 4.401. H-Index-54.0, Q-1, CiteScore-6.6. Процентиль: ##21/113:81-й. 1-цитирований. 3. Assemgul K Sadvakasova, Meruyert O Bauenova, Bekzhan D Kossalbayev, Bolatkhan K Zayadan, Zhiyong Huang, Jingjing Wang, Huma Balouch, Hesham F Alharby, Jo-Shu Chang, Suleyman I Allakhverdiev Synthetic algocyanobacterial consortium as an alternative to chemical fertilizers // Environmental Research. – 2023. – V. 233. 116418. https://doi.org/10.1016/j.envres.2023.116418. Импак-фактор

	8.3. H-Index-54.0, Q-1, CiteScore-9,0. Процентиль: 90. 1-цитирований. 4. Sadvakasova A.K., Kossalbayev B.D., Bauenova M.O., Balouch H., Leong Y.K., Zayadan B.K., Huang Z., Alharby H.F., Tomo T., Chang J.S. et al. Microalgae as a key tool in achieving carbon neutrality for bioproduct production // Algal Research. Journal article. – 2023. – V. 72, 103096. https://doi.org/10.1016/j.algal.2023.103096. Импак-фактор 5.5. H-Index-164, Q-1, CiteScore-11. Процентиль: 91. 0-цитирований. 5. Nurziya R. Akmukhanova, Yoong Kit Leong, Sandugash N. Seiilbek, Aigerim Konysbay, Bolatkhan K. Zayadan, Assemgul K. Sadvakasova, Fariza K. Sarsekeyeva, Meruyert O. Bauenova, Kenzhegul Bolatkhan, Hesham F. Alharby, Jo-Shu Chang, Suleyman I. Allakhverdiev Eco-friendly biopesticides derived from CO_2-Fixing cyanobacteria // Environmental Research. – 2023. – V. 239. 117419. https://doi.org/10.1016/j.envres.2023.117419. Импак-фактор 8.3. H-Index-54.0, Q-1, CiteScore-9,0. Процентиль: 90. 3-цитирований. 6. Gulzhanay K. Kamshybayeva, Bekzhan D. Kossalbayev, Asemgul K. Sadvakasova, Meruyert O. Bauenova, Bolatkhan K. Zayadan, Ayshat M. Bozieva, Hesham F. Alharby, Tatsuya Tomo, Suleyman I. Allakhverdiev Screening and optimisation of hydrogen production by newly isolated nitrogen-fixing cyanobacterial strains // International Journal of Hydrogen Energy. – 2023. –V. 48 (44). – P. 16649-16662. https://doi.org/10.1016/j.ijhydene.2023.01.163 Импак-фактор 2020: 5.816. H-Index - 215, Q-1, CiteScore-9.0. Процентиль: ##22/224: 90-й. 4-цитирований. 7. Gulzhanay K. Kamshybayeva, Bekzhan D. Kossalbayev, Asemgul K. Sadvakasova, Meruyert O. Bauenova, Bolatkhan K. Zayadan, Anastasia A. Krapivina, Gaukhar A. Sainova, Hesham F. Alharby, Suleyman I. Allakhverdiev. Effect of the photosynthesis inhibitors on hydrogen production by non-heterocyst cyanobacterial strains // International Journal of Hydrogen Energy. – 2023. https://doi.org/10.1016/j.ijhydene.2023.03.453. Импак-фактор 2020: 5.816. H-Index - 215, Q-1, CiteScore-9.0. Процентиль: ##22/224: 90-й. 1-цитирований. 8. Gulzhanay K. Kamshybayeva, Bekzhan D. Kossalbayev, Asemgul K. Sadvakasova, Ardak B. Kakimova, Meruyert O. Bauenova, Bolatkhan K. Zayadan, Chi-Wei Lan, Saleh Alwasel, Tatsuya Tomo, Jo-Shu Chang, Suleyman I. Allakhverdiev Genetic engineering contribution to developing cyanobacteria-based hydrogen energy to reduce carbon emissions and establish a hydrogen economy // International Journal of Hydrogen Energy. – 2023. https://doi.org/10.1016/j.ijhydene.2022.12.342 Импак-фактор 2020: 5.816. H-Index - 215, Q-1, CiteScore-9.0. Процентиль: ##22/224: 90-й. 7-цитирований. 9. Assemgul K. Sadvakasova, Bekzhan D. Kossalbayev, Aziza I. Token , Meruert O. Bauenova, Jingjing, Wang , Bolatkhan K. Zayadan, Huma Balouch , Saleh Alwasel , Yoong Kit Leong , Jo-Shu Chang, Suleyman I. Allakhverdiev Influence of Mo and Fe on Photosynthetic and Nitrogenase Activities of Nitrogen-Fixing Cyanobacteria under Nitrogen Starvation, Cells, Volume 11 (5) 904, 2022. https://doi.org/10.3390/cells11050904. Импак-фактор 2020-2021: 6.663. H-Index-22, Q-2, CiteScore-4.33. Процентиль: ##41. 1-цитирований.

	10.N. R. Akmukhanova, B. K. Zayadan, A. K. Sadvakasova, M. M. Torekhanova, N. P. Timofeev, M. O. Bauenova, D. A. Todorenko & D. N. Matorin Determination of the Promising Microalgal Strain for Bioremediation of the Aquaculture Wastewater // Microbiology. – 2022.- V. 91, 533–541. https://doi.org/10.1134/S0026261722601166. Импак-фактор: 2.7. Q-3. 1-цитирований. 11.Akmukhanova, Nurziya R. Sadvakasova, Assemgul K., Torekhanova, Makpal M., Bauenova, Meruyert O., Zayadan, Bolatkhan K., Shalgimbayeva, Saule M., Bolatkhan, Kenzhegu, Alwasel, Saleh, Leong, Yoong Kit, Chang, Jo-Shu, Allakhverdiev, Suleyman I. Feasibility of waste-free use of microalgae in aquaculture // Journal of Applied Phycology. 2022. Impact factor: 5.816. H-Index - 127, Q-2, CiteScore-9.0. Percentile: 90th. 2-citations. 12. Zayadan, B.K., Sadvakasova, A.K., Matorin, D.N., Akmukhanova N.R.,. Kokociński M., Timofeev N.P., Balouch, K., Bauenova, M.O. Effect of Cadmium Ions on Some Biophysical Parameters and Ultrastructure of *Ankistrodesmus* sp. B-11 Cells, Russian Journal of Plant Physiology, Volume 67 (5), 2020, P. 845–854. https://doi.org/10.1134/S1021443720040196. Импак-фактор 2020: 1.481. H-Index-46, Q-2, CiteScore-2.1. Процентиль: ##203/445: 54-й. 1-цитирований. 13.Asemgul K.Sadvakasova, Nurziya R.Akmukhanova,Kenzhegul Bolatkhan,Bolatkhan K.Zayadan, Aizhan A.Usserbayeva, Meruert O. Bauenova, Akbota E.Akhmetkaliyeva, Suleyman I. Allakhverdiev. Search for new strains of microalgae-producers of lipids from natural sources for biodiesel production, International Journal of Hydrogen Energy, Volume 44, Issue 12, 2019, Pages 5844-5853.https://doi.org/10.1016/j.ijhydene.2019.01.093. Импак-фактор 2020: 5.816. H-Index - 215, Q-1, CiteScore-9.0. Процентиль: ##22/224: 90-й. 21-цитирований. 14.Akmukhanova, N.R., Zayadan, B.K., Sadvakasova, A.K., Bolatkhan, K., Bauenova, M.O. Consortium of higher aquatic plants and microalgae designed to purify sewage of heavy metal ions, Russian Journal of Plant Physiology, Volume 65 (1), 2018, P. 143–149. https://doi.org/10.1134/S1021443718010028. Импак-фактор 2018: 1.481. H-Index-46, Q-2, CiteScore-2.1. Процентиль: ##203/445: 54-й. 6-цитирований. 15.Балоуч Х., Бауенова М.О., Садвакасова А.К., Сарсекеева Ф.К., Кирбаева Д.К., Болатхан К., Мустапаева Ж.О. Сравнительная характеристика видового разнообразия альгофлоры озер Алматинской области // Вестник КазНУ, Серия экологическая. – 2020. – Т 63 (2). - С.72-82. DOI: https://doi.org/10.26577/EJE.2020.v63.i2.08 16.Asemgul K. Sadvakasova, Bekzhan D. Kossalbayev, Meruert O. Bauenova, Zhuldyz O. Mustapayeva, Bolatkhan K. Zayadan. Nitrogenase activity of wt cyanobacteria of soils in rice fields of Kazakhstan // "1th International Conference on Experimental Sciences and Biotechnology (ICESB). Mugla, Turkey. 2021. - P. 86. 17.Kossalbayev B. D., Nuralibekov S. Sh., Bauenova M.O., Mustapayeva Zh.O., Sadvakasova A. K. Effect of different concentrations of Mo, V, and Fe on the nitrogenase activity of cyanobacteria // 5th Symposium on EuroAsian Biodiversity (SEAB-2021). P. 240. 18.Nuralibekov S. Sh., Bauenova M.O. Kossalbayev B. D., Mustapayeva Zh.O. Sadvakasova A. K. Study of the effect of cyanobacteria biomass isolated from rice fields in Kazakhstan on

	the growth of rice culture // 5th Symposium on EuroAsian Biodiversity (SEAB-2021). P. 241. 19. Akmukhanova N.R., Kokocinski M., Bauyenova M.O., Bolatkhan K., Sadvakasova A.K., Zayadan B.K. The opportunities to use consortium of higher aquatic plants and microalgae in the treatment of polluted aquatic ecosystems. Eurasian journal of ecology. – 2018. - Vol. 56. № 3. P. 4-11. https://bulletin-ecology.kaznu.kz/index.php/1-eco/article/view/824 20. Акмуханова Н.Р., Заядан Б.К., Бауенова М.О., Садвакасова А.К., Болатхан К., Сейилбек С. Формирование структурированных биоценозов высших водных растений и фототрофных микроорганизмов для применения в очистке сточных вод. Вестник КазНУ. Серия экологическая, V. 52, n. 3, p. 46-53, apr. 2018. ISSN 2617-7358. https://bulletin-ecology.kaznu.kz/index.php/1-eco/article/view/780 21. Акмуханова Н.Р., Заядан Б.К., Садвакасова А.К., Бауенова М.О., Кирбаева Д. К., Карабекова А.Н. Альгофлора и биологическая оценка Кольсайских озёр. – 2018. Том 55 № 2. – С- 69-79. Вестник КазНУ Серия экологическая. https://bulletin-ecology.kaznu.kz/index.php/1-eco/article/view/819
Patent information	1. Садвакасова А.К., Бауенова М.О., Заядан Б.К., Косалбаев Б.Д., Сарсекеева Ф.К., Акмуханова Н.Р. Патент РК № 2022/0224.2 на полезную модель «Штамм микроводоросли *Parachlorella kessleri* Bh-2, используемый для очистки загрязненных вод от ионов тяжелых металлов кадмия и хрома» от 16.03.2022. 2. Садвакасова А.К., Бауенова М.О., Заядан Б.К., Косалбаев Б.Д., Кирбаева Д.К., Ыбраи С.Н., Нуралибеков С.Ш. «Штамм цианобактерии *Trichormus variabilis* K-31, используемый для обогащения почвы азотом и повышения урожайности сельскохозяйственных культур» Патент РК № 2022-15500 на полезную модель, от 13.05.2022. 3. Садвакасова А.К., Бауенова М.О., Косалбаев Б.Д., Заядан Б.К., Кирбаева Д.К., Ыбраи С.Н. «Штамм цианобактерии *Tolypothrix tenuis* J-1, используемый для обогащения почвы азотом и повышения урожайности сельскохозяйственных культур» Патент РК № 2023-10801на полезную модель, от 16.03.2023. 4. Косалбаев Б.Д., Садвакасова А.К., Залетова Д.Е., Белкожаев А.М., Қамшыбаева Г.Қ., Бауенова М.О. «Фотобиореактор для культивирования фототрофных микроорганизмов» Патент РК № 2023-13323 на полезную модель, от 04.04.2023