# ABSTRACT

of the dissertation for the doctor of philosophy degree (PhD) on specialty «6D060700 – Biology»

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## Microbiological aspects of obtaining energy-efficient fuel based on brown coals

**General description of the work.** The dissertation discusses the main aspects of the biological processing of brown coals (lignites) from the deposits of Kazakhstan with active strains of microorganisms in order to enhance energy yield and to improve technological and environmental performance.

**Relevance of the research topic.** A very progressive direction of sustainable use of brown coal is their bioprocessing for the production of energy resources for various purposes.

Kazakhstan is one of the ten countries in which the largest deposits of coal in the world are located. Brown coals make out at least 62% (more than 24 billion tons) of the total coal reserves in Kazakhstan. Lignite is characterized by the low heat of combustion (about 26 MJ/kg), high humidity (up to 40%), low carbon (about 60%) and hydrogen (about 6%) content, high oxygen (17-34%) and high amount of volatile substances (up to 50%). In addition, it is not mechanically strong enough; it quickly loses moisture in the air, crushes and turns into detrital, friable rocks. For these reasons, it is less suitable for energy use. During the extraction, brown coals are thrown into the dumps, so huge heaps are gradually formed, the height of which reaches 70-120 m and each of them holds up to 2500 thousand $m^3$ of rock with an annual large replenishment. These heaps occupying massive land areas lead to intense gas-dust pollution of the atmosphere, deterioration of soil fertility and chemical poisoning of ground and surface water. The development of coal deposits negatively affects both the hydrodynamic regime and the balance of groundwater.

The current environmental situation in individual countries calls for strict requirements for the quality of municipal and industrial fuels. In addition, the fuel must have a low sulfur content, low smoke and ash emissions, and a specific particle size distribution. Therefore, it is important to find and implement modern environmental and economic ways to increase fuel resources of improved quality.

Biological processing of coals, including transformation and conversion can be utilized to obtain various solid, liquid, gaseous fuels and their products. Moreover the technical and consumer characteristics can be improved. Various groups of bacteria and fungi are used for the development of biotechnological processes both in mesophilic and thermophilic conditions in the presence of oxygen.

Coal solubilization and depolymerization occur rapidly when exposed to microbes. In addition to the structural modifications described above, a number of bacteria can grow directly on coal. To do so, they use portions of the mobile phase - a complex mixture of low molecular weight aromatics, and aliphatic compounds

such as paraffin as the sole carbon source. There is currently no information on the exact nature of these organic compounds, but studies using low molecular weight models show that they contain phenols, benzoic acids, biphenyls and diphenyl ethers, as well as various cycloalkanes, n-alkanes. Residual cellulose and hemicellulose (e.g. xylitol, which preserves wood structure) found in some coals can be an additional source of carbon for microorganisms. Moreover, the addition of mineral solutions (N, P, S, metal ions or mineral salts) stimulates the growth of microbes.

Particular interest in the development of the raw material base for the production of agglomerated coal fuels is given to the lignites of group B2-B3, due to the constant growth of their production. The intensity of their application is determined by the fact that they are extracted in an open, i.e. the cheapest, way. However, these coals are characterized by a high content of ash and moisture, characterized by a low combustion temperature, quickly destroyed during storage and cannot be transported. The expansion of the possibilities of using and increasing the volume of transport of brown coal can be accomplished by modifying the properties of these coals by the method of biotechnological refinement, in particular, by briquetting.

The main reasons that determine the need and feasibility of obtaining briquetted solid fuel from Kazakhstani brown coals are their relative humidity, low ash content, the possibility of spontaneous combustion during storage and significant losses during transportation.

The shortage of high-quality fuel today is one of the most important problems of our time. In most cases, this leads to forced combustion in furnaces with layered combustion of raw coals with a high content of duff and rubble, which contributes to a significant decrease in the heat coefficient of the furnaces and, consequently, to unproductive losses of thermal energy of the fuel. Therefore, the development of the most modern and efficient ways to increase the resources of improved high-quality coal fuel and the subsequent implementation of its results is of great scientific and economic importance.

The technology for producing smokeless solid fuel from brown coals of various classes has not received commercial implementation due to the lack of a high-quality binder for briquetting, as well as high ash content and low heat of combustion. In connection with these circumstances, the development of a technology for producing briquetted smokeless fuel from brown coal deposits in Kazakhstan is relevant. Considering that in Kazakhstan a significant part of the population lives in settlements and villages, the problem of producing environmentally friendly and safe fuel briquettes for public utilities acquires a broad energy and environmental meaning. Since solid fuel is an environmentally friendly product and burns almost without smoke, it is ideal for heating various premises, including production and service areas (greenhouses, hotbeds, tents, saunas, swimming pools, vegetable pits, insulated soils).

For these reasons, the study of the interaction of brown coal with microorganisms and the search for ways to create new effective technologies for the

production of solid fuel, including smokeless fuel, is a timely solution to an urgent problem.

**Purpose of the research work.** The study of the biological bases for the interaction of coal and microorganisms of coal deposits in Kazakhstan and development of methods for obtaining smokeless fuel.

**Research tasks**

1. Study of the physical, chemical, mechanical and thermal properties of brown coals from the Lenger and Oikaragai deposits.

2. Determine the taxonomic composition and the number of microbial communities of lignite, as well as study their physiological and biochemical properties.

3. Study of the physicochemical properties of biomodified coal suspension used as a raw material in the production of fuel briquettes from brown coal.

4. Research of technological and design parameters for the production of biomodifiers for briquetting.

5. Development of a radical technological scheme for the separation of fuel briquettes obtained by biomodification of brown coal.

6. Development and implementation of a safe briquetting technology using biological binders, which are durable, water-resistant, ash-free, i.e. minimize the formation of negative substances during combustion, allow to obtain smokeless heat-resistant briquettes.

**Research objects.** B3 class brown coal (coals from the Lenger and Oi-Karagay deposits) and RKB 7 - *Bacillus* sp., RKB 10 - *Providencia* sp. bacterial strains.

**Research methods**. Experiments were carried out in the laboratory using modern methods of physicochemical, genetic, biochemical and microbiological research.

**Scientific novelty of research:** For the first time, metagenomic analysis of lignite was carried out to study microbiological diversity on brown coals in Kazakhstan. As a result of the study, two pure cultures of bacteria were isolated from these coals - bacterial strains RKB 7 - *Bacillus* sp., RKB 10 - *Providencia* sp.. The biosolubilizing properties of the isolated bacteria were studied, and it was found out that RKB 7 - *Bacillus* sp., RKB 10 - *Providencia* sp., actively release biosurfactants during coal biosolubilization.

As a result of the study, highly efficient smokeless bio-briquettes from Lengersky and Oi-Karagay brown coals were obtained as well as novel bio-binders. It was found that the fuel and energy efficiency of burning biobriquettes in household stoves, which is estimated by thermal efficiency, became higher (up to 81.1%) compared to biobriquettes from primary coal. A basic technological scheme for the production of bio-briquettes from brown coal using a bio-binder suitable for long-term storage and transportation is presented.

**Scientific and practical significance of the work.**

The isolated strains RKB 7 - *Bacillus* sp., RKB 10 - *Providencia* sp. were included in the collection of the Laboratory of Applied Microbiology at KazNU for further research.

Technological scheme for the production of biofuel based on bioprocessing of

brown coal has been developed and patented ("Method of coal processing", No. 34536, 28.08.2020, "Method of coal processing" No. 34556, 04.09.2020). For the use of brown coal in coal deposits, it was proposed to use the technological scheme shown in the work.

Theoretical and methodological basis for the creation of biobriquettes has been created.

The bacteria isolated during the research work are used in the laboratory for the production of biocomposites from brown coal by combining biofertilizers and coal ash + biohumus + bacteria.

A new hard brown coal lignite has been developed to improve its energy efficiency. The results of the study can be used as a material for special and theoretical courses for undergraduates, master and doctoral students in higher education institutions.

**The main provisions for the defense**

1. The results of the physical, chemical, mechanical and thermal properties of brown coals from Lenger and Oikaragai deposits;
2. Taxonomic composition and the number of microbial communities in brown coal, as well as their physiological and biochemical properties;
3. The results of the studies on physical and chemical properties of biomodified coal suspension used as a raw material in the production of fuel briquettes from brown coal;
4. The results of technological and design parameters of the isolation of the biomodifier for their briquetting;
5. Radical technological scheme of the process of creating fuel briquettes based on biomodification of brown coal;
6. The results of safe briquetting technology using biological binders, which are durable, water-resistant, ash-free, minimize the formation of negative substances during combustion, and make it possible to obtain smokeless heat-resistant briquettes.

**Personal contribution of the author**. All the main results of the work, analysis of the literature, design of the work, experimental studies, and statistical processing and analysis of the results were carried out with the personal participation of the author.

**Connection of work with the plan of state programs.** The dissertation work was carried out within the framework of AP05133758 "Development of biotechnology for obtaining environmentally friendly, smokeless briquetted fuel based on brown coal from the Lenger coal deposit and surfactant-synthesizing microorganisms for fuel and energy efficient use" and AP05134797 "Development of biotechnology for obtaining a highly active preparation "biohumus-plus" based on oxidized brown coal and zoomicrobial consortium ”projects.

**Approbation of work.** The main provisions of the dissertation and research results were presented and discussed at the following international scientific conferences and symposia:

1. Republican scientific and methodological conference "Modern biology and topical issues of biodiversity conservation in the Republic of Kazakhstan" (Almaty, November 24, 2017);

2. International scientific-practical conference "Actual problems of ecological genetics and experimental biology" (Almaty, January 25, 2018);

3. 22nd International Pushchino School-Conference of Young Scientists "Biology - Science of the XXI Century" (Pushchino, Russia, April 23 - 27, 2018);

4. International Symposium ASTANA BIOTECH 2018, (Astana, June 12-13, 2018);

5. Bulletin of the South Kazakhstan Medical Academy (Shymkent, 2018);

6. V International Farabi Readings, International Scientific Conference "World of Farabi" (Almaty, April 10-11, 2018);

7. VI International Farabi Readings, International Scientific Conference "World of Farabi" (Almaty, April 9-11, 2019);

8. International Conference "Modern Problems of Chemistry and Technology of Organic Substances and Materials" (December 5-6, 2019, St. Almaty);

9. International Conference on Recycling and Waste Management (30$^{th}$ July 2019, Toronto, Canada).

**Publications.** The main content of the dissertation is reflected in 30 published works, including 6 articles in republican scientific journals of the Committee for Control in Education and Science of the Republic of Kazakhstan, 3 articles in scientific journals, 3 articles in the Scopus database and 13 abstracts presented at international conferences and symposia, published 2 patents, 2 certificates for the work of science.

**The structure and volume of the thesis.** The dissertation work consists of 127 pages, a list of abbreviations, an introduction, a literature review, materials and methods, results and discussion, conclusions and 305 references. The scope of work includes 20 tables and 44 figures.