# ABSTRACT

of the dissertation work by Mauletbekova Bulbul Kusmankyzy on the topic: «Improving the Efficiency of the Fractionation Process of Spent Drilling Fluids of Technological Wells for Disposal Using Dispersing Devices», submitted for the degree of Doctor of Philosophy (PhD) in the educational program 8D07110 – «Digital Engineering of Machinery and Equipment»

**Relevance of the research.** The relevance of the topic of dissertation research lies in the insufficient efficiency of the technique used for the separation of used drilling fluids into liquid and solid phases, which is due to the insufficient study of the processes of fractionation of multicomponent solutions due to their physico-chemical and physical properties and hydrodynamic conditions.

The theoretical and practical significance determined the choice of these studies, the target direction, the structure and the choice of methods for solving the tasks set.

Analysis of ways to dispose of used spent drilling fluids can be carried out in various contexts, such as industrial uranium mining, geological surveys or well construction. The process of utilization of spent drilling fluids used in the drilling of uranium deposits depends on the Constituent composition of the solution, its volume, concentration of special chemical reagents, chemical properties, etc.

The main components of clay-based drilling fluids widely used in well drilling are liquid, viscous (clay) and solid components. In order to reduce the impact on the environment and human health, these solutions need to be disposed of in a certain way in accordance with existing safety standards and standards.

In practice, the following two methods of disposal are widely used: the first is the transportation of used drilling fluids to sludge collectors (sand settling tanks). This is where the natural deposition of the solid phase occurs, and the surface part of the liquid phase evaporates into the atmosphere in a natural way. Sedimentary silt and waste containing crushed rocks require burial in specially designated burial sites.

However, the processes of natural deposition of solid particles in solution require a long time and require the development of highly effective complex physico-chemical and technical methods and means of fractionation of solution.

The most preferable is the method of secondary disposal, which is forced fractionation of the solution, where special technical devices are used to separate solid particles from the liquid phase, after which their secondary use is envisaged, in particular, for the purpose of use as building materials. This method also provides for the possibility of using special chemical reagents to increase the efficiency of fractionation of the solution.

However, the efficiency of reagents in the fractionation process can increase several times in the case of high-quality mixing with the solution being processed, which is ensured by the use of special decomposing devices.

Thus, the results of theoretical and experimental research presented in the dissertation work are aimed at studying the process of decomposition of the used drilling mud together with special chemical reagents – flocculants and determining its influence on the efficiency of subsequent fractionation.

**The aim of the work** is to develop an original design of a dispersing device and conduct experimental studies to select and determine the optimal concentration of reagents for the activation and acceleration of drilling fluid fractionation. This will enable the creation of an

environmentally efficient method for the disposal of spent clay-based drilling fluids for practical use.

**The concept of the work** lies in the application of an original design of a drilling fluid disperser, which increases the efficiency of mixing and activation of chemical reagents with the drilling fluid through hydrodynamic and mechanical forces, thereby improving the efficiency of the fractionation process into solid and liquid phases.

**Research objectives:**

1. Monitoring and analysis of the composition of spent clay-based drilling fluids (SDF) at drilling sites, including the assessment and analysis of the areas occupied by sludge collectors and sand traps at uranium mining enterprises, and calculating their total volume;
2. Studying the stability of highly dispersed SDM particles by determining the particle size distribution and the sedimentation time of fractions in liquids with various physicochemical properties;
3. Designing and manufacturing a dispersing device for the activation of reagents and acceleration of the fluid fractionation process.

Based on the stated objectives, the following will be determined:

– conditions for the interaction of different reagents in the SDM fractionation process;

– the influence of the pH level of the liquid phase and various electrolytes on the stability of dispersed SDM particles;

– optimal concentrations and compositions of reagents for SDM particle fractionation.

4. Development and creation of an experimental setup to evaluate the efficiency of SDM fractionation into liquid and solid phases using the original dispersing device;
5. Development of a methodology for experimental studies aimed at selecting the optimal reagent concentration and operating mode of the dispersing device;
6. Conducting experimental research to refine the technology and evaluate the efficiency of the developed SDM disposal (fractionation) method.

**Scientific propositions submitted for defense:**

1. The method and technique of activating the decomposition process by cavitation-hydrodynamic and impact-contact mechanical action on the used drilling mud, which can reduce the consumption of reagent flocculants by up to 30% and accelerate the process of subsequent fractionation of the solution into solid and liquid phases by 25-40;
2. Original device for hydrodynamic and impact-contact mechanical impact on the used SDM;
3. Mathematical model of the solution decomposition process, which is different from existing models, taking into account cavitation, acoustic and vortex waves in the size of the decomposer;
4. Analytical dependencies for determining the stability of highly dispersed particles of the used drilling mud and establishing the stages of deposition of fractions in liquids with different physico-chemical properties, which make it possible to determine the optimal amount of flocculant and coagulant during quitation-hydrodynamic and hydromechanical activation.

**Scientific novelty of the research results lies in the following:**

1. Analytical dependencies of the stability of highly dispersed SDM particles have been established, and sedimentation periods of fractions in liquids with different physicochemical properties have been determined;

2. The fundamental possibility of increasing the efficiency of the dispersion process through preliminary cavitational-hydrodynamic and hydromechanical activation of spent drilling fluid has been established;

3. Rational parameters of the dispersing device design have been determined, and optimal operating modes in combination with the solution-feeding pump have been justified to accelerate reagent activation and fluid fractionation;

4. It has been established that cavitational-hydrodynamic and hydromechanical activation of spent drilling fluid using a disperser of this design allows for a 15–30% reduction in flocculant reagent consumption and a 25–40% decrease in the time required for fractionation into liquid and solid phases.

**Practical significance of the work.**

1. An effective technology for the fractionation of multiphase fluid into liquid and solid phases has been developed and scientifically justified. It allows for the acceleration of the process and reduction in flocculant reagent consumption through cavitational-hydrodynamic and hydromechanical activation using a disperser of original design. This makes it possible to further utilize the solid waste as construction material, etc.;

2. Analytical dependencies for the selection and concentration of reagents for dosing into liquids with various physicochemical properties prior to being fed into the dispersing device have been established;

3. A methodology for mathematical modeling of the fractionation process of a multiphase fluid under cavitational-hydrodynamic and hydromechanical influence has been developed;

4. An original design of a dispersing device has been developed, which increases the efficiency of the fluid dispersion process when introducing reagents for its fractionation into liquid and solid phases.

The proposed technical device and the technology for its application are characterized by high efficiency of the fractionation process, allowing the separation of up to 76% of moisture from solid fractions, while ensuring environmental friendliness during the processing and disposal of spent drilling fluids and minimizing the emission of environmentally hazardous radioactive substances into the atmosphere.

5. The economic benefit from the application of this equipment and technology will allow for a 15% reduction in capital expenditures for drilling operations, a 50% reduction in transport needs and transportation costs, and a 25% reduction in personnel required for the handling and transportation of SDM.

**Methodology and research methods.** The research employed the methodology of theoretical and mathematical analysis, as well as methods from reliability theory and the processing of statistical and experimental data under laboratory conditions. A comprehensive research method was chosen to achieve the stated goals and accomplish the objectives. This method includes analysis of the current state of the issue, techno-economic analysis, mathematical statistics, decision-making theory, and selection theory. Additionally, field experiments were conducted to study the sedimentation processes of products obtained during rock drilling. Pilot industrial studies of reagent compositions of flocculants and coagulants were also carried out under various mining and geological conditions with differing content of elements in drilling waste.

These methods ensure high standards of scientific research. The foundation for the scientific study of the project is based on fundamental principles of mechanics, fluid and gas physics, and the chemical interactions between natural elements and reagents. The described forms of research and the design of a new super-reagent aimed at improving the sedimentation

characteristics of solid and liquid components in drilling waste are essential for the implementation of an innovative technical solution. This solution is aimed at preventing the release of environmentally hazardous radioactive elements into the atmosphere during the drilling of technological wells, as well as at increasing the productivity and efficiency of settling tanks. The research process includes both theoretical and experimental stages, ranging from analytical studies to the creation of an industrial prototype and its implementation in production.

Hydraulic calculations were performed using the Flow Simulation module in SolidWorks.

**The applicant's personal contribution includes:**

– analysis and generalization of the research results obtained;

– formulation of the research goals and objectives;

– development of a structural model to determine the optimal geometric and operational parameters of the dispersing device and the experimental setup;

– conducting, processing, and analyzing the results of the full cycle of field experimental research.

**Processing of Research Results.**

Experimental studies were conducted:

1. Using laboratory stands of the Department of «Technological Machines and Equipment» of the Kazakh National Research Technical University named after K.I. Satbayev and the Institute of Metallurgy and Ore Beneficiation, where the experimental part of the dissertation was carried out;

2. The processing of experimental data was performed in accordance with the algorithm of the spent drilling fluid disposal technology developed by JSC «Volkovgeologia», taking into account the methodology created by Doctor of Technical Sciences N.K. Tusupbayev from the Institute of Metallurgy and Ore Beneficiation for the concentration of flocculants, coagulants, and electrolytes, as well as the subsequent separation into liquid and solid phases;

3. Based on the processing and analysis of experimental data, the following results were obtained:

– Analytical dependencies of the stability of highly dispersed SDM particles were established, and sedimentation periods of fractions in liquids with various physicochemical properties were determined;

– Rational values for the geometric parameters and operating modes of the developed and manufactured dispersing device for reagent activation and acceleration of solution fractionation were determined;

– The parameters of the experimental setup for assessing the efficiency of spent drilling fluid fractionation into liquid and solid phases were justified and established.

Thesis validation.

**The main points and scientific results were discussed at seminars and international scientific and technical conferences:**

1. At technical seminars of the Department of «Technological Machines and Equipment», NJSC «KazNRTU named after K.I. Satpayev»

2. At the Forum of Young Scientists of the CIS Member States «Science Without Borders», Lobachevsky University, Nizhny Novgorod, Russian Federation, November 1-4, 2022.

**Publications.** Based on the results of the dissertation research, 2 articles were published in journals indexed in the Scopus database with CiteScore percentiles Q2 and Q3; 3 articles were published in journals included in the list of publications recommended by the Committee for

Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan; and 1 paper was presented at an international conference.

**Structure and volume of the work.** The dissertation work consists of an introduction, 4 sections and a conclusion, set out on 104 pages, contains 18 figures, 13 tables, a list of references from 53 titles and 1 appendices.