ABSTRACT

of the dissertation work by Mauletbekova Bulbul Kusmankyzy
on the topic: «Improving the Efficiency of the Fractionation Process of Spent Drilling Fluids from 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 experimental topic lies in the current absence of specialized equipment that enables the separation of spent drilling fluids into liquid and solid phases, as well as the insufficient level of study in this area. The theoretical and practical significance has determined the choice, targeted focus, structure of the present research, and the selection of methods for solving the stated tasks.

The analysis of methods for the disposal of spent clay-based drilling fluids can be carried out in various contexts, such as industrial uranium mining, geological exploration, or well construction. The process of disposing of spent clay-based drilling fluids during the drilling of uranium deposits can be quite complex and depends on many factors, such as the composition of the fluid, its volume, chemical properties, etc. Spent drilling fluids from barren zones of uranium deposits represent a mixture of water, clay, and special chemical reagents that participated in reducing the permeability properties of the drilling mud in the rock. Depending on the drilling method and the purpose of the technological wells, the spent drilling fluids may have different compositions and concentrations of liquid and dense components. To minimize the impact on the environment and human health, these fluids must be collected and processed in accordance with relevant safety norms and standards.

Existing technologies for the disposal of spent drilling fluids involve two methods: the first – transportation to sludge collectors (sand traps) with accumulation until the liquid evaporates, after which the residue is buried in designated disposal sites (landfills) and the second – fractionation of the fluid followed by the separation of solid particles from the liquid component for their subsequent use.

The second method is considered more preferable due to the possibility of using the solid residue as a construction material, etc. However, the processes of natural sedimentation of the solution's solid particles are lengthy and require the development of highly efficient, integrated physical-chemical methods and means for fluid fractionation.

The complex of theoretical and experimental studies presented in the dissertation is based on the rational selection of chemical reagents and the concentration of flocculants and electrolytes for ultraflocculation treatment, aimed at enhancing the activity and intensifying the sedimentation processes of solid particles, as well as the development of a special device that increases dispersion activity and intensifies the sedimentation of solid particles.

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 (SDM) 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 statements submitted for defense:

1. Determination of the optimal type and dosage of flocculant and coagulant, and the establishment of the optimal hydrodynamic treatment mode of the studied suspension through the use of the developed disperser, which operates based on hydrodynamic forces. The disperser is installed vertically on the discharge line of the drilling pump and ensures asymmetric elliptical circular motion of the suspension, which is 35% more effective for the complete penetration of reagents into the spent fluid compared to classical shale shakers with linear amplitude motion;

2. Expansion of the application range of separation products of treated drilling fluids and improved management of drilling waste through the use of the developed experimental setup, which enables the separation of spent drilling fluids into solid and liquid fractions without the use of mechanical devices;

3. The system effectively separates low-density solid phases and solid particles from the liquid medium, which are difficult to remove and too fine for conventional mechanical treatment methods of spent drilling fluids;

4. Reduction in the volume of operating and newly constructed sludge collectors and sand traps, as well as a decrease in transportation volumes (from 20 to 50 km) and the number of transport vehicles, due to the use of an autonomously operating unit directly at the worksite.

Scientific novelty of the research results is as follows:

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 90 pages, contains 20 figures, 10 tables, a list of references from 40 titles and 3 appendices.