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COMBINED ULTRASOUND TECHNOLOGIES FOR EXTRACTION OF OIL AND BITUMEN FROM BITUMINOUS ROCKS AND POLLUTED SOIL

ABSTRACT

of dissertation for the degree of Doctor of Philosophy (PhD)
6D072100 – Chemical technology of organic substances

Actuality of the research issue. In connection with increase in consumption and rise in the cost of oil, the problem of extracting oil products from oil bituminous rocks (OBR) and polluted soil, as well as processing of substandard natural raw materials in the world and in Kazakhstan, is becoming increasingly important. At present, some sources of alternative energy are being considered in the world due to the shortage of oil. Therefore, in the future, stone coal and OBR can certainly be used as a fuel, the Canadian state is a proof of that. There are several OBR are known in the world (billion cubic meters): Canada – at least 425, Venezuela – at least 180, the USA – 5.5, Iran – 4.5, Madagascar – 3.9, this is more than oil reserves. Large OBR reserves are available in Kazakhstan. In the western region of the Republic of Kazakhstan, Imankara field contains about 4.5 billion OBR tons, and all the world knows that oil regions, oil ponds, earth storages, sludge reservoirs, soils near drilling units, oil refineries, as well as places for oil preparation, transportation and processing, contain hundreds of thousands tons of residual oil products.

The OBR formation is accumulated due to the oil extraction from deep rocks and its absorption of sandy and clay soils or in the form of oil lagoons in the lower forms of relief and due to the atmospheric factors such as temperature, light, air, light oil components volatilize, therefore the oil viscosity increases, oxidizes and becomes a natural bitumen.

Separation of the organic part from the mineral part is a serious problem, since the OBR organic part is a bituminous oil dispersed system, it consists of oils, resins and asphaltenes. The presence of resins, asphaltenes and high-molecular compounds can lead to the formation and strengthening of intermolecular compounds, thus creating adhesive properties in the system. At the same time, the interaction of mineral and organic particles is enhanced. As a result, the separation of the organic part from the mineral part becomes a problem. In order to solve this problem, foreign and Kazakhstan scientists have contributed and proposed various methods for separating the organic part from the mineral one, these methods are based on the use of mechanics, heat, solvents, and chemical reagents, and also based on heat treatment up to 600 – 650°C.

However, these methods are very complex and require a large amount of mineral and energy costs, i.e. vacuum drying and heat treatment up to 600°C.

Therefore, one of the most acute and urgent problems in the modern world is oil and oil products extraction from polluted soil, as well as obtaining necessary raw materials for oil products and road bitumen production.

Relation of the work with research programs. The dissertation is related to the research work No. B-11-03-02 (2011-2015) on the theme: “Development of technology for producing monomers, polymers, emulsifiers of oil fractions, stabilizers of drilling fluids and using new composite materials, polyelectrolytes, interpolymer complexes, surface-active agents (surfactants) based on hydrocarbon raw materials of heavy oil residues and cotton cellulose”. Also, the work was carried out in accordance with the research work No. B-16-03-02 (2016-2020) on the theme: “Development of effective technologies for obtaining water-soluble polymers, depressants, additives for oil and oil product properties regulation”, in accordance with 018/Program-target-oriented financing (2015-2017) on the theme: “Development of technologies for obtaining new effective materials for oil and gas industry from waste products of fat and oil industry” in priority: 055 – budgetary financing of the program of the Ministry of Education and Science of the Republic of Kazakhstan.

The research object. The research object of the dissertation is Imankara field OBR, soil polluted with oil products during oil drilling, extraction, collection and transportation in the vicinity of Atyrau, Aktobe, Petro Kazakhstan Oil Products oil refinery, as well as ultrasonic equipment necessary in the process for obtaining oil products, road bitumen, organic solvents: benzene, hexane, hexene, kerosene, gasoline, diesel fuel, white spirit, depressants, surfactants, flocculants used during development of technology for separation of the organic part, screw mixer, distillation column, ultrasonic reactor, reactor for bitumen production, etc.

The research methods. To solve the problems, experimental physicochemical and analytical research methods were chosen. They include: chromatography, IR spectroscopic expertise, Miracle apparatus of Pike Technologies, showing the inside of Shimadzu IR Prestige-21 plate on FT-IR spectrometer, X-ray energy dispersive microanalyzer INCA Energy (Oxford INSTRUMENTS), determining elemental composition and microstructure, ISM-6490LV microscope (SVA), electron liquid microscope, X-ray diffractometer DRON-3, analyzing the OBR mineral composition, ARNS device, determining fractional composition of the organic part extracted from the OBR, ARN-2 rectifying apparatus (designed for oil rectification at 470-500°C), examining oil products and its components, and also separating oil fractions, AT-HP apparatus, automatically determining the oil products’ aniline point, SIM-12 analyzer, determining mechanical particle in the oil products’ composition, VUN-20 devices, determining conditional viscosity. At the same time, several standards were used in the work: technique for determining the OBR decomposition and dissolution in asphalt-resinous paraffin deposits (STP 03-153-2001, Bashneft OJSC), methods for determining asphaltenes composition by “cold” Golden method, adsorption methods for determining the total composition of asphalt-resinous compounds (recommended by Marcusson), etc.

Aim and tasks of the research. The aim of the dissertation is to develop a technology for separating the organic part from Imankara field OBR mineral part, and polluted soil using methods of dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants and obtaining the oil products and road bitumen on their basis.

To achieve this aim, the following tasks were solved:

- investigating physicochemical properties of Imankara field OBR and polluted soil, as well as materials and raw materials, used in the process of separating the organic part from the mineral one;
- determining factors, which influence on increase in the speed of the process of separating and releasing the organic part from the mineral one of Imankara field OBR and polluted soil when using the methods of dissolution, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants, which result in the original structure change;
- investigating the influence of dissolution, suspending, saponification (hydrolysis) of the organic part in order to increase the yield of the OBR organic part from the mineral one by 96-98%, and the speed by 2-3 times;
- investigating physicochemical properties of Imankara field OBR organic part and polluted soil by the methods of electron microscopy, IR- spectrometry, elemental analysis for identification of its structure formation in the mineral part sedimentation, and also considering possibilities to produce oil products and road bitumen;
- developing effective and economically rational technology for separating Imankara field OBR organic part and polluted soil from the mineral part and producing oil products and road bitumen on their basis.

Scientific novelty of the research. The novelty of the dissertation is the following:

- mechanical mixing, ultrasound power, solvents, suspending, saponification, depressants, surfactants, flocculants influence on the extraction speed of the organic part from Imankara field OBR and polluted soil was investigated. In this process, the ultrasonic apparatus was installed directly in the working reactor, thereby accelerating the separation process and increasing the organic part yield;
- investigating the OBR organic part microstructure before and after the mechanical and ultrasonic treatment in the presence of surfactants, depressants, flocculants allowed establish that complete separation of the organic part from the mineral is achieved only in cases of the OBR crystalline structure change;
- on the basis of investigating Imankara field OBR structure, chemical composition and physicochemical properties, the separation of the organic part from the mineral one reveals transition of the crystalline structures to a new crystalline-amorphous system, as a result, a method for separating the organic part consisting of 3 rational and effective stages was developed;
- based on physicochemical investigations and thermal destructive analysis of Imankara field OBR organic part, its fractional composition, parameters and effective conditions of complex processes necessary for obtaining oil products and road bitumen were determined;
- the technology for separating the organic part from Imankara field OBR mineral part, and polluted soil using methods of dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants and obtaining the oil products and road bitumen on their basis was developed.

Conceptual issues, submitted for the defense:

- physicochemical properties of Imankara field OBR and polluted soil, as well as materials and raw materials, used in the process of separating the organic part from the mineral one;

- factors, which influence on increase in the speed of the process of separating and releasing the organic part from the mineral one of Imankara field OBR and polluted soil when using the methods of dissolution, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants, which result in the original structure change;

- main indicators of the dissolution, suspending, saponification (hydrolysis) of the organic part, as well as dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants ensuring increase in the yield of the OBR organic part from the mineral one by 96-98%, and the speed by 2-3 times;

- structure of Imankara field OBR organic part and polluted soil in the mineral part sedimentation process, obtained as a result of using the methods of electron microscopy, IR-spectrometry, elemental analysis and possibilities to produce oil products and road bitumen based on that;

- effective and economically rational technology for separating Imankara field OBR organic part and polluted soil and producing oil products and road bitumen on their basis.

Theoretical value of the research. The theoretical value of the dissertation is in theoretical justification of the technology for obtaining the organic part from the mineral of Imankara field OBR and polluted soil, as a result of using the methods of dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants and methodological layout for producing the oil products and road bitumen on this basis. At the same time, the complex processes parameters that ensure the oil products and road bitumen production from the separated organic part from the mineral of Imankara field OBR and polluted soil were determined.

The mechanism for separating the organic part from Imankara field OBR and polluted soil on the basis of investigating the structure, chemical composition and physicochemical properties as a result of using the methods of dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants, was identified.

Practical value of the work. The practical value of the dissertation is in development of the technology for separating the organic part from Imankara field OBR mineral part, and polluted soil, as a result of using the methods of dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants and obtaining the oil products and road bitumen on their basis.

The developed technology for separating the organic part from Imankara field OBR mineral part, and polluted soil, as a result of using the offered methods of dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants, in the future will contribute in

formation of scientific bases for production of oil products and road bitumen in the Republic of Kazakhstan.

Personal contribution of the PhD-student is consisted in analysis of results of scientific and patent literature analytical researches by the dissertation theme; in choice of the research methods; in carrying out laboratory experiments when separating the organic part from the mineral of the OBR and polluted soil using the methods of dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants.

Degree of reliability and approbation of the results. The offered technique for separating the organic part from the mineral of the OBR and polluted soil using the methods of dissolution in solvents, suspending, saponification, mechanical, ultrasonic treatment in the presence of depressants, surfactants, flocculants and developed on this basis combined unit was introduced in the academic process when training students of such specialties as 5B072100 – Chemical technology of organic substances, 5B073900 – Oil chemistry, as well as when training master students of such specialties as 6M073900 – Oil chemistry, 6M072100 – Chemical technology of organic substances.

The technology for separating the OBR organic part and obtaining bitumen from it, as well as recommendations for the rational choice of technological and regime parameters for bitumen production were tested at LLP “DezFumex”.

The reliability of scientific provisions and conclusions formulated in the dissertation is provided by the use of a set of complementary methods adequate to the research aim and tasks, involving extensive factual material and its versatile analysis, as well as correct use of modern research methods. During the dissertation research, domestic and foreign sources of scientific literature were analyzed and examined. The scientific results were supplemented with materials obtained during the research.

Publications by the dissertation theme. The research results by the dissertation theme were published in 18 scientific works, including:

- 4 works in editions recommended by the Committee for control in the sphere of education and science of the Ministry of Education and Science of the Republic of Kazakhstan;
- 1 work in scientific journal included into Scopus database;
- 7 works in international conferences, including 3 works in the proceedings of foreign conferences;
- 2 teaching aids;
- 1 monograph;
- 3 innovative patents.

Structure and volume of the dissertation. The dissertation work consists of 140 pages, 18 tables and 43 figures. The work consists of introduction, five chapters, conclusion and references, including 219 items.