Outlooks of the Development of Scientific Foundations for the Efficient Use of Sapropelite Raw Material Resources in Russia

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Abstract

Outlooks for carrying out problem-oriented prospecting investigations and for building up the scientific and technical basis in the area of the efficient use of sapropelite raw material resources.

INTRODUCTION

The problem connected with the efficient use of the sapropelite raw material resources is due to the need of the society for the products of petrochemical industry and therefore for discovering new oil deposits and search for its possible substituents. A special part in this respect is to be played by sapropelite coal and shale oil because they may be used to obtain the products similar to those obtained from natural oil. In order to predict, explore and discover new oil fields, new methods and tools for the molecular diagnostics of oil-generating sapropelite beds are necessary. Development of efficient methods of processing sapropelite coal and shale oil into alternative products of petroleum chemistry also requires similar methods and tools of molecular diagnostics. In other words, it is necessary to have methods and means for the evaluation of the interconnection between the structure of the organic mass of sapropelites and their chemical properties not only in natural processes but also in technological ones.

The urgency of this subject of investigation is determined by the necessity to develop and use the theoretical notions on the chemical nature of the sapropelite organic matter and its transformations into oil components in natural and technological processes. In spite of the fact that the world investment into research and development of the projects aimed at processing shale oil account for millions dollars, Russian technologies developed as long ago as in the Soviet times still remain relevant. The technology of pyrolysis processing of shale oil (Krzhizhanovsky Power Engineering Institute (ENIN), Moscow) using the installations with a solid heat carrier UTT-3000 is operating in Estonia [1]. The enterprises of Russian shale-mining industry supply the raw material to Estonia; in this situation, in Russia itself shale oil processing is carried out only in the Samara Region and involves only the manufacture of ichthyol and some technical cleansers ("Polinka", "Omega", "Afol", laundry soap). At the same time, the Estonian concern Viru Keemia Grupp (VKG) only in 2003 sold 156 thousand tonns of synthetic oil (shale oil), arranged manufacture of a broad range of phenols. These phenols under the trademarks of Cresolics, Honeyol, Rezol are used to obtain various kinds of adhesive resins for the production of resin-bonded chipboard materials, modifying agents for tyre and mechanical rubber industry, synthesis of epoxy resins and other products of chemical industry.

Attention to the Estonian experience of the production of synthetic oil is expressed by the world's largest fuel concerns "Total" and "Petronas". In 2006, the leaders of these concerns announced the intention to order the analysis of recoupment to solve the question concerning their participation in this business. According to the report of the news agency BNS, Saudi Arabian International Corporation for Oil Shale Investment announced a plan to invest ten milliard dollars into processing the Jordan shale. It was also stated that Jordan needs the Estonian experience and qualification information. According to the report of the Kursor News Agency, in Israel they announced the start of construction of an experimental plant aimed at the production of oil from shale on the basis of the technology developed by a group of scientists from Haifa (the majority of them are new repatriates from the former Soviet Union). In China, as reported by the Interfax-China News Agency (www.bloomberg.com), it is planned to construct a plant for the production of synthetic oil together with the South African Sasol Company. Separate investigations aimed at the development of the technology of obtaining synthetic oil are carried out at the Research Institute of Coal in Shanci province.

Taking into account the experience of the use of the fundamental Russian preliminary work in the area of efficient use of sapropelite shale by the VKG Company, it seems reasonable to carry out in-depth theoretical and experimental studies aimed at the generation of new knowledge about the interconnections between the structure of the organic mass of sapropelites and their chemical properties in natural and technological processes.

PROMISING DIRECTIONS OF SCIENTIFIC RESEARCHES

The most profitable approach to solving the indicated problem is to develop new universal methods and means to evaluate interconnections between the structure of the organic mass of sapropelites and their chemical properties. The universal character of these methods should mean their applicability to all the sapropelite raw material resources independently of the geographic position of deposits and the kinds of raw material (sapropelite coal and shale, beds with scattered or weakly concentrated sapropelite organic matter). The notion of universal methods implies theoretical modelling of structural elements of the organic mass of sapropelites (a schematic system-structural description of their transformations as a result of computer synthesis and decomposition) and experimental verification of the predicted behaviour of these elements by means of the controllable selective decomposition into the components the composition and structure of which depict the structural features of initial or purposefully modified organic fragments. Such a combination of the theoretical and experimental methods will open new possibilities for obtaining the most comprehensive information about the interconnection between the structure of the organic mass of sapropelites and their properties. Development of these methods and means is a key scientific problem; it is necessary to solve it in order to pass to the purposeful development of high-technology methods of processing the organic mass of sapropelites into chemical products and materials.

The above-described approaches to solving the formulated problem are the elements of the strategy of investigations into coal chemistry; these elements are to be taken into account in order to provide the leading positions in the area of development of the high technologies of deep processing for sapropelite coal and shale. Two approaches to the use of high technologies of deep processing of solid fuel are possible in Russia. The first one involves purchase of the finished technologies abroad and their slight modification taking into account local conditions, In this case, one may limit the activities to the establishment of consulting firms for promoting foreign developments to the Russian market. The second approach is the accumulation of our own new experience by using the scientifically valid strategy of investigations in coal chemistry [2]. Such a strategy implies separate theoretical and experimental investigations having the key importance for efficient use of sapropelite raw material resources.

Development of the foundations of new methods and means to evaluate interconnections between the structure of the organic mass of sapropelites and their chemical properties

implies the use of the organic mass of sapropelites in the state of permanent changes starting as early as during the life of sapropel-forming organisms and finishing with the achievement of the last stage of their transformation into purely carbonic material. In this case, the specific subjects of investigation are the basic structural elements of the organic mass of sapropelites, while the goal of investigations is the main determination of their connection with the properties of lipids of the initial living substance and the already formed organic mass as the natural polypeptide material. As a rule, these structural elements have rather complicated structure; however, bridging bonds can be determined in it. The strength of these bonds may vary substantially, depending on the structure of bridged structural fragments and the presence of functional groups in the latter.

Broadening of the knowledge about the main structural elements of the organic mass of sapropelites, expected as a result of research in this area, consists in the revelation of the cause-and-effect relations between their genesis, structure, arrangement and properties in the processes of catagenetic maturing and pyrolytic processing. Specifically, this will be expressed in the possibility to choose reactions causing the destruction of the selected bridging bonds, and to extract the target structural fragments. The latter may be considered as the reagents for subsequent synthesis of valuable chemical products and carbon materials with high technological properties. The possibilities to realize these approaches are connected with the achievements of the instrumentation of the structural analysis of the organic matter of sapropelites and computer modelling of its main structural elements. The verified structural models will allow us to advance upon planning the direct ways of the conversion of the organic mass of sapropelites into valuable chemical products.

The organic matter of sapropelite coal and shale, with its mainly aliphatic structure, is a promising raw material fro the production of surfactants and petrol components. The demand for these materials is almost unlimited. In turn, aromatic monomers accompanying the aliphatic compounds are necessary for the growing market of polymer materials: technical plastics, polyester fibres, polyimides and liquid crystal polymers.

OUTLOOKS OF DEVELOPMENT AND EXPERIMENTAL-TECHNOLOGICAL WORKS

On the basis of experimentally confirmed results of the anticipated research, the following outlooks of the arrangement of development and experimental-technological works take shape. First of all, experimental investigation of the organic mass of sapropelites will require a workstation with microreactors for pyrolytic decomposition of sapropelite kerogen, with the units for the collection of pyrogenetic fractions and for their gas chromatographic – mass spectrometric analysis, and with computers equipped with the special software. Second, for the purpose of a wide-scale rapid molecular diagnostics of oil-generating beds, it will be necessary to combine the entire chain of the developed theoretical and experimental methods into a united set.

The above-mentioned workstation will allow us to: 1) characterize the organic mass of sapropelites at the molecular level; 2) reveal the regularities of the structure – property type. It main goal is determination of the structural features of the organic mass and the use of thus obtained information for developing all the possible efficient methods of processing sapropelite coal and shale (coal chemical industry, shale processing). At the same time, such a workstation will find its application also in oil geology for molecular diagnostics of oil-generating beds (at first hundreds, then thousands of samples per year). It will allow us to supplement the data on the evaluation of the oil-bearing capacity of sedimentary basins; at present the data of this kind are obtained [3] with the help of standard or modified Rock-Eval technique. The use of the expected results in oil geology will promote discovery and development of new deposits of natural oil; in the chemical branch it is promote involvement of sapropelite raw material resources into chemical production (to obtain synthetic oil for the industrial organic synthesis).

In view of the absence of the own shale-processing industry in Russia, sapropelite raw material resources for the present moment do not have the monetary value and does not belong to the strategic kinds of fossils. However, the use of products and services created on the basis of the results of above-mentioned

investigations will open the outlooks for achievement of social and economic effects due to the establishment of the own shale-processing production, reject of the budget subsidies for shale-mining enterprises, and liquidation of the dependence of shale-mining works on shale export. The own production of fuel-energy raw materials in the regions possessing the resources of sapropelite coal and shale will provide job creation not only directly in the production but also at the servicing enterprises connected with it.

The new methods and means of evaluation of the interconnection of the composition and structure of the organic mass of sapropelites with their properties will allow one to pass to the purposeful development of high-tech methods of processing coal and shale into chemical products and materials. The patent ability and licensing possibilities of the new developments will be ensured by their novel character and efficiency. The technologies based on these methods should become an essential basis for the creation of the new coal chemical branch of industry. These achievements will enable claiming for high scientific awards including international ones.

PREREQUISITES FOR OBTAINING THE ANTICIPATED RESULTS

The modern state and the world level of investigations in the area of the studies of the organic mass of sapropelites are to a large extent determined by a twenty-five-year experience of the work in this direction at the institutes of the Novosibirsk and Kemerovo science centres of SB RAS: Novosibirsk Institute of Organic Chemistry, Institute of Coal, Institute of Carbon Materials Chemistry, Institute of Coal and Coal Chemistry (V. A. Koptyug, N. V. Bodoev, Yu. V. Rokosov *et al.*, 1981–2006, see [4] and references therein). The dynamic progress in the investigation of sapropelites which was achieved with the help of non-destructive physicochemical methods [5–7] provided further development of the existing notions about the mechanisms of the processes involved in the formation of the main structural elements of the organic mass of sapropelites. The first results of modelling the possible routes of formation of these structural elements confirmed the correctness of the formulated statements [4] concerning the important role of the reaction of peroxide oxidation of lipids of microbial (algaic) cells during the formation of the organic mass of sapropelites. Moreover, they showed that not only oxygen, polymethylene and sulphide bridges but also direct carbon-carbon cross-linking bonds including polyconjugated ones occur in polymer lipid components comprising the major organic mass of sapropelites. Finally, this allows complex consideration of all the key problems of the interconnection of the genesis, structure and arrangement of the organic mass of sapropelites with their properties in natural and technological processes. The results of modern fundamental investigations of the organic mass of sapropelites were analysedThe professional community of the necessary level has been formed in the Institute of Coal and Coal Chemistry, SB RAS, in the Laboratory of Sapropelite Coal Chemistry (1983–2002). At present, there exists a potential possibility to unite highly skilled specialists within one project to solve the proposed problem. The financial support of this investigation will help conserving and developing the Russian scientific school in the area of coal chemistry. The risk for work implementation seems insignificant at present because evident factors that might have a negative effect on the anticipated works are almost absent, with the available financial support.

It should be noted that it is not reasonable to carry out the assumed investigations into the effective ways of using the sapropelite raw material resources at present within the frameworks of international cooperation: the previous fundamental experience in our country allows us to obtain the results of the world level working without foreign participants.

CONCLUSIONS

Anticipated results, in the form of new methods and means of evaluation of an interconnection between the structure of the organic mass of sapropelites and their properties, are likely to be obtained within only five

years due to the available fundamental rpevious experience in the area of chemistry of sapropelite coal. This fundamental experience was accumulated on the basis of the ideas developed by the prominent scientific schools of V. I. Vernadsky, A. P. Vinogradov, N. B. Vassoevich, V. A. Uspensky, E. M. Galimov, A. E. Kontorovich, G. Urisson and others. They established in the investigations of the role of living matter in the processes of the formation of carbonaceous sediments that the main precursors of the sapropelite organic matter are lipids of algae, zooplankton and bacteria. Within the framework of the new scientific research areas – chemistry of algenanes and chemistry of hydrothermal decomposition of sapropelite carbonaceous rocks [10] – geochemical (theoretical) models have becomes recognized as extremely important tools of investigation of the organic mass of sapropelites. In the course of the development of these scientific directions, an original experimental method was developed for the investigation of sapropelites: high-temperature alkaline (HTA) hydrolysis [11, 12]. This method may become a basis for the development of an efficient method of selective dismantling of the high-molecular structure of the organic mass of sapropelites into relatively low-molecular components depicting the features of the molecular structure of the initial or purposefully modified organic fragments.

The nearest plans concerning the solution of the problem of efficient use of sapropelite raw material resources must include now direct development of high-technological ways of processing the organic mass of sapropelites into alternative petrochemical products.

As the experience of scientific teams in the USA suggests, the lower limit of financing similar research projects is 300 thousand dollars per year for 5–7 researchers. However, with rather small salary, this amount includes very high (50–60 %) overhead charges, so nothing is left for purchasing equipment. Under the Russian conditions, within the federal task programme, an annual amount of 10 million roubles for financing the assumed work would be acceptable. Relatively small money from off-budget sources may be obtained from shale-mining enterprises interested in solving the formulated problem. In the case of launching shale-processing plants at the territory of Leningrad Region, the amount of the off-budget money may be large because shale-processing plants are directly interested in the creation of the scientific basis for the development of the technologies of the use of sapropelite raw material resources.

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