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ORGANIZATIONAL AND ECONOMIC MECHANISMS FOR ATTRACTING INVESTMENT IN THE HYDROGEN SULFUR MIXTURE PROCESSING OF THE BLACK SEA

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Key words:
hydrogen, sulfur, hydrogen sulfide, hydrogen sulfide mixture processing, ecological safety, absorption, mass transfer process, electrochemical reactor, tools and means

The article is devoted to the hydrogen sulfide mixture usage containing in the depths of the Black Sea as a raw material for processing into hydrogen and obtaining sulfur as a by-product. Some prospects and problems of energy resources utilization under the energy crisis in Ukraine have been considered. Hydrogen sulfide mixture reserves have been established as a result of geological exploration and analytical studies; the procedure for its processing into hydrogen has been proposed. The expediency of application of absorption-electrochemical method of hydrogen purification from sulfur has been considered. It can be used as a by-product for the branches of national economy. It was found that long-term operation leads to partial destruction of the electrochemical reactor elements, so the efficiency of existing treatment equipment is reduced compared to the allowable values. It was established that sanitary protection measures for the processing of raw materials do not comply with the State Sanitary Rules for the Protection of Atmospheric Air of Settlements. The economic and mathematical modeling of mass transfer processes in a gas-liquid system taking into account hydrodynamic processes in absorption-electrochemical installations of air purification from hydrogen sulfide has been proposed from the ecological point of view. The ways to intensify scientific research on this and related issues of its economic efficiency have been identified. The economic, ecological and safety factors influencing the hydrogen sulfide processing have been studied. Some measures to develop the appropriate scientific and technical programs and create a favorable investment climate to attract investment for their implementation have been proposed.

ОРГАНІЗАЦІЙНО-ЕКОНОМІЧНІ МЕХАНІЗМИ ЗАЛУЧЕННЯ ІНВЕСТИЦІЙ У ПЕРЕРОБКУ СІРКОВОДНЕВОЇ СУМІШІ ЧОРНОГО МОРЯ

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Ключові слова:
водень, сірка, сірководень, переробка сірководневої суміші, екологічна безпека, абсорбція, процес масообміну, електрохімічний реактор, інструменти та засоби

Стаття присвячена використанню сірководневої суміші, що міститься в надрах Чорного моря, як сировину для переробки на водень та отримання сірки як побічного продукту. Розглянуто деякі перспективи та проблеми використання енергетичних ресурсів в умовах енергетичної кризи в Україні. В результаті геологорозвідувальних і аналітичних досліджень встановлені запаси сірководневої суміші; запропоновано процедуру його переробки на водень. Розглянуто доцільність застосування абсорбційно-електрохімічного методу очищення водню від сірки. Може використовуватися як побічний продукт для галузей народного господарства. Встановлено, що тривала експлуатація призводить до часткового руйнування елементів електрохімічного реактора, тому ефективність існуючого очисного обладнання знижується порівняно з допустимими значеннями. Встановлено, що заходи санітарного захисту при переробці сировини не відповідають Державним санітарним правилам охорони атмосферного повітря населених пунктів. З екологічної точки зору

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запропоновано економіко-математичне моделювання процесів масообміну в системі газ-рідина з урахуванням гідродинамічних процесів в абсорбційно-електрохімічних установках очищення повітря від сірководню. Визначено шляхи інтенсифікації наукових досліджень з цього та супутніх питань його економічної ефективності. Досліджено економічні, екологічні та безпечні фактори, що впливають на переробку сірководню. Запропоновано заходи щодо розробки відповідних науково-технічних програм та створення сприятливого інвестиційного клімату для залучення інвестицій для їх реалізації.

Problem Formulation

In the context of the energy crisis, the use of hydrogen as a high-energy resource is the subject of security, environmental and other discussions. However, the reserves of natural gas on the Black Sea shelf, in the maritime economic zone of Ukraine are about 50 billion cubic meters. Gas flows from the bottom of the Black Sea are divided into conductive (scattered) and convective (concentrated) gas flow types. The Ukrainian scientist-geophysicist, Doctor of Geological Sciences, Professor, Corresponding Member of the National Academy of Sciences of Ukraine V. Kobolev classifies the methane seeps as scattered, and gas torches, gas fountains and mud volcanoes as concentrated. There are hundreds of mud volcanic channels and other tectonic faults in the sedimentary stratum of the Black Sea bottom, through which powerful streams of deep hydrocarbon degassing enter the bottom surface. The reserves of gas hydrate fields are more than 20 trillion cubic meters according to geological and geophysical data of the Black Sea. These reserves would be enough to supply the whole of Europe for 400 years, provided they are processed efficiently. In fact, these and other circumstances determine the timeliness and relevance of the issues discussed in the article.

Analysis of recent research and publications

The analysis of scientific papers on the research topic shows that this scientific aspect is not fully revealed by the Ukrainian scientists. Numerous articles and the targeted comprehensive research program of the National Academy of Sciences of Ukraine (Hydrogen in Alternative Energy and New Technologies) (scientific reporting session December 9, 2014, Kyiv, abstracts and session programs) focused on studying the ways to obtain, preserve and use the hydrogen. Based on the available information, they can be divided into scientific researches concerning:

I. The hydrogen production.

1.1. Development of highly productive processes of hydrogen production from water with the nano-structured energy-accumulating substances using activated zinc, manganese, aluminum, bismuth, iron and other components with the recovery of waste oxides by carbothermic method (Kozin L.H., Volkov S.V., Svyatogor A.V., Daniltsev B.I., Institute of General and Inorganic Chemistry named after V.I. Vernadsky of the National Academy of Sciences of Ukraine).

1.2. Research of regularities of anodic synthesis of hydrogen peroxide and development of a process of alternative anodic oxygen evolution in the production of hydrogen by electrolysis of an alkaline solution (Kozin L.H., Manilevich F.D., Kutsiy A.V., Lisogor N.M., Institute of General and Inorganic Chemistry named after V.I. Vernadsky of the National Academy of Sciences of Ukraine).

1.3. Optimization of catalyst composition and CO vapor conversion conditions during carbon vapor conversion (Trypolsky A.I., Kalyshyn E.Yu., Institute of Physical Chemistry named after L.V. Pisarzhevsky of the National Academy of Sciences of Ukraine).

1.4. Steam reforming of liquid oxygenates on oxide catalysts modified by functional impurities (Dolgikh L.Yu., Stolyarchuk I.L., Stara L.O., Vasylenko I.V., Pyatnitsky Y.I., Strizhak P.E., Institute of Physical Chemistry named after L.V. Pisarzhevsky of the National Academy of Sciences of Ukraine).

1.5. Research and design of new nanocomposite electrode materials for hydrogen-oxygen fuel cells, hydrogen release and CO2 utilization (Titov V.E., Kuris Y.I., Mishura A.M., Ustavitska O.O., Koshechko V.G., Pokhodenko V.D., Institute of Physical Chemistry named after L.V. Pisarzhevsky of the National Academy of Sciences of Ukraine).

1.6. Influence of reagent ratio on the course of paroxygen reforming of methanol with the catalyst ZnO-MgO-CuO / AL2O3 / cordierite (Kapran A.Yu., Orlyk S.M. Institute of Physical Chemistry named after L.V. Pisarzhevsky of the National Academy of Sciences of Ukraine).

1.7. The role of hydrogen in the catalytic processes of oxidative conversion of C1-C4-alkanes with NI-AL2O3-catalysts (Gubareni E.V., Solovyov S.O., Kurylets P., Institute of Physical Chemistry named after L.V. Pisarzhevsky of the National Academy of Sciences of Ukraine).

1.8. Development of technological schemes for obtaining hydrogen in the treatment of natural and wastewater by photocatalytic and electro membrane methods (Kucheruk D.D., Dulneva T.Yu., Institute of Colloid Chemistry and Water Chemistry named after A.V. Dumansky of the National Academy of Sciences of Ukraine).

1.9. Information support of scientific works concerning the programme projects «hydrogen in alternative energy and new technologies» (Chernyshev L.I., Bilan I.I., Gudimenko T.V., Levina D.A., Kovaleva L.A., Institute of Problems of Materials Science named after I.M. Frantsevich of the National Academy of Sciences of Ukraine).

1.10. Developing new modified environmentally friendly solid fuels using biomass and organic waste for hydrogen production (Dudnyk O.M., Sokolovska I.S., Institute of Coal Energy Technologies of the National Academy of Sciences of Ukraine).

1.11. Determination of parameters of hydrogen production with the use of electrolyzers and renewable energy sources and for automatic processing and

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transmission of information (Kudrya S.O., Morozov Y.P., Kuznetsov M.P., Institute of Renewable Energy of the National Academy of Sciences of Ukraine).

1.12. Investigation of hydrogen production by tungsten-steam method under concentrated radiant heating using tungsten-containing wastes (Zenkov V.S., Pasichny V.V., Ostapenko S.O., Rogozinskaya A.O., Rogozinsky A.A., Institute of Problems of Materials Science named after I.M. Frantsevich of the National Academy of Sciences of Ukraine).

II. Hydrogen storage.

2.1. Photoelectrochemical properties, efficiency of hydrogen release and accumulation in electrochemical system based on modified photoanodes and their use in photo accumulator with cathodes (Rusetsky I.A., Slobodyanyuk I.O., Kolbasov G.Ya., Shcherbakova L.G. (1), Solonin Y.M. (1) Institute of General and Inorganic Chemistry named after V.I. Vernadsky of the National Academy of Sciences of Ukraine, (1) Institute of Problems of Materials Science named after I.M. Frantsevich of the National Academy of Sciences of Ukraine).

2.2. Development of physical and chemical bases for the creation of new highly porous metal-organic frame materials for hydrogen accumulation (Lampeka J.D., Tsymbal L.V., Gavrish S.P., Gurtovy R.I., Institute of Physical Chemistry named after L.V. Pisarzhevsky of the National Academy of Sciences of Ukraine).

2.3. Detection of the R and ME impact on the hydrogen absorption of AB5 alloys (Zaginaichenko S.Y., Matisina Z.A., Shchur D.V., Shaposhnikova T.I., Zolotarenko A.D. Institute of Problems of Materials Science named after I.M. Frantsevich of the National Academy of Sciences of Ukraine).

2.4. Investigation of hydrogen desorption processes from hydrofullerites and their structural and physicochemical features (Shchur D.V., Savenko O.F., Kopilova L.I., Zolotarenko A.D., Zaginaichenko S.Yu., Institute of Problems of Materials Science named after I.M. Frantsevich of the National Academy of Sciences of Ukraine).

2.5. Investigation of electrodes destruction processes from AB5 alloys during hydrogen absorption in reversible electro- and photoelectrochemical systems (Shcherbakova L.G., Spodaryk M.I., Solonin Yu.M., Institute of Problems of Materials Science named after I.M. Frantsevich of the National Academy of Sciences of Ukraine).

2.6. Mechanical synthesis of hydride-forming magnesium alloy with NI, TI, AL and study of hydrogen-absorbing properties, temperature and kinetics of its decomposition (Dobrovolsky V.D., Ershova O.G., Solonin Yu.M., Institute of Problems of Materials Science of the National Academy of Sciences of Ukraine).

2.7. Development of methods for estimating hydrogen damage of ferromagnetic materials according to the parameters of magnetoelastic acoustic emission signals (Skalsky V.R., Pochapsky E.P., Klim B.P., Sergienko O.M., Dolishniy P.M., Velyky P.P., Physico-Mechanical Institute named after G.V. Karpenko National Academy of Sciences of Ukraine).

2.8. Investigation of the insoluble components impact on the accumulation and release of hydrogen from magnesium composites (Neklyudov I.M., Morozov O.M., Zhurba V.I., Progolaeva V.O., Kuprin O.C., Ovcharenko V.D., Kolodiy I.V., National Research Center «Kharkiv Institute of Physics and Technology» of the National Academy of Sciences of Ukraine).

III. Hydrogen usage.

3.1. Development of polymer electrolyte membranes based on organo-inorganic hybrids of different types for hydrogen fuel cells (Shevchenko V.V., Klimenko N.S., Stryutky O.V., Lysenkov E.A., Yakovlev Y.V., Klepko V.V., Institute of Chemistry of Macromolecular Compounds of the National Academy of Sciences of Ukraine).

3.2. Investigation of the influence of conditions and methods of obtaining nano porous carbon materials based on natural organic substances on their adsorption (nitrogen and hydrogen) properties (Yaremov P.S., Shcherban N.D., Filonenko S.M., Ilyin V.G., Institute of Physical Chemistry named after L.V. Pisarzhevsky of the National Academy of Sciences of Ukraine).

3.3. Investigation of the influence of titanium oxide nanospheres structure on the physicochemical and final proton-conducting properties of nafion composite polymer membranes (Telbiz G.M., Leonenko E.V., Romanovska N.I., Khizhun O.Y., Gorbanyuk T.I., Institute of Physical Chemistry named after L.V. Pisarzhevsky of the National Academy of Sciences of Ukraine, Institute of Problems of Materials Science named after I.M. Frantsevich of the National Academy of Sciences of Ukraine, Institute of Semiconductor Physics named after V.Ye. Lashkaryova of the National Academy of Sciences of Ukraine).

3.4. Synthesis and research of thick films of zirconium dioxide stabilized with complex scandium-containing additives for low-temperature (600°) fuel cell (Vyunov O.I., Yanchevsky O.Z., Kovalenko L.L., Solopan S.O., Belous A.G., Institute of General and Inorganic Chemistry named after V.I. Vernadsky of the National Academy of Sciences of Ukraine).

3.5. Establishment of the structural-phase mechanism for products recombination of destructive hydrogenation of intermetallics and alloys (Kucheryavy O.V., Skorokhod V.V., Bratanich T.I., Dobrovolsky V.D., Institute of Problems of Materials Science named after I.M. Frantsevich of the National Academy of Sciences of Ukraine).

3.6. Investigation of structural and chemical heterogeneity of the PDA electrolyte, which occurs during its manufacture and operation, and its impact on its mechanical and electrochemical properties (Vasiliev O.D., Brodnikovsky E.M., Brichevsky M.M., Brodnikovsky D.M., Brodnikovskaya I.V., Lisunenko N.O., Podgurskaya V.Ya., Vasyliv B.D. (1), Ostash O.P., Samelyuk A.V., Ushkalov L.M., Golovkova M.E., Institute of Problems of Materials Science named after I.M. Frantsevych of the National Academy of Sciences of Ukraine, Institute of Physics and Mechanics named after G.V. Karpenko of the National Academy of Sciences of Ukraine).

3.7. Development of basic local criteria of strength and serviceability of structural steels in hydrogen environment and construction of diagrams of their local destruction (Dmytrakh I.M., Sirotyuk A.M., Barna R.A.; Leshchak R.L., Physico-Mechanical Institute named after G.V. Karpenko National Academy of Sciences of Ukraine).

3.8. Development of a method for manufacturing sintered magnets from nanostructured anisotropic powders of alloyed alloys based on Nd2Fe14B compounds and research of their properties (Bulyk I.I., Trostyanchin A.M., Burkhovetsky V.V., Physico-Mechanical Institute named after G.V. Karpenko National Academy of Sciences of Ukraine, Donetsk Institute of Physics and Technology named after O.O. Galkin of the National Academy of Sciences of Ukraine).

3.9. Investigation of the microstructure evolution of powder systems based on zirconium and titanium hydrides with powders of alloying elements under the action of solid-phase diffusion (Ivasyshyn O.M., Savvakin D.G., Institute of Metal Physics named after G.V. Kurdyumov National Academy of Sciences of Ukraine).

3.10. Computer and physical mod modeling of the increasing the permeability process of collectors of oil and gas well reservoirs taking into account the hydro conversion of asphalt-resin-paraffin substances and the effect of hydrogen activation of diffusion (Kravchenko O.V., Veligotsky D.O., Avramenko A.M.).

3.11. Investigation of catalytic characteristics of electrocatalysts in real electrodes of a fuel cell and identification of factors influencing energy characteristics (Pirsky Yu.K., Ogenko V.M., Lysyuk L.S., Panchyshyn T.M., Tupchienko O.S., Sharanda L.F., Krupennikova O.S., Institute of General and Inorganic Chemistry named after VI Vernadsky National Academy of Sciences of Ukraine).

In all scientific papers, the authors note that the optimal efficiency of hydrogen sulfide removal, for example, in sewerage from the air by absorption-electrochemical method is achieved at values of redox potential for catholyte from –250 mV to –300 mV and anolyte 3 from +250 mV up to +300 mV. It is established that the maximum volumes of hydrogen sulfide release are observed from 60 to 120 C from the starting of pumping pumps.

The authors propose the calculating method of the mass transfer apparatus and practical recommendations for improving the absorption-electrochemical method of air purification from hydrogen sulfide. This method reduces the material consumption of treatment equipment, improves energy performance and increases the efficiency of hydrogen sulfide emissions, which is the most common in utilities.

Meanwhile, the problems of the hydrogen sulfide mixture processing from the depths of the Black Sea to hydrogen and its subsequent transportation to consumers and use for an intended purpose, developing the ways to obtain a by-product of sulfur, remained in the field of view of Ukrainian scientists.

Main research material presentation

It is known that the Black Sea water are saturated with hydrogen sulfide H_2S and methane CH_4 at depths of more than 150–200 meters. Methane is a swamp or ore gas, colorless, odorless gas. Methane is found in the Black Sea in several types.

The scientists Kovalev I.O., Kobyzsky D.S. in their paper on «Hydraulic installation and the extraction of fuel gases of the Black Sea» consider that methane dissolved in water is at depths of about 200 meters in a layer 100–150 meters thick. This is methane of biological origin due to methane-forming bacteria. The main methane reserves in the Black Sea are methane gas hydrates. There is a layer of 300–400 meters thick with dissolved methane at the sea bottom. Therefore, the scientists consider that methane production involves the gas hydrates extraction and processing.

Hydrogen sulfide is a colorless gas (at high dilution has the smell of rotten eggs). It exists as a solution in seawater at depths of more than 120–150 meters. This gas is a product formed in the process of decay of organic residues as well as coming from the subsoil. The concentration of dissolved hydrogen sulfide at a depth of 200 m is from 0,07 to 0,16 ml/l and gradually increases to 13 ml / l at a depth of 2000 m.

At least 108 tons per year (or 66*109 m^3 per year) of hydrogen sulfide is generated annually in the Black Sea. Calculations show that no more than 25 % of all hydrogen sulfide is processed into sulfates per year as a result of oxidation in the Black Sea. Therefore, about 250 million tons of hydrogen sulfide can be taken from the Black Sea annually without harming the environment, which exceeds the current needs of Ukraine. The estimated reserves of hydrogen sulfide are 1012–1013 m^3 or at least one billion tons. In terms of energy (heat of combustion), one cubic meter of hydrogen sulfide is equivalent to 0.65 m^3 of methane. When hydrogen sulfide burns, sulfur dioxide is formed. Its further processing allows to obtain additional thermal energy and sulfuric acid $2SO_2 + 2H_2O = 3O_2 + 2H_2S$; $2S + 2H_2O = O_2 + 2H_2S$. It is known that a mixture of hydrogen sulfide and air is explosive, especially at a concentration of 4 to 45 %. Thus, hydrogen sulfide can be obtained from Black Sea and used as an unconventional fuel gas or as a valuable chemical product for hydrogen and sulfur: $S + H_2 \rightarrow H_2S$.

Nowadays, a number of an advanced projects have already been developed for the extraction of methane and hydrogen sulfide from Black Sea by exposure to water by electro-hydraulic shock according to the effect of Yutkin L.O.; acidification of sea water to a pH of 4.5 to 5 with the vibrations with a certain frequency; pumping air into the deep layers and raising water to the surface, etc. It is clear that the project with the least cost may be of the greatest interest. Thus, given the fact that the maximum concentration of hydrogen sulfide at a depth of 2000 m is under a pressure of 21 MPa, the experts suggest lowering a pipe of appropriate diameter from the platform to this depth. From the upper part of the pipe the pump pumps a certain amount of sea water and in its place will raise the water from deeper layers, where it will begin to emit excess dissolved gas. The movement of a two-phase medium (sea water-gas fraction) is expected in the pipe, and the movement of sea water upwards will be observed, as in the known airlifts. In addition, the movement of sea water will be carried out under the difference of hydrostatic pressure at the same depths inside the pipe and outside. The gas-water mixture is collected on the surface in a special apparatus, where the gas fraction (hydrogen sulfide) and sea water are separated.

Oxygen-enriched water can be returned to the depths, and hydrogen sulfide is further processed according to a defined process. It should be noted that the rise of sea water and the release of dissolved gas from it will not require any external energy costs. Thus, we can conclude about the development prospects of energy potential of the Black Sea fuel gases and the efficiency of the above-described method for its implementation as one of the options.

In order to preserve the environment and achieve zero emissions and decarbonization, as well as the abandonment of fossil fuels in 2020, the EU presented a hydrogen strategy aimed at using the «green» hydrogen [2]. The expected investment in the «green» hydrogen production in Europe will range from 180 to 470 billion Euros till 2050. The EU wants to achieve climate neutrality, when greenhouse gas emissions can be absorbed by the ecosystem. The experts distinguish four types of hydrogen. The most common is gray hydrogen obtained from gas. Blue hydrogen is produced in a similar way, but with subsequent disposal of CO_2 emissions, and black or brown hydrogen is produced from coal. The «green» hydrogen should be produced from electricity obtained from renewable energy sources (RES), such as wind or solar energy.

NJSC Naftogaz of Ukraine and German energy trading company RWE Supply & Trading have signed a Memorandum of understanding in the hydrogen economy. Furthermore, Naftogaz and RWE intend to jointly explore commercial opportunities for the sale of Ukrainian green hydrogen in European markets, with a focus on RWE's core markets. Ukraine is projected to have incredible prospects in the production and supply of «green» gas to Europe. The experts say we can start exporting by 2024. According to various estimates, it is planned to reach a capacity of 9,8 GW by 2030. Anka Feldguzen (Ambassador Extraordinary and Plenipotentiary of the Federal Republic of Germany to Ukraine) has noted that Ukraine should become a pilot country for the export of «green» hydrogen. It is planned to produce «green» hydrogen in four regions of Ukraine: Zaporizhia, Kherson, Dnipropetrovsk and Odesa and transport hydrogen through the existing gas transmission system. The experience has shown that ecological gas is not entirely safe. In addition, this gas corrodes a standard low pressure metal pipe in a few hours and a high pressure pipe in months [2]. Therefore, this system requires total modernization with expensive composite materials that do not chemically react with hydrogen or build a new one near the old one. The experts consider that the addition of about 20 % of hydrogen to the transported gas will avoid costly modernization of the gas transmission system.

The diplomat and many other experts consider the hydrogen as our energy future. «Green» hydrogen is going to produce by electrolysis of water. As known, freshwater reserves are quite low and according to the UN account for only 2,5 % of all water reserves, the rest of the reserves are concentrated in glaciers.

Ilyenko B. (Scientific Secretary of the Gas Institute of the National Academy of Sciences of Ukraine) [3] pointed out that Spain is better suited for solar electricity and the North Sea for wind turbines, and the efficiency of these two sources in Ukraine is about 13 %. In particular, Germany is richer in fresh water reserves than Ukraine. According to the European Economic Commission standards, if the water reserves of the country do not exceed 1,5 thousand m^3 of annual runoff per person, the state is considered not supplied with water.

Available water reserves per capita in Ukraine are 1,09 thousand m^3 in medium water years, and 0,62 thousand m^3 in low water years. That's why Ukraine is one of the least water supplied countries in Europe. However, the biggest problem is not the lack of water, but its poor quality and constant pollution. In addition, the above-mentioned southern regions of Ukraine depend on water supplied on schedule, and imported water is used for food purposes [4]. Also B. Ilyenko in his article notes that to obtain 1 ton of hydrogen by electrolysis requires 9 tons of distilled water or about 20 tons taken from fresh water, and taking into account 13 % efficiency of solar and wind turbines, which have already been mentioned, and to ensure 9,8 GW is about 500 thousand tons of water. Therefore, it can be concluded that the use of drinking water to produce hydrogen is not entirely rational and all the benefits must be considered in detail.

Conclusions

Thus, an alternative to the use of fresh water (and other water sources) to obtain ecological hydrogen is a patented Ukrainian scientist D. Turchenko's method of extracting hydrogen from the Black Sea hydrogen sulfide water mixture. The main idea of this method is to obtain hydrogen found in the deep sea layers of the Black Sea from various substances by decomposing hydrogen sulfide into hydrogen and sulfur. By the way, this is not the only one patent of this author for the extraction of hydrogen sulfide gas from the seabed.

The solution of the current scientific and practical problem is to improve the environmentally friendly method of absorption and electrochemical purification of hydrogen sulfide by substantiating the rational parameters of treatment equipment and the mass transfer process between hydrogen sulfide and absorbents generated in the electrochemical reactor.

The features of hydrogen sulfide extraction, the characteristics of existing methods of its purification from sulfur impurities and sulfur obtaining as a by-product for certain sectors of the economy have been revealed based on the analysis of scientific literature and papers. In particular, the expediency of using the absorption-electrochemical method of purification of hydrogen from sulfur, which is used as a by-product for the national economy, has been substantiated. It was found that long-term operation leads to partial destruction of the elements of the electrochemical reactor, so the efficiency of existing treatment equipment is reduced by 10 % compared to design levels. It was found that sanitary protection measures for the processing of raw materials do not comply with the State Sanitary Rules for the Protection of Atmospheric Air of Settlements, etc. The economic and mathematical modeling of the mass transfer process in a gas-liquid system taking into account hydrodynamic processes in absorption-electrochemical installations of air purification from hydrogen sulfide has been offered to use from the ecological point of view.

According to the experimental study results, the new data were obtained on the efficiency of using regression dependences to determine the rate constant of the chemical reaction and the average mass transfer coefficient for different absorbents. Practical recommendations for improving the absorption-electrochemical method of purification of hydrogen sulfide from other impurities have been offered. These recommendations are aimed at reducing the material consumption of treatment equipment and improving energy performance. Scientific and practical recommendations concerning the sulfur as a by-product that can be widely used in various sectors of the national economy have been given.

In general, the benefits of this method are to reduce energy costs for the production of hydrogen in large industrial quantities and at the same time the production of sulfur as a by-product. In addition, the industrial extraction of large amounts of hydrogen sulfide from seawater can improve the ecology and hydrology of the Black Sea.

We consider that the Cabinet of Ministers of Ukraine, the State GeoCadastre, other ministries and public authorities should take measures to develop the appropriate scientific and technical programs and create a favorable environment for attracting investment in their implementation.

References

1. Stokholmska konferentsiia [Stockholm Conference]. URL: https://necu.org.ua/stokgolmska-konferencziya/
2. Chy mozhlyvo zaminyty haz v ukrainskii HTS na «zelenyi» voden [Is it possible to replace the gas in the Ukrainian GTS with «green» hydrogen]. URL: https://www.dw.com/uk/chy-mozhlyvo-zaminyty-haz-v-ukrainskii-hts-na-zelenyi-voden/a-58759745
3. «Zelenyi» voden. Liknep dlia Ukrainy : Povidomlennia NAN Ukrainy [«Green» hydrogen. Liknep for Ukraine : Report of the National Academy of Sciences of Ukraine]. URL: https://www.nas.gov.ua/UA/Messages/Pages/View.aspx?MessageID=8261
4. Yak Ukraini ne zalyshytysia bez pytnoi vody? [How can Ukraine not be left without drinking water?]. URL: https://ua.interfax.com.ua/news/blog/770389.html
5. Sposib vydilennia vodniu z sirkovodnevoi vodianoi sumishi [Method of isolating hydrogen from hydrogen sulfide water mixture] : pat. 72279 Ukraina: C01B 17/04, C01B 3/06, № u2012 01770; zaiavl. 17.02.2012; opubl. 10.08.2012, Biul. № 15. 10 p.
6. Kovalov I.O., Kobyzskyi D.S. Hidroustanovka ta sposib dobuvannia palyvnykh haziv Chornoho moria [Hydraulic installation and method of extraction of fuel gases of the Black Sea]. URL: https://essuir.sumdu.edu.ua/bitstream-download/123456789/6643/1/2.pdf
7. Patsurkovskyi P.A. (2017). Udoskonalennia ekolohichno bezpechnoho absorbtsiino-elektrokhimichnoho metodu ochyshchennia povitria vid sirkovodniu [Improvement of ecologically safe absorption-electrochemical method of air purification from hydrogen sulfide] : Kvalifikatsiina naukova pratsia na pravakh rukopysu. Dysertatsiia na zdobuttia naukovoho stupeniv kandydata tekhnichnykh nauk (doktora filosofii) za spetsialnistiu 21.06.01 «Ekolohichna bezpeka» / Natsionalnyi universytet korablebuduvannia imeni admirala Makarova. Mykolaiv.
8. Patsurkovskyi P.A., Leibovych L.Y. (2013). Ochystka vozdukha ot serovodoroda absorbtsyonno-elektrokhymycheskym metodom [Air purification from hydrogen sulfide by absorption-electrochemical method]. *Sbornyk nauchnykh trudov SWorld*. Odessa. T. 39. Vyp. 2. P. 73–79.
9. Leybovych L.I., Patsurkovskiy P.A. (2015). Influence of Water Salinity on Air Purification from Hydrogen Sulfide. *Problemele Energeticii Regionale*. Kishinev. № 3(29). Pp. 92–99.
10. Leibovych L.Y., Patsurkovskyi P.A. (2015). Okyslenye serovodoroda vo vlazhnom vozdukhe [Oxidation of hydrogen sulfide in moist air]. *Vestnyk Kharkovskoho natsyonalnoho avtomobylno-dorozhnoho unyversyteta*. Kharkov. № 71. P. 85–90.
11. Leibovych L.Y., Patsurkovskyi P.A. (2016). Modelyrovanye dynamyky postuplenyia serovodoroda v okruzhaiushchuiu sredu pry rabote kanalyzatsyonnoi nasosnoi stantsyi [Simulation of the dynamics of hydrogen sulfide entry into the environment during the operation of a sewage pumping station]. *Vestnyk Kremenchuhskoho natsyonalnoho unyversyteta ymeny Mykhayla Ostrohradskoho*. Kremenchuh. Vyp. 3(98). Ch. 1. P. 100–105.
12. Leibovych L.Y., Patsurkovskyi P.A. (2014). Otsenka effektyvnosty okyslenyia serovodoroda, absorbyruemoho vodoi [Evaluation of the efficiency of oxidation of hydrogen sulfide absorbed by water]. *Problemy ekolohii ta enerhozberezhennia v sudnobuduvanni – Problems of ecology and energy saving in shipbuilding* : materialy IX Mizhnarodnoi naukovo- tekhnichnoi konferentsii (m. Mykolaiv, 5–7 chervnia 2014 r.). Mykolaiv : NUK. P. 64–67.
13. Patsurkovskiy P.A., Leibovich L.I. Absorptively-electrochemical method of air purification from hydrogen sulfide at the municipal solid wastes processing plants. 2nd International Conference on Sustainable Solid Waste Management (Greece, 12–14 June 2014). Greece, 2014. URL: http://athens2014.biowaste.gr/pdf/patsurkovskiy_leybovych.pdf (Last accessed: 10.03.2017).
14. Leibovych L.Y., Patsurkovskyi P.A. (2015) Uslovyia yntensyfykatsyy okyslenyia serovodoroda v hazozhydkostnykh systemakh [Conditions for the intensification of hydrogen sulfide oxidation in gas-liquid systems]. *Problemy ekolohichnoi bezpeky – Environmental safety issues* : materialy XIII Mizhnarodnoi naukovo-praktychnoi konferentsii (m. Kremenchuk, 6–8 zhovtnia 2015 r.). Kremenchuk : KrNU. P. 41.
15. Patsurkovskyi P.A., Leibovych L.Y. (2016) Opyt ekspluatatsyy ustanovky absorbtsyonno-elektrokhymycheskoi ochystky vozdukha ot serovodoroda [Operating experience of the installation of absorption-electrochemical air purification from hydrogen sulfide]. *Problemy ekolohichnoi bezpeky – Environmental safety issues* : materialy XIV Mizhnarodnoi naukovo-praktychnoi konferentsii (m. Kremenchuk, 12–14 zhovtnia 2016 r.). Kremenchuk : KrNU. P. 83.