

Development of installation for the preparation of biosorbents from waste petrochemical industry

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Abstract: The article considers the problem of environmental pollution by oil spills. A solution is proposed in the form of a developed device and a method for its implementation. Its technical characteristics for the preparation of biosorbents from wastes from the petrochemical industry, in particular surplus activated sludge after heat treatment, are presented. The parameters that are necessary for the effective preparation of the biosorbent are given. Parameters are obtained by experiment.

1. Introduction

Beginning in 2011, Russia has seen steady growth in oil production volumes and at the same time the amount of oil pollution is increasing, so the amount of breaching in oil pipelines has increased by 31% over the past five years. [1]

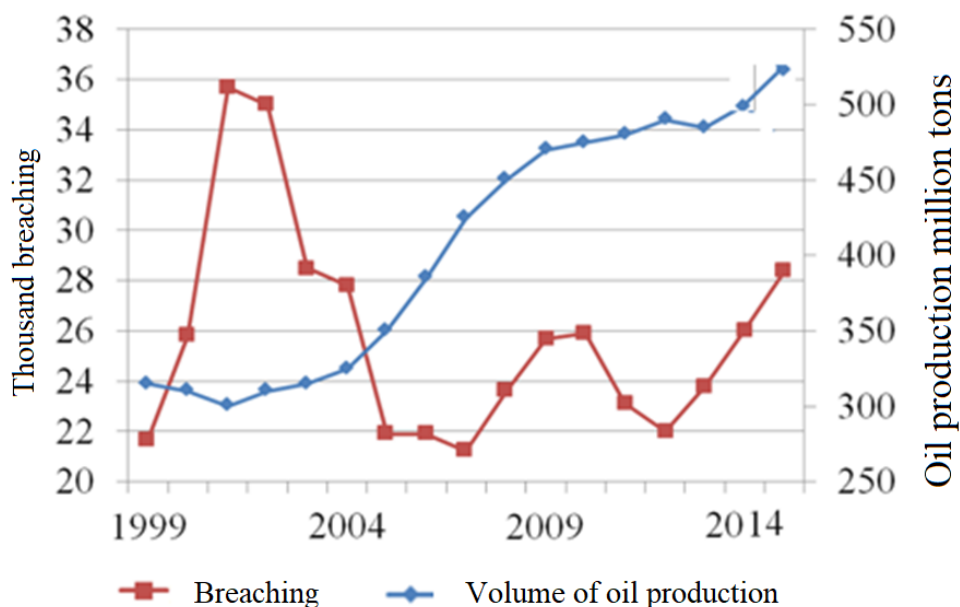


Figure 1. Amount of pipeline breaching and oil production.

Taking into account the current dynamics, the production and technical base and the program for the development of the fuel and energy complex, the scale of pollution will only increase.



The importance of minimizing the damage inflicted is reflected in the state policy, namely: "Socio-economic development of the Arctic zone of the Russian Federation for the period until 2020" No. 336 of 21.04.2014; Federal target program "Elimination of accumulated environmental damage" for 2014 - 2025"; The program of import substitution in the direction "Perspective technologies of management and environmental protection of water resources". So, the state annually allocates about 17 billion rubles through targeted state programs. Only in 2015, oil companies allocated more than 11 billion rubles for land reclamation.

The greatest demand is observed in biosorbents, which are a complex of different types of sorbents and oil-oxidizing microorganisms immobilized on it. [2]

The analysis of the effectiveness of the currently used biosorbents shows the presence of a number of shortcomings. The most significant shortcomings are high cost and insufficient effectiveness of sorbent carriers. Investigating the technological scheme for the production of biosorbents, processes were identified modifying which it would be possible to improve the adsorption properties of the bases used for the biosorbent and the efficiency of the ligament of oil-oxidizing bacteria and the base.

As a result of the analysis of the process of biosorbents production, the necessary parameters of the effective sorbent carrier and the possibility of utilization of waste from the petrochemical complex, it was found that the most optimal is the carbon substrate from the heat treated activated sludge that is taken to a specialized storage facility. By developing special equipment, it will be possible to reduce the labor and financial costs of enterprises and increase the efficiency of refining. [3,4]

2. Formulation of the problem

In oil companies, there has been a shift from mechanized oil spill cleanup to the use of sorbents and biosorbents. To date, the market for biosorbents in Russia is about \$450 million, with an annual growth rate of 6%. Using the SWOT-analysis of the market, the following problems were identified: labor intensity of preparation, a high proportion of expensive imported equipment and the need for recycling of wastage from the petrochemical complex. Since the market of sorbents is represented by foreign companies by more than 70%, the policy of import substitution is of great importance.

The main tasks of the research are:

- Develop a schematic diagram and a method for preparing a carbon-based biosorbent;
- Obtain the boundary parameters for the preparation of the sorbent;
- Construct a 3-D model of a biosorbent preparation plant.

3. Results and discussion

To achieve these goals, a device for the preparation of biosorbents from wastes from the petrochemical industry is proposed.

The installation is a vertical cylindrical technological equipment intended for the production of biosorbents by creating the necessary physical conditions for the successful immobilization of the microorganism strain on a carbon base. Installation consists of waste petrochemical enterprises. Installation has a mechanical and pneumatic mixing system. The installation regulates such parameters as: stirring speed, temperature, pH (acidity of the medium), pressure and humidity. This is done by means of the presence of the following elements in the installation: a circulation circuit for temperature control; mobile diffusers which create circulation of air masses throughout the volume and, at high speeds of air masses, it provides active mixing with blowing and drying; stirring mechanical device; outlet for loading nutrient media and strains of microorganisms and unloading the finished material; a vacuum pump to provide pressure parameters.

The process of preparation of biosorbent in the installation occurs at a temperature regime of 18 to 60 degrees Celsius, under conditions of excess pressure. The humidity range is from 20 to 95%. Air flow rate is up to 15 m³/min.

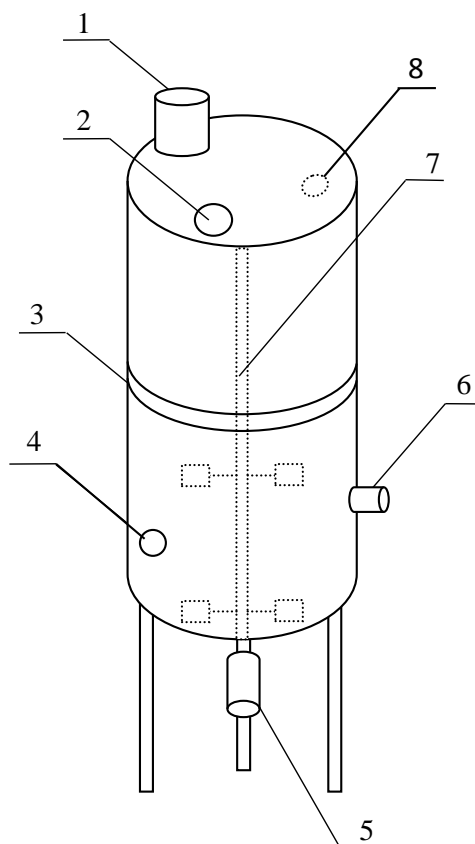


Figure 2. Sketch of the installation for the preparation of biosorbents from waste petrochemical industry. 1- access hatch, 2-sight window, 3-section circulation circuit, 4-hatch of bacteria, 5- water disposal system, 6-sampler, 7-agitating mechanical device, 8-mobile diffuser.

Method of preparation of biosorbent. Sludge with low adsorptive properties received as a result of low-temperature separation is loaded into the reception hatch of installation. Then sludge is exposed to activation, i.e. crushing and hashing at the expense of the mixing mechanical device and establishment of temperature condition for couples of a section circulating contour with the subsequent drying by the mobile diffuser. As a result, necessary structural parameters, namely the size of a macropores which is suitable for a further immobilization, turn out since the basis has high adsorptive properties. After stopping the supply of steam and drying, certain parameters are set: humidity 40% -50%, temperature 150-180 °C, speed of the mixing mechanical device 150-200 rpm for 20-30 minutes.

Then, the mixture is loaded into installation which consists of various chemical compounds which contains the strains of microorganisms relating to the sorts *Pseudomonas* sp., *Rhodococcus* sp., *Mortierella*. The pH of the medium is set to 5.8-6.0; temperature 26 ± 5 °C; the speed of the mechanical stirrer in the range of 80-100 rpm. Then process of hashing by means of the device mixing mechanical and/or giving a stream of air by the mobile diffuser is carried out. Then via the reception hatch commodity oil with a density up to 910 kg/m³ immobilization moves in a small amount for an additional. After thorough mixing, the drying process begins, at which the mixing process stops. The temperature, humidity and pressure parameters change and dry warm air flows through the mobile diffuser. Diffusers, moving in a small interval, contribute to the drying process. The liquid that settles at the bottom is disposed of using a water disposal system.

At the end, the resulting substance, called biosorbent, is removed from the installation and packaged.

The installation for the preparation of biosorbents from the waste petrochemical industry, the vertical type has a cylindrical shape and works as a fermenter, inoculator and adsorber simultaneously.

The installation performs sequential actions in a single system, where there is no need to extract or redistribute the biosorbent. [5,6]

During the use of the offered Installation key difference of a way of preparation of a biosorbent is the possibility of use of silt after heat treatment as an effective basis for a biosorbent.

During the implementation of the research, the obtained biosorbent has a component composition with a component ratio of dry matter, % (Table 1), has characteristics (Table 2) and can be reproduced under the conditions of preparation (Table 3).

Table 1

Surplus activated sludge	89-93
Suspension of microorganisms	7-11

Table 2

Humidity	15-19%
Macropore volume	0.551 – 0.538 cc/g
Water capacity	0.62 cc/g
Oil capacity	0.51 g/g

Table 3

Humidity range, %	15-85
Temperature range, °C	+15...+250
Pressure range, atm	0.7 to 2.5
Range of turns at mechanical hashing, rpm	0-700
Range volume air supply at pneumatic mixing, l/min	0-100
Range of pore size of the carbon base biosorbent, micrometer	0.2 -0.5

Design features of the installation. The installation case is a cylindrical container consisting of two cylinders of identical shape made of stainless steel 08H18N10 or 10H17N13M2T, differing in structural dimensions such that a small cylinder is placed in a large cylinder and forms a gap into the inner cavity of which the thermal insulation is placed. Each cylinder consists of a solid sheet of metal with structural dimensions: length - 1350 mm, width - 8 mm, height - 1600 mm. A cylinder is created by welding a sheet into the shape of a cylinder with a welding top cover.

In the tank occurs a process of fermentation, inoculation and drying.

Dimensions of the installation: diameter of the cylindrical base - 420 mm, height - 1500 mm

Insulation layer: glass fibre mineral insulation «ursa geo», parameters:

- flammability class; non-combustible
- noise figure: 56 dB;
- material density: 15 kg/m³;
- heat conduction: 0.036 W/m °C;
- heat-transfer resistance: 1.39 m²K/W;
- operating temperature: from -60 to +220 °C

The system for regulating the temperature in the inner cavity of the main tank is represented in the form of a pipeline made of stainless steel. The pipeline is located along the perimeter of the main tank and has a closed cycle of electrical type with the possibility of controlled heating and heat exchange (cooling system), parameter:

- pipeline diameter – 20 mm
- wall thickness – 3 mm
- heat carrier – liquid, steam
- range of temperatures of the heat carrier: 12-300 °C

System of mechanical hashing. It is carried out by the bladed mixer connected to a shaft and the electric motor (power: 3-5 kW) with a range of turns up to 700 rpm.

Pneumatic mixing system. It is carried out by means of the directed air stream from the diffusers defining the direction. Volume giving: up to 100 liters of air a minute by means of the pneumatic membrane pump. In addition coal sorption with function of aeration for purification of air and creation of the clean environment contains the filter.

The diffuser is adjustable, a mobility corner (the angle of change of the direction) in each part is up to 15°.

The system of liquid discharge is located in the lower part of the camera and presented in the valve form with automatic discharge with the vacuum engine. In the camera, the formed condensate flows down and the remains from processes of fermentation and an inoculation. Discharge volume: 2 liters.

The sight window is located in the opening of the top cover with double thick glass. It has a diameter of 50 mm and a glass thickness of 7 mm.

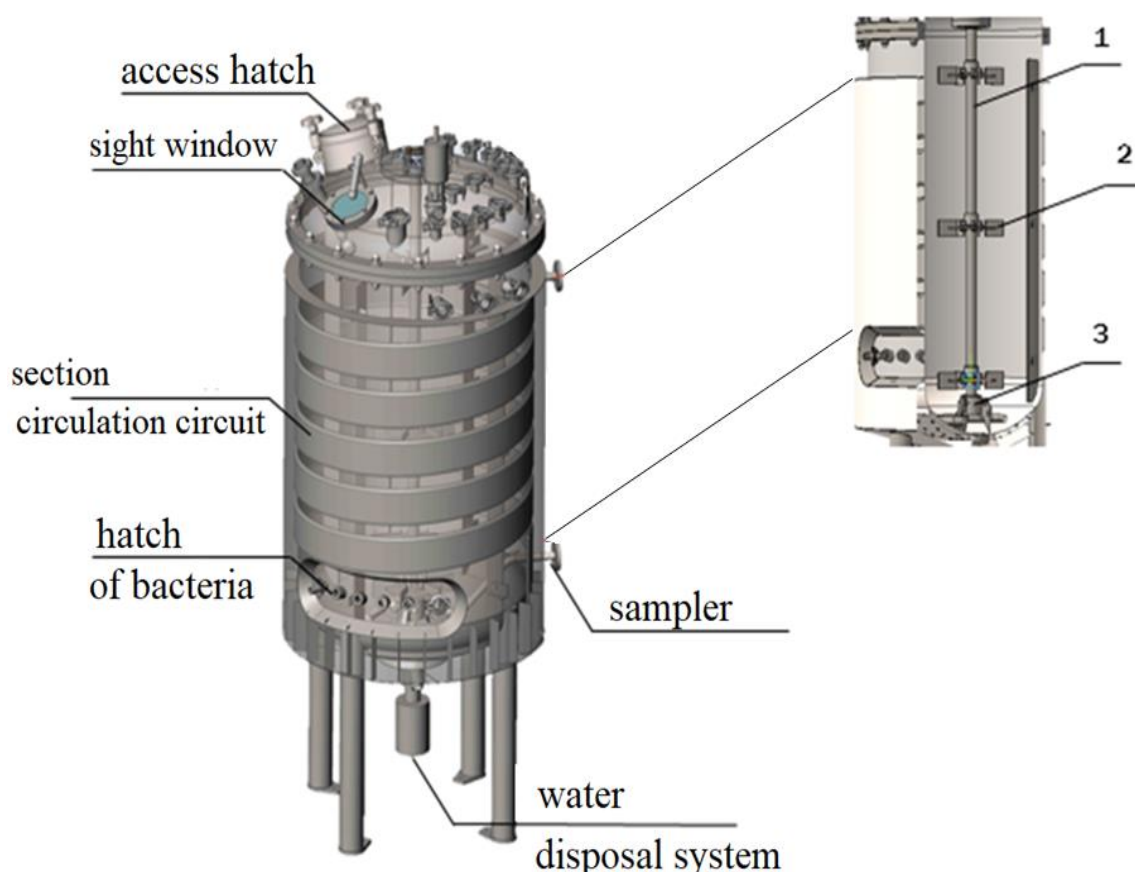


Figure 3. - 3D model installation for the preparation of biosorbents from waste petrochemical industry.

1 - Shaft of agitating mechanical device; 2 - Blade of agitating mechanical device; 3 - operating head of agitating mechanical device.

A comparison was made with analogs.

Analogues among technological installations are:

1 - Fermenter LP351, made in Russia, the company Bioengineering AG.

2 - Fermenter F-250, made in Russia, the company NPG "Priority".

Analogues among patents are:

- 1 - Installation for receiving a biosorbent RU 2012110076;
- 2 - Method of producing a sorbent for cleaning of firm surfaces of oil and liquid oil products RU 2396112;
- 3 - Method of producing a sorbent RU 2362619.

The main a shortcoming in listed analogs:

- 1 - Absence of combined systems of mixing (mechanical and air flow), reducing the efficiency and quality of mixing and fixing oil-oxidizing microorganisms;
- 2 - Absence of a combined thermodynamic parameters control system;
- 3 - Absence of speed regulation system and angular range of mechanical agitator;
- 4 - Absence of a system for the complex preparation of biosorbents;
- 5 - Absence of a system for increasing the adsorption properties of carbon sorbents.

Also assessment of costs of purchase of the equipment has been made by production of one installation for preparation of a biosorbent (Table 4).

Table 4 - Assessment of costs of purchase equipment for production of one installation for preparation of a biosorbent.

Costs of purchase equipment	
Designation	Cost, rub.
Mechanical mixing system (mechanical agitating, rod, electric drive)	23 000
Metal case from stainless steel	31 000
Thermal insulation	7 800
Vacuum pump	6 600
The control system (pressure sensors – 1 pieces, temperature sensor – 4 pieces, the humidity sensor – 2 pieces)	22 000
Metal framework	9 600
Thermal control system	11 000
System of pneumatic mixing	7 400
System of discharge of liquid	7000

Thus, total expenses make 125 400 rubles. At prime cost of the equipment in 125 400 rubles the estimated cost of production will be 520 000 rubles.

4. Conclusion

In the course of the studies, based on theoretical calculations, laboratory studies, analysis of scientific and industrial literature, the following results were obtained:

- A schematic diagram and a method for preparing a carbon-based biosorbent have been developed;
- Parameters for the preparation of biosorbents;
- 3-D model of installation on preparation of a biosorbent.

The developed installation can be used in the field of environmental protection, in particular for production of the biosorbent made from waste of petrochemical production. The biosorbent is intended for elimination of emergency oil spills and oil products.

Thus, the installation is intended for creation of a carbon-based biosorbent.

The installation has to surpass the existing analogs both in a cost index, and efficiency indicators: the adsorptive properties, efficiency of absorption at low temperatures and degree of immobilization of the petrooxidizing bacteria.

Functional purpose: Ensuring technical, physical and chemical parameters for effective preparation of a biosorbent on the basis of waste of a petrochemical complex (thermally processed excess activated sludge).

The developed complex installation will solve the following problems:

- 1 – low degree of immobilization of the existing bases of biosorbents for the petrooxidizing microorganisms;
- 2 – unsatisfactory efficiency of bioremediation of the existing biosorbents;
- 3 – high cost and complexity in operation of the existing technological conveyors on preparation of biosorbents;
- 4 – presence of large volume of secondary waste of a petrochemical complex which are disposed of on specialized grounds, polluting the environment;
- 5 – high cost of services for placement of secondary waste on specialized grounds;
- 6 – large size of the redeemed areas under specialized grounds.

The main direction of further research is the approbation of the obtained biosorbent in commercial conditions in order to identify possible shortcomings of the obtained biosorbent and, if necessary, subsequent design modifications of the installation parameters.

References

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