Prospects for the development of biogas technologies at reservoirs of energy facilities

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Abstract. In connection with the increase in energy prices and the deterioration of the environmental situation, the problem of introducing biogas plants is becoming increasingly important. In this case, the selection of promising raw materials for the production of biogas becomes actual. The organization of energy-biological complexes on cooling reservoirs will allow not only to solve the problem of thermal emissions of power plants, but also to obtain biogas. The article deals in detail with the creation of energy-biological complexes at reservoirs of power engineering objects. Special attention is paid to the use of aquatic vegetation for the production of biogas, as a stage of utilization of excesses of the higher aquatic vegetation of the cooling reservoir of the power station.

Introduction

One of the promising areas of alternative energy is bioenergy. This direction unites ways of reception of energy from a waste, biofuel from plants, use of nonconventional kinds of fuel.

To date, around 60 varieties of biogas technologies are used or are developing in the world, which differ in the composition and preparation of raw materials, the conditions and technological parameters of methanogenesis and the designs of biogas plants. In Europe, the use of biogas systems has found wide application, primarily as one of the ways to solve environmental problems associated with the utilization of agricultural waste, as well as a way of obtaining additional energy and organic fertilizers.

In this case, the use of biogas technologies in the organization of energy-biological complexes on reservoirs of energy facilities, where promising raw material for obtaining biogas is the higher aquatic vegetation.

The relevance of studies of the vegetation of the cooling reservoirs is attached to the importance of their results for solving a number of problems related to ensuring the safety of the operation of power plants. Excessive development of vegetation makes it difficult to operate the cooling reservoir. Floating plants and weakly attached forms, clogging the grids of water intake facilities, can even create an emergency situation in the operation of the technical water supply system of a power plant. Thus, preventing the overgrowing of cooling reservoirs macrophytes allows both to ensure the safety of the operation of power plants, and to obtain a promising fuel for biogas plants.

Energobiological complex on reservoirs of energy facilities

One of the most effective ways of utilizing low-potential waste water is the organization of energy biological complexes (EBC).
The EBC includes a number of mini-enterprises: basin aquaculture enterprises, cooling pond, microbiological production, refrigeration, heating ground, mushroom growing, greenhouse production. Separately, they are self-sufficient, modern, at high level of technology of production. In EBC, the technology of each of them is associated with the use of warm water and with each other in such a way that the final cycle of production of one of them becomes the beginning of the production of the other, thereby achieving an almost complete waste-free and intensified production.

Basin aquaculture - cultivation of aquatic organisms. Aquaculture is currently progressing rapidly in its development - an increase in production of 10% per year for 20 years. The use of warm water for fish breeding is, at present, the most developed way of utilizing the heat taken off, both in our country and abroad [1].

Temperature plays an extremely important role in the life of fish and other aquatic organisms that are related to cold-blooded animals. When growing fish in warm water, the terms of ripening of valuable commercial fish are shortened: sturgeon eggs can be obtained at the age of 4-8 years instead of 12-18 years in natural conditions, and on average the growth process is accelerated 3-4 times or more (up to 10 times). The diverse requirements of fish for optimal temperature regimes make it possible to use practically all the waste cooling water: heat-loving fish (carp, eel, buffalo, etc.) - + 20-30 °C (up to + 35 °C), cold-loving (salmon, trout) 16 °C. The yield of commercial fish from 1 m³ of fish-breeding capacity can reach 40-300 kg depending on the fish species and biotechnology used. Many species of higher aquatic plants and algae, rich in iodine and other useful substances, can also be grown in these conditions.

The cooling pond ensures the reliability of the power plant operation, it can grow numerous highly productive thermophilic fish species - meliorators feeding on zoo- and phytoplankton, detritus (white, bighead, silver carp, grass carp), a number of mollusks for water purification, directional shaping of fodder base allows to increase its biological productivity several times.

Microbiological production is characterized by an exceptionally high rate of accumulation of bioproducts - in single-celled organisms protein synthesis is 1000 times higher than in higher plants, efficiency of use of solar energy for photosynthetic microalgae is up to 5%, and in special installations up to 15-20%, while for higher plants - no higher than 1-1.2%. Among the important, already proven food products are 119 different microalgae from the known more than 34,000 species. Feed yeast, containing up to 30-40% protein with a full set of micro- and macroelements, can be up to 30-40% in the carp's diet, for other fish - slightly less.

Schemes for processing biowaste in biogas were mastered [2]. The main equipment of the biogas plant is a hermetically sealed container with a heat exchanger (Figure 1) (coolant - water, heated to 50-60 °C), devices for input and output of biomass and for gas removal.

Figure 1. Scheme of tank for producing biogas with a conical bell, where 1 - pit with plant raw materials; 2 - the bell; 3 - outlet connection; 4 - a pipeline (hose) of biogas feed; 5 - water sealed channel with water.
The biogas plant is intended for processing of various production wastes for obtaining environmentally friendly organic fertilizers of natural type, energy resources, feed additives, waste utilization. The biogas plant uses the process of methane fermentation. A high degree of conversion of organic matter in waste allows obtaining an increased yield of biogas and liquid sludge. Depending on the raw material, the sludge can be used as ready-to-use fertilizer (manure processing, litter) or high-efficiency feed additives (food industry waste, beer industry) [1, 3, 8-10].

The refrigeration facilities of the energy-biological complex are based on the use of warm water (for obtaining cold) by the adsorption method. Refrigeration plants are used not only to store products, but also in the production process for a short-term change in temperature at a certain point in the cultivation of organisms, creating an optimal temperature regime in a given period, in a particular installation. Heated soil intensifies all soil processes, allows to increase the yield of plants several times.

Mushroom production needs for its purposes heat of a relatively low potential - +16-17 ºC, and only in the production of mycelium - +29 ºC. For substrates can be used waste from many industries, yield of protein with mushrooms is 25-30 times higher than with 1 hectare of the most used arable land. About 40 species of fungi are artificially cultivated. In greenhouse production, the productivity of 1 hectare is 20-30 times higher than the productivity of 1 ha of open ground, in high-rise greenhouses it is hundreds of times higher. The heating of 1 hectare of greenhouse area consumes 1.5-1.8 million m³ of natural gas. At the same time, the optimal temperature for growing plants in greenhouses is +18-35 ºC and even lower (cucumbers and tomatoes +20-21 ºC, flowers +14-16 ºC).

To create such a temperature, coolant with a temperature of +90-70 ºC is used [2].

The constant growth of energy prices places the industry on the brink of existence and encourages to look for new ways of heating greenhouses, layout solutions that would suit both greenhouse production and energetics. Heating high-rise greenhouses can be carried out with the help of dry cooling towers, cascade greenhouse-cooling towers can potentially perform a dual role: serve as a cooling system for waste water from a power plant and act as a greenhouse for growing plants in it.

The biomass of greenhouse plants is a potential reserve, both for microbiological production and for processing by earthworms in fish feeds [1-3, 11]. One ton of organic material is potentially capable of yielding 70 to 100 kg of this protein product.

**Biogas plants**

The leader in the application of biogas technologies is China, where 40 million of small units have been built, with reactor volumes of no more than 10 m³, up to 2020 it is planned to increase their number to 80 million, in India - 4.4 million units, Nepal and South Asian countries - 355 thousand installations. In China, India there are state programs for the introduction of small biogas plants. In Europe, more than 10,000 large biogas plants have been built, Germany leads with 5000 large agricultural biogas plants. In the USA, there are more than 170 large plants with a reactor volume of more than 2000 m³, of which 153 produce electric and thermal energy.

A biogas plant is a closed container in which raw materials are processed (Figure 2). Any organic waste can be used as raw material. The principle of the biogas plant is that after preparation, the raw material is fed to the reactor, where it is processed while maintaining certain conditions. During fermentation, biogas is released, which can be used in various gas appliances. Fermented mass is a highly efficient and environmentally friendly fertilizer [4].

Biogas plants differ in the way of loading raw materials. Batch loading plants are fully loaded with raw materials, and then completely released after a certain processing time. For this type of loading, installations of any design and any type of raw materials are suitable, but such installations are characterized by unstable production of biogas. Continuous loading plants are loaded daily with small amounts of raw materials. When loading new raw materials, an equal portion of the processed sludge is unloaded. Raw materials processed in such plants must be liquid and homogeneous. Gas production is stable and quantitatively exceeds the volume of biogas produced in batch plants. Virtually all
installations under construction in developed countries now operate as continuous load installations [5, 9].

![Biogas plant diagram](image)

**Figure 2.** Biogas plant: 1 – raw material receiver; 2 – water heating boiler; 3 – loading hopper; 4 – reactor; 5 – water seal; 6 – safety valve; 7 – electrocontact manometer; 8 – compressor; 9 – gas stirrer; 10 – receiver; 11 – biofertilizer storage; 12 – branch pipe for loading in transport; 13 – gasholder; 14 – gas reducer.

The amount of biogas produced depends on the type of feed and temperature in the reactor. On average, the output of biogas is 1 - 2 m³/day from 1 m³ of the reactor - 30 m³ from 1 ton of raw materials. The composition of biogas: 60-70% of methane, 30-40% of carbon dioxide. Calorific value: 20-25 MJ/m³, which is equivalent to combustion of: 0.6 liters of gasoline, 0.85 liters of alcohol, 1.7 kg of firewood, or use - 1.4 kW of electricity [3,8].

**Water vegetation of reservoirs of energy facilities as a promising raw material for biogas plants**

In cooling reservoirs of electric stations, higher aquatic plants are actively developing, which disturbs the ecological balance of the reservoir, causes its siltation and shallowing, and can disrupt the operating of power plants. It is advisable to apply the clearing of reservoirs of power engineering objects from higher aquatic vegetation and use this vegetation and bioorganic waste of the blocks of the energy-biological complex as a raw material for producing biogas.

Such higher aquatic plants as *Elodeya Canadian*, hornwort and eichornia can be used as the main element for biofuel production in combination with purification of water of cooling reservoirs [6]. The macrophytes under consideration have high growth rates.

The amount of green biomass per day, ensuring the uninterrupted operation of the biogas reactor, is determined by the production capacity of a particular complex. For intensive plant growth, certain conditions are necessary: water temperature + 24-28 °C, air temperature + 24-28 °C, humidity above 90%, intensive lighting, balanced nutrition and a number of other parameters. In open water bodies, the amount of biomass produced depends on climatic conditions and nutrient medium. In the conditions of the middle and southern strip from one hectare of the water surface per season (four months), several hundred tons of fresh green mass can be obtained. Elodea, hornwort and eichornia are well kept and do not lose their nutritional qualities in dry form, and also in fresh condition in the form of dense rolls wrapped in polyethylene film. This allows growing and storing surpluses of grown green biomass, compensating for the decline in the intensity of growth during the winter season, and also growing them in artificial and natural water bodies in the spring-summer-autumn period in an amount sufficient to ensure year-round operation of biogas complexes [6].

Collected in the pond macrophytes are placed in the chopper, and from there the ground biomass falls into the methantanks. In methane tanks, under the influence of a special preparation, methane
fermentation takes place with the formation of biogas, which is used by the plant for burning and generating electricity. The cost of such electricity is very low, since no special expenses are required to reproduce higher aquatic plants. The main investments are necessary for the construction of the installation, and the costs of its maintenance become current expenses.

The introduction of microorganisms into the reactor occurs only once during the first run. In the future, the addition of microorganisms and additional costs are not needed. At the output there are two main products: biogas and a series of biofertilizers in the form of composted and liquid substrates. For storing biogas, a special tank is used - a gasholder, and from it biogas is continuously supplied to a gas power generator that produces electricity and heat. The fermented mass is actually ready for use biofertilizer.

It is estimated that from 1 ton of biomass of higher aquatic plants, about 500 cubic meters of biogas is produced, with the combustion of 1 cubic meter of which 2 kW of electricity and 2 kW of heat are generated [5].

On the basis of experimental data, we developed a computer program for modeling the operation of a water treatment plant using the higher aquatic vegetation “CLEANING”, which not only makes it possible to evaluate the efficiency of cleaning ("self-cleaning") of aquatic plants in natural flowing water bodies, but also to simulate the volumes of aquatic vegetation for subsequent disposal [7].

Thus, at present, the use of higher water plants in reservoirs of energy facilities as raw material for biogas plants is a promising direction in bioenergy.

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