Livestock enterprises waste utilization for heat system supply to rural buildings in Yakutia

V P Druzyanova1, G E Kokieva2, I A Savvateeva1, N S Khiterkheeva3 and O K Kilchukova4

1 The North-Eastern Federal University named after M.K. Ammosov, st. Belinskogo, h. 58, 677007, Yakutsk, the Republic of Sakha (Yakutia), Russia
2 The Arctic State Agrotechnological University, sh. Sergelyakhskoe 3 km, h. 3, 677007, Yakutsk, the Republic of Sakha (Yakutia), Russia
3 The Buryat State University named after D. Banzarov, st. Smolina, h. 24a, 670000, Ulan-Ude, the Republic of Buryatia, Russia
4 The Kabardino-Balkarian State Agrarian University named after V. M. Kokov, st. Lenina, h. 1v, 360030, Nalchik, Russia

E-mail: druzvar@mail.ru

Abstract. In recent years, interest in issues of using natural energy sources significantly increased due to limited resources of fossil fuels and state missions of environment protection from pollution. One of the main areas of the researches is heating and hot water supply system development for country house using heat pump systems (HPS) based on non-traditional power sources in moderate climate conditions.

Key words: heat pump systems, power sources, solar power plants, manure processing, ground power, livestock farms, resource-saving technologies, mechanization and automation, methane fermentation, water supply, biogas, ecological system.

1. Introduction

In recent years, interest in processes of biogas production significantly increased. It can be seen in increasing number of planned and under-construction biogas plants, and even in increasing number of farmers’ interest, community facilities, businesses, politicians and private households which closely monitor the sector development.

Power industry treats decentralization of production with no caution because of biogas plants construction. Technology of biogas production provides an opportunity for cheap utilization of organic waste and food residues in biogas plants with benefits for agriculture for the food industry, gastronomy, large restaurants, catering establishments and food waste processing enterprises. This technology is gaining great amount supporters among people who has seen its benefits for the environment.

There is a lack of technologies for manure processing in the central Yakutia where nearly 90% of cattle number is concentrated. The manure challenges normal and safe functioning of livestock farms in localities. The lack of technologies for manure processing leads to long-term gathering outside of farms near still water reservoirs that can cause to further heavy pollutions.

Content of nitrates, nitrites, ammonium and phosphates exceeds allowed norms caused by leaked biogenic elements into lakes. Exceedance of nitrates LOK in 110-120 times and phosphates in 70-80
times was noticed in some lakes of the Zarechnyi districts of the Republic of Sakha (Yakutia). Local people use and drink water from those reservoirs with no purification. There is no doubt that manure is the main factor of infections and invasive diseases spreading among people and animals. It is a source of infections spreading through pasture lands and reservoirs.

Solar power, bioenergy, and ground energy can be used as natural sources of low-grade heat. It is relevant to consider the type of power supply of farming region for further selection the most suitable source. The anaerobic technologies for cattle manure processing require special adaptation for profitable implementation in Yakutia according to several significant technical issues.

One of the major factors for optimal flow of microbiological processes in methane tanks is the microorganisms’ residence time in environment (retention time). It is necessary to have enough amount of microorganisms in the substrate; to supply the required residence time in environment for metabolism substrate; to exclude bacteria vanish for complex organic substances decompose to CH4 and CO2.

Therefore, these factors should be decisive when choosing the operation mode of the BEU. Organic substances degradation in methanogenesis conduct as a multi-stage process which requires the participation of at least four groups of microorganisms: hydrolytics, fermenters, acetogens, and methanogens. Methane archaea of the genera Methanosarcina, Methanosaeta (Methanothrix), Methanomicrobium, and others have key roles in organic substances anaerobic degradation to methane.

It is necessary to maintain temperature for normal functioning of anaerobic bio-energetic plant in mesophilic and thermophilic modes. Temperature fluctuations in these modes are immediately reflected in the process indicators. The authors [1-8] note, that as higher the fermentation temperature is, the narrower the CE fluctuations limits are. The admissible variation in a temperature of 38 C is ±2.8 C, and in 53-55 C it is ±0.3 C. Therefore, the modes using will definitely lead to excessive power consumptions required for optimal temperature maintenance in the bioenergy plant’s reactors in conditions of Yakutia.

The humidity of the loaded manure is 90%. Such number of humidity percent leads to good fluidity of manure, reduced storage cost, processing and transportation cost, saving of a clean water and low number of potential environmental pollution possibility percent. Solar plants are widely used in areas in the South of 45° from the North latitude. This zone covers the South of Kazakhstan, republics of Central Asia, the Caucasus and Transcaucasia, regions of Krasnodar and Stavropol and the southern coast of Crimea.

In these regions, the amount of direct solar radiation to the horizontal surface ranges from 1340 to 1850 kW h/m² per year. Annual number of sunshine hours is t=2000...3000h. Introduction of low-waste, resource-saving technologies with mechanic and automatic production processes play an important role in protecting the environment from livestock waste in the conditions of their further development.

Nowadays, there are several ways to utilize the waste of agriculture and off-flow. Methane fermentation with the production of organic fertilizers and biogas is the most promising utilization [1-5]. Utilization of animal waste off-flow with use of biogas plants gives a significant socio-economic effect, expressed in improving working conditions, increasing the culture of production and land use.

2. Goal of the study

Natural animal waste has a great value for agricultural production. Using of animal waste in regions with common livestock husbandry is not particular problem. Livestock husbandry is well developed, in this regard, there is a problem of manure utilization in Yakutia [5-10].

It is a big issue according to great animal number in a limited area and imbalance between livestock and land squares. The goal of the research is to study the utilization technology of animal waste by anaerobic treatment for thermal energy withdrawal.

3. Methods of the study

Manure can be as biomass in conditions of agricultural production. It is rational to consider the manure anaerobic digestion process, which produces biogas to assess the potential energy of the biomass (see table 1).
Table 1 shows that it is possible to save 26.8 million tons of conventional fuel per year due to bioenergy obtained from manure. If we take into account the possibility of obtaining bioenergy from field waste, drain water and household waste, total number increases to 40 million tons. For comparison, we note that the total annual demand of the household sector of the rural population is about 80 million tons of conventional fuel.

| Farm           | Exposure time, day | Organic matter decomposition, % | Energy of produced biogas, mln t of coal equivalent |
|----------------|-------------------|---------------------------------|---------------------------------------------------|
| Cattle breeding| 9                 | 25.9                            | 16.9                                              |
| Pig breeding   | 8                 | 45.9                            | 2.5                                               |
| Hennery        | 43                | 44.0                            | 7.4                                               |
| Total          | -                 | -                               | 26.8                                              |

Thus, bioenergy would be enough to provide 50% of the heat supply to rural residential buildings. It requires about 15 tons of manure per year for 90% heat supply for one rural house.

4. Main part

The ground can be considered as a huge battery of solar power. Moreover, the power "reservoir" temperature is equal to the environment air average annual temperature. It is characterized by the fact that there is a "pumping" of its thermal energy in summer, and it return to the environment in winter.

To assess the natural heat flow quantity \( q \) in summer and winter time, we can assume that at a depth of \( L = 2 \) m the ground temperature approximately matches with the average annual air temperature, and the maximum difference between the average monthly air temperature and the average annual air temperature is \( \Delta t = 15 ^\circ C \). When the thermal conductivity \( \gamma \) is equal to 1.4 W/(m*deg), we get

\[
Q = \frac{\gamma \Delta t}{L} = 10.5 \text{ W/m}^2
\]  

(1)

The analysis of heat supply systems work on the basis of alternative power sources used in our country in the pilot rural buildings showed, that the most promising systems are those, that meet the following requirements: maximum possible reduction of heat loss through the building envelope (improving thermal insulation); the inclusion of heat pump in the heat supply system; ground low-grade thermal power use as a primary source; the use of cheap solar collectors in moderate climate conditions. Figure 1 shows a schematic diagram of an experimental heat supply system for a rural buildings:
Figure 1. Schematic diagram of an experimental heat supply system for a rural buildings.

It must be noted, there are no clear principles of projecting such schemes in accordance with power releasing total cost developed despite many existing heat supply systems based on non-traditional power sources for individual houses. Many buildings are laboratories for optimal solutions searching in the system’s design.

5. Conclusion
To sum up, a rational combination of calculation and experiment allows us to expand the boundaries of research, reduce number of experiments and significantly speed up the work on establishing and enhancement of manure utilization technologies. Thus, the utilization of livestock cattle liquid manure contributes to the establishment of an additional source of fuel as biogas.

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