Using of the complex mobile station for heat and energy supply of residential villages, located on the protected areas

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Abstract. The results of studies of a complex mobile station for life support systems are presented. This station has the electric energy and thermal energy production functions, so as wastewater treatment and drinking water preparation. The production of electrical energy occurs through the conversion of solar energy and the use of microbial fuel cells. Thermal energy for the hot water system is obtained using solar collectors. A wastewater treatment plant is proposed based. The required number of complex mobile stations for life support systems, namely for wastewater treatment and hot water supply of the sports and recreation camp «Polytechnic», which is located at 17 km of the Baikal Highway, has been calculated. The calculations took into account the number of residents per season, water consumption and wastewater rate, the geographic location of the camp, the average number of cloudy days in the area and the number of sunny hours. The developed complex mobile station will ensure energy supply and disposal of wastewater from facilities located in recreational and protected areas without environmental consequences and violation of environmental and sanitary requirements. At the same time, the installation can be used on various types of objects.

1. Introduction
The Baikal Natural Territory is the recreational area and also it is the main object in Eastern Siberia for research and application of high-tech, environmental and energy-saving technologies.

Development of the infrastructure of the Baikal Natural Territory is necessary because of the presence of residential villages and the development of its tourism potential, however, there are many problems with energy supply and wastewater disposal in protected areas, associated with increased environmental requirements and restrictions. Using of traditional energy technologies and treatment plants often has environmental consequences, therefore, a number of restrictions existing in protected areas greatly complicate the energy supply and disposal of wastewater from residential areas in these territories. Not to mention the villages located along the Baikal Highway (the route from Irkutsk to Listvyanka), which belongs to the water protection zone due to the presence of the Irkutsk water intake downstream of the Angara river.

The use of renewable energy sources [1-14] can solve many of the above problems, but even they alone cannot solve the problems of mobility and dependence on external factors [15-17]. The complex mobile station, at the Irkutsk National Research Technical University (INRTU), can help to solve such difficulties [18].

2. Complex mobile station
The developed power plant allows to provide hot water supply, electricity supply and wastewater treatment of individual houses, residential villages and tourist camps, even located in water protection zones, recreational and protected areas. The use of renewable energy sources will make it possible to obtain environmentally friendly generation of heat and electricity, as well as provide wastewater treatment, that meets the requirements of protected areas.

The station may consist of a various equipment combination, which depends on the requirements of the end user, on the environmental conditions of the location zone of the customers, on the environmental and sanitary requirements applied to the customers, as well as on available energy sources. It can consist of solar collectors and panels, wind generators, a heat pump, microbial fuel cells, a water treatment and wastewater utilization plants, and even a diesel or gasoline generator.

The station has a modern automation system that provides the effective interaction of all engineering systems used in it, as well as full monitoring and dispatching.

3. Using of the energy station on the protected area

To test the complex mobile station, it was decided to use the territory of the Irkutsk National Research Technical University. INRTU has at its disposal a sports and recreation camp "Polytechnic", which is located at 17 km of the Baikal Highway. The camp has all the conditions for a good rest: summer houses, a club, a gym, a football field, volleyball and basketball courts, a cross-country track. The camp is ready for children, the necessary sanitary standards have been met, the area has been treated with anti-mite drugs. There is a shower near the football field.

Since the "Polytechnic" camp is located in the protected area, and the Central Irkutsk water intake is located downstream of the Angara river, there is no centralized disposal of sewage in the camp, electricity is supplied from the general electricity network running along the Baikal Highway, the camp is supplied with water, and hot water is provided by electric heaters. Given all the above circumstances, it was decided to develop a power station that works exclusively from renewable energy sources, which will reduce energy costs and ensure environmentally friendly wastewater disposal.

The lack of the necessary wind power in the available area makes it impossible to use wind generators. Due to the fact that the camp operates exclusively in the summer, the use of heat pumps is also impractical. As a result, it was decided to use the combination of systems shown in Figure 1 [19-26].

![Figure 1. Mobile station of life support systems for recreational areas, consisting of 7 cells.](image-url)
The complex mobile station for life support systems can be placed between the showers and canteen. This place is located near the road, that's why it will be easy to operate and drive up the equipment.

About 300 students and another 30 children of employees will stay in the camp for three arrivals. The average number of people per arrival will be 115 people, including employees.

Water consumption per person is taken 60 l per day (including 25.5 l per day of hot water), in accordance with the regulatory documentation of the Russian Federation. The flow rate of cold and hot water was calculated according to formulas (1) and (2), respectively:

\[
Q_{1} = \frac{q_{1} \cdot m}{1000} = \frac{34.5 \cdot 115}{1000} = 3.97 \text{ m}^3/\text{day} \tag{1}
\]

\[
Q_{2} = \frac{q_{2} \cdot m}{1000} = \frac{25.5 \cdot 115}{1000} = 2.93 \text{ m}^3/\text{day} \tag{2}
\]

\(q_{1}, q_{2}\) - water consumption /wastewater level per person for cold water and hot water;
\(m\) – number of people.

In winter, the calculation was performed according to formulas (3) and (4), respectively:

\[
Q_{1} = \frac{q_{1} \cdot m}{1000} = \frac{34.5 \cdot 30}{1000} = 1.04 \text{ m}^3/\text{day} \tag{3}
\]

\[
Q_{2} = \frac{q_{2} \cdot m}{1000} = \frac{25.5 \cdot 30}{1000} = 0.77 \text{ m}^3/\text{day} \tag{4}
\]

The calculation of the number of installations is carried out according to the summer period, since during this period the maximum water consumption occurs. One installation has a capacity of 5 kW, which allows to treat 4 m\(^3\) of waste water per day. Then, 2 installations are required for treatment, 6.9 m\(^3\) per day.

For to calculate the required number of solar collectors for 115 people per race, it will be needed to take into account a number of amendments, such as: the number of cloudy days per month and the average monthly length of a sunny day. The season in the camp lasts for 3 months. The calculations used the flat solar collector SUN 1 [27], developed and patented at INRTU. In the future, these installations will also use SUN 3 solar collectors [28].

The calculation results are shown in table 1.

### Table 1. The results of calculating the required number of solar collectors

| Month                      | June  | July  | August | Total  |
|----------------------------|-------|-------|--------|--------|
| Duration of month, days    | 30    | 31    | 31     | 92     |
| Monthly average solar energy values falling on an optimally oriented surface, kW\(\cdot\)h/m\(^2\)\cdot\)day | 5.4   | 4.7   | 4.31   | 4.80   |
| Amount of cloudy days      | 8.1   | 11.1  | 9.5    | 28.7   |
| Average sunny day duration, hours | 8.8   | 7.8   | 7      | 7.9    |
| The total value of solar energy per month, kW\(\cdot\)h/m\(^2\) | 118.26| 93.53 | 92.67  | 304.05 |
| The average hourly value of solar energy per month, kW\(\cdot\)h/m\(^2\) | 0.61  | 0.60  | 0.62   | 0.61   |
| Hot water consumption per hour, l/hour | 122.19| 122.19| 122.19 | 122.19 |
| Daily hot water consumption, l/day | 2 932.50 | 2 932.50 | 2 932.50 | 2 932.50 |
| Daily heat load on hot water supply, kW/day | 126.10 | 126.10 | 126.10 | 126.10 |
One station can contain from 2 to 10 solar collectors, depending on the configuration. For "Polytechnic" camp, the optimal number of solar collectors per installation is 6. It will increase the number of equipment for generating electricity in the station, such as microbial fuel cells and solar panels. Thus, for the wastewater treatment and heating water, 4 mobile stations will be needed.

4. General conclusions
As a result of research, a complex mobile energy station was developed. It additionally purifies wastewater to an utilization quality based on patented energy-efficient wastewater treatment technologies. It was accounted the number of facilities for the camp "Polytechnic" of INRTU, which is located on protected area, where there are more stringent requirements for engineering systems mounting. The station is an autonomous system, that provides power for two-three-phase alternating current and heat supply for objects using wind, solar and internal combustion engines. In addition to major renewable energy sources, such as the sun and wind, the use of microbial fuel cells is contemplated.

A distinctive features of the station are to increase the reliability and quality of energy supply, reduce fuel consumption when using a diesel or gasoline generator set by optimizing its operation in the system, increase the efficiency of the system by controlling the operation mode of a complex mobile energy station using an automatic control system.

| Required solar collectors performance, kW/h | 14.33 | 16.17 | 18.01 | 16.03 |
|---------------------------------------------|-------|-------|-------|-------|
| The average monthly SUN 1 solar collector performance, kW/h | 0.75  | 0.74  | 0.75  | 0.74  |
| Required number of SUN 1 solar collectors | 19    | 22    | 24    | 22    |

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