From the experience of utilization of sewage heat in Hostel

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Abstract. This research paper explores the feasibility of utilizing heat from sewage effluent to heat the drying room in student hostel No. 2 of the State Energy Institute of Turkmenistan. Temperature measurements revealed that sewage water typically ranges around 29.5 °C. While initial measurements indicated that drainage from the washing machine, reaching 36.5 °C, held limited potential for space heating due to low overall thermal capacity, the authors investigated the possibility of reusing this thermal energy. The study found that preheating water in a heat exchanger using the washing machine discharge (36.5 °C) resulted in a reduction of 0.065 kWh of electrical energy consumption over a 60-minute operation.

1 Introduction

Sewage discharged into the sewerage system carries a significant amount of heat energy. The issue of efficient utilization of sewage heat deserves the closest attention [1]. To this end, the "State Energy Saving Programme for 2018-2024" was adopted in Turkmenistan on 21 February 2018. The program envisages measures aimed at reducing energy consumption to reduce harmful emissions into the environment. Within the framework of this program, action is planned to prepare and implement a project on the use of sewage heat in residential buildings and administrative buildings (due 2020-2024) [2].

1.1 Problem Statement

Space heating and cooling and hot water supply account for the largest share of energy in residential buildings and student hostels [3]. Hot water in buildings is used in a variety of ways, including showers, bathtubs, sinks, dishwashers, and washing machines. In almost all cases, sewage retains a significant portion of its original energy that can be recovered and used every day, and warm water discharged from washing machines requires the most careful attention to reuse.

The objectives of this research work are:

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- Utilization of sewage water heat for heating the drying room of Hostel No. 2 of the State Energy Institute of Turkmenistan.
- Use of discharged hot water from the washing machine for water heating for water reuse.

The object of the study is sewage and hot water discharged from a washing machine.

1.2 Literature review

It is important to note that the energy performance of buildings has significantly improved in recent years, with advancements in energy consumption patterns, energy efficiency, and construction materials used. New buildings and structures are even being issued with so-called "Green Certificates" to recognize their sustainability efforts. However, past building designs primarily focused on achieving optimal temperature, humidity, air conditioning, and other indoor comfort criteria, often neglecting other aspects related to water efficiency or reuse [4].

In a study [5], the authors cited the results of work carried out in Switzerland and found that 15% of the thermal energy supplied to buildings is lost through the sewerage system.

The work presented in [6] is particularly interesting, in which the study explored the feasibility of utilizing heat from sewage systems in Slovakia, both within and outside buildings. The methodology involved modeling energy flows in various recovery systems and conducting experimental measurements of small heat exchanger systems designed for preheating hot water in buildings.

In the paper [7] the issues of optimization of sewage heat exchangers and economic efficiency of use are considered. The utilized heat energy was used for heating, cooling, and also for hot water supply. A positive economic effect is provided in the example of an administrative building.

In [8], about 200 sewage heat exchangers were modeled and then simulated with different materials and under different boundary conditions using CalA software. The best results were obtained for the type 1 heat exchanger. This sewage heat exchanger achieves a power of about 2.2 kW per 1-meter length at an average annual temperature for all selected materials.

1.3 Positioning is a task

To study the possibility of evaluating the energy reserves of sewage within the scope of scientific research, the temperature of sewage was measured by specialized sensors from December 1, 2022, to January 31, 2024, and their results are shown in Figures 1 and 2 below.

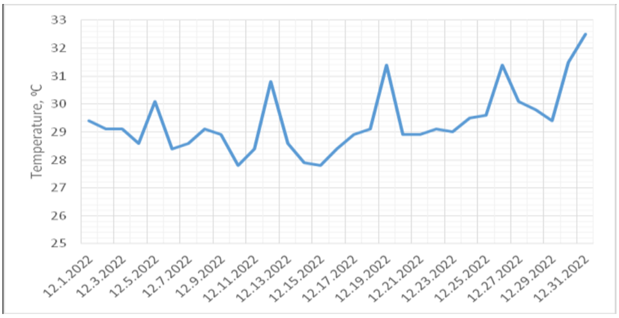


Fig. 1. The average sewage temperature in December, 2022.

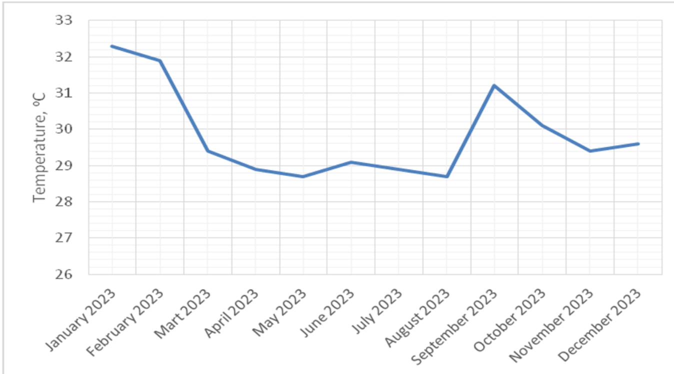


Fig. 2. The average sewage temperature in the 2023.

As can be seen from the links, the temperature of the sewage is between 27.5 and 32.5 °C, and it has a maximum value on Sundays of the week.

2 Materials and methods

The amount of heat energy used for heating water for hot water supply needs is 20-25 % of the total energy consumption in a residential apartment building. Most of the load is for heating water for bathing or showering. For hygienic procedures, a person needs only 1/10th of the water used in the shower. Consequently, about 90 % of the warm water supplied to the shower mixer is discharged unused into the sewer system [9].

The system design starts with the determination of the inlet (T_i) and outlet (T_u) temperatures and the water flow rate (V_F). The heat power transferred from the sewage (Q_F) through the heat exchanger to the heat transfer medium is determined by the heat balance equation [10]:

$$Q_F=\Delta T_W \cdot C_p \cdot \rho_w \cdot V_F \quad (1)$$

Where ΔT_W- Temperature difference, K; C_p- specific heat capacity as 4.186 [kJ/kg°K]; ρ_w- density [as 1 kg/l]; V_F- pump performance, (performance pumping Wilo Star-RS 25/6-130-RK-3600 l/h) [11]

The sewage temperature can be calculated using formula (2), in which the mass and temperature of the hot and cold water consumed are substituted:

$$t_{tm}=\frac{t_c \cdot m_c + t_h \cdot m_h}{m_c + m_h} \quad (2)$$

Where: t_c - cold water temperature equal to 15 °C, t_h - hot water temperature equal to 55 °C, m_c - mass of cold water effluent, kg; m_h - mass of hot water effluent, kg.

Making measurements of water consumption in the hostel is not possible due to the lack of meters, so we will use the building codes SNiP (Building code) 2.04.01-85 * [12], wherein Annex 3 is the norms of water consumption by consumers (Table 1).

Table 1. Water consumption standards.

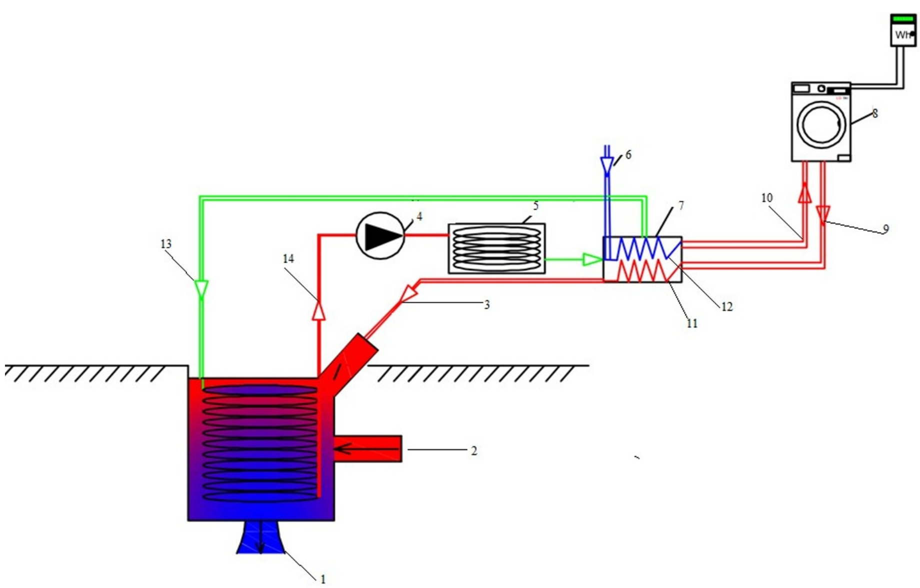
Object	Indicator	Water consumption rate, liters						Calculated water consumption l/s (l/h)	
		On average per day		On the day of the highest water consumption		On the hour of the highest water consumption			
		Total (including hot)	Hot	Total (including hot)	Hot	Total (including hot)	Hot	Total (cold and hot)	Cold or hot
Hostels with showers in all living rooms	per person	110	60	120	70	12.5	8.2	0.12-0.2 (100)	0.14 (60)
Hostels No. 2 with showers in all living rooms	For 200 students	28600	15600	31200	18200	3250	2132	156 (26000)	36.4 (15600)

Data on the consumption of hot and cold water in Hostel No. 2 of the State Energy Institute of Turkmenistan, calculated for 260 places, were taken for calculations.

3 Results and Discussion

So, in the hostel, where 260 students live, 28,600 l of water is consumed on average per day, of which 15,600 l/h is hot, with a temperature of about 32-37 °C.

To use the heat of the sewerage, a scheme was assembled, which is shown in Figure 3.



1- main sewage line, 2- sewage from other buildings, 3- sewage from the 2nd hostel, 4- pump, 5- battery for heat supply, 6- pipe of tap water, 7- tank with a volume of 100 liters, 8- washing machine, 9- sewage from the washing machine, 10- he ated water going to the washing machine, 11-12- heat exchanger, 13-14- pipelines for circulating water entering and leaving the heat exchanger in the well.

Fig. 3. Diagram of the structures that allow to use of the heat of sewage water.

3.1 Experiment #1. Using the heat of sewage water to heat the drying room

In the set of devices, water (1) with a temperature of 15 °C goes to the heat exchanger installed in the sewage well and absorbs the heat of the sewage, passes through the pipe (14) through the pump (4) to the battery (5) and cools the water to a certain level. Then it goes to the expansion tank (7) with a volume of 100 l, and from the tank through pipes (13) to the heat exchanger again. And so the incident repeats itself. In the research, the temperatures of the sewage, the battery, and the water in the tank were measured and the relationship shown in Figure 4 below was obtained.

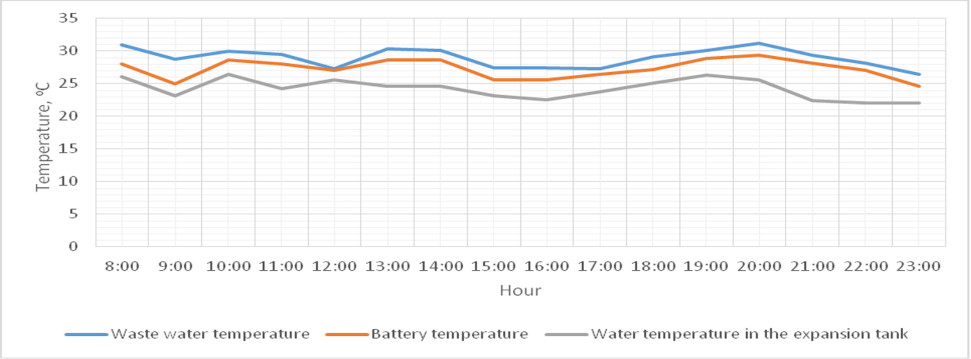


Fig. 4. Time dependence of tap water, battery, and expansion tank water temperatures.

As can be seen from the link, the temperature of the sewage is between 27-31 °C, which is lower than that of the sewage due to the heat losses of the water in the battery and the expansion tank to the environment. The average temperature of the battery is between 24-28 °C, the amount of energy received is shown in Figure 5 below.

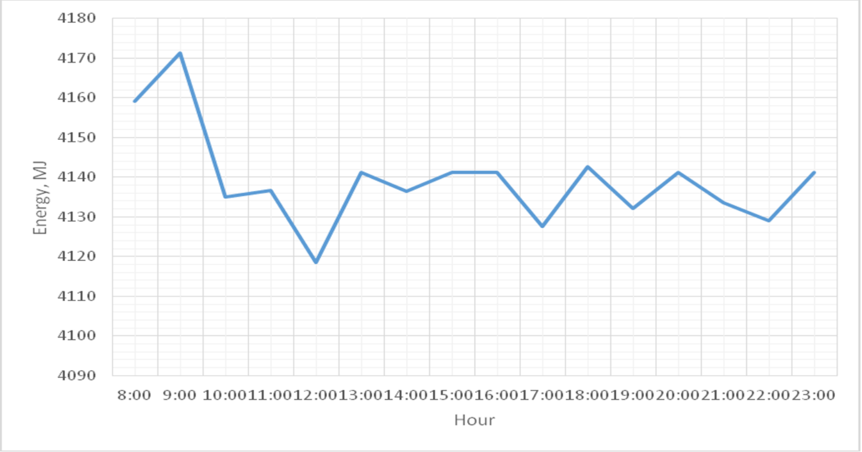


Fig. 5. Graph of the dependence of the received energy supplied to the battery due to wastewater heat versus time.

As can be seen from the relationship in Figure 5, morning peaks in water consumption, wastewater temperatures are high, indicating that the possibility of use in the heating system is low.

3.2 Experiment #2. Using sewage water heat to preheat washing machine water

Water from the cold water system comes to the washing machines at a temperature of 15 °C and is heated to the required temperature by an electric heater installed in the washing machine. In this case, electricity is used to heat the water. Therefore, two heat exchangers (11,12) were installed inside the expansion tank to use the heat of the water with a temperature of 22.1-26.3 °C in the expansion tank (7). The 15 °C water in the pipe leading to the washing machine passes through the heat exchanger (12), heats it, and goes to the washing machine (8). The sewage water leaving the washing machine at an average temperature of 60 °C passes through the heat exchanger in the expansion tank (11) and transfers its heat to the water inside it and the water entering the washing machine through the heat exchanger (12). Therefore, the temperature of the water going to the washing machine increases from 15 °C to 26 °C due to the temperature of the water in the tank.

Table 2. Experiment results.

	Washing mode	**Time, *min***	**Water temperature during washing, *°C***	**Water consumption, Liter**	**Temperature of inlet water *°C***	**Consumed electrical energy, kW·h**
1st washing machine	Active	60	60	35	26	0.16
2nd washing machine	Active	60	60	35	15	0.2

3.3 Experiment #3. Using the heat from the sewage from the washing machine to heat water for consumption

So, the temperature of the water going into the washing machine to rewash the clothes is 36 °C instead of 26 °C. This, in turn, made it possible to save electricity used for heating water. To confirm the above, two LG Direct Drive (6 kg) [12] washing machines installed in the laundry room on the first floor of the 2nd hostel of the State Energy Institute of Turkmenistan were set up with the same operating modes and experimented and studies were conducted (Table 3).

Table 3. Experiment results.

	Washing mode	**Time, *min***	**Water temperature during washing, *°C***	**Water consumption, Liter**	**Temperature of inlet water *°C***	**Consumed electrical energy, kW·h**
1st washing machine	Active	60	60	35	36	0.135
2nd washing machine	Active	60	60	35	15	0.2

As can be seen from the table, supplying the washing machine with water preheated to 22-36 °C will save an average of 0.065 kW·h of electricity every time (every 60 minutes).

4 Conclusion

As the temperature of sewage water is a low-potential energy source, it was found that the possibility of using it in the heat supply system of houses and buildings is low (the average temperature of batteries is 27 °C).

It allows to save 0.04 kWh of electricity when the water in the washing machines is heated due to the heat of the sewage water.

When the water going to the washing machines is heated due to the heat of the high-temperature (about 60 °C) water coming out of it, it allows to save 0.065 kWh of electricity.

It is suggested to use the above-mentioned set of devices in specialized enterprises that use low-potential heat to obtain water with a temperature of 22-36 °C using the heat of sewage.

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