University of Banja Luka
Faculty of Mechanical Engineering

DEMI 2017

13th International Conference on Accomplishments in Mechanical and Industrial Engineering

BOOK OF PROCEEDINGS

Banja Luka, 26 - 27 May 2017

University of Banja Luka
Faculty of Mechanical Engineering

PROCEEDINGS

Banja Luka, May 2017

Print:
Grafomark, Laktaši

Circulation:
200

ISBN:

CIP - Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

13TH INTERNATIONAL CONFERENCE ON ACCOMPLISHMENTS IN MECHANICAL AND INDUSTRIAL ENGINEERING

Supported by:
MINISTRY OF SCIENCE AND TECHNOLOGY OF
THE REPUBLIC OF SRPSKA

Organizer and publisher:
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POSSIBILITY OF USE HEAT ENERGY FROM WASTE WATER SEWAGE SYSTEM FOR HEATING OF BUILDINGS

Veselin Blagojević[1], Vanja Šušteršič[2]

Summary: *This paper presents the initial research on the possibility of using energy from the sewage. The analysis presented in the paper aims to show how the system of waste water in buildings reject energy, which can be re-used to heat hot water and buildings. Waste water from toilets, washing machines, showers and kitchen has a certain thermal energy which can be used in heating systems with heat pumps. The waste water can be used via heat exchangers to increase the coefficient of efficiency of the heat pump COP. In this way it is possible to achieve substantial savings of energy required for heating. The analysis was conducted for the City of Doboj, Bosnia and Herzegovina.*
Key words*: Energy, sewage water, sewage sludge, heat pump.*

1 INTRODUCTION

The implementation of the concept of energy efficiency in buildings never completely will not be realized, unless they consider every aspect during construction. The zero energy house never completely will not be achieved until done a full analysis of the application of exergy. Exergy is a part of the energy that can be transformed into work, ie. The return process Exergy remains constant. The heating of buildings has become a major problem when it comes to energy use, energy and environmental pollution. One area that deserves the most attention is the hot water consumption and recovery systems waste air. The latest survey in the US shows that the production of hot water represents 17% of total energy consumption [1]. The energy potential is possible to use the system waste sewage and sewage sludge, while in this paper is primarily given to the possibilities of utilization of waste heat. Initially it was necessary to make an analysis and model with real annual data on the use of hot water. After that analysis is necessary to focus on short time intervals, which appears high temperature waste water. In these time intervals return energy to work exchanger is maximum. This system of energy recovery can best function integrated into the system with a heat pump.

[1] MSc Veselin Blagojević, Faculty of Engineering, University Kragujevac, Sestre Janjić 6, 34000 Kragujevac, Serbia,e-mail:veso.doboj@gmail.com
[2] dr Vanja Šušteršič, Faculty of Engineering, University Kragujevac, Sestre Janjić 6, 34000 Kragujevac, Serbia, e-mail: vanjas@kg.ac.rs

2 WASTEWATER HEAT RECOVERY

In the olden times people have practiced the treatment of sewage sludge (faecal matter and urine), but it was not a safe way. The development of cities have emerged large quantities of sewage sludge and waste, and the people began to use them as organic and mineral fertilizers in gardens for growing vegetables. Urine is used as a source koncetrovanog ammonia. What was not provided for the possibility of infection, since each gram of fecal matter from a sick person can hold several thousand infected bacteria and the contact with them can threaten human health. By using medicines, care products and pesticides that risk is further increased. However waste water are still not used a great resource. Wastewater has great energy potential which according to some calculations is 80-85 euros for devices annually under the terms of the EU, or about 1 euro per m3 of treated water. Previous studies have shown that the average temperature of the waste water of 17.5 °C [2].

Approach to the modeling has begun analyzing the necessary quantities of drinking water. The data used for the simulation are usually obtained from statistical data. Modeling includes an analysis of the data by population, age, sex, type of housing and the area in which it is located. The energy potential of the waste water should start by analyzing the use of water consumption in the kitchen, toilet, shower, bathtub, washing machines and dishwashers in use and out of use. Water used in addition valve is considered as a waste water.

It is important to note that the biggest problem with the use of sewage water for the effect of the chemical composition and aggressive substances in the heat. That is why when designing the system needs to perform a chemical analysis of waste water, and based on the results predicted filtering system. During filtration, the heat loss can be expected from the waste water.

3 ENERGY ANALYSIS OF DOBOJ MUNICIPALITY

In this paper are presented data on the analysis of the possible use of energy from waste water in the area of Doboj in Bosnia and Herzegovina.

The area of Doboj is located in the northern part of Bosnia and Herzegovina. It is located along the river Bosnia, Spreča and Usora area about 653 square kilometers.

According to preliminary results of the census of population, households and apartments in BiH in 2013 in the town of Doboj live 69,343 inhabitants, which makes 5.23% of the total population of the Republic of Serbian, or 1.83% of the total population of Bosnia and Herzegovina. Of these 42,356 inhabitants or 61.08% live in rural and 26,987 inhabitants or 38.92% live in urban areas [3].

In the area of Doboj vodosadbijevanje is done with two pumping stations (C.S.Luke and C.S.Rudanka). Data on water supply and available quantities of waste water are given in the table 1.

Table 1 *Analysis of the consumption of water for the town of Doboj in the last 9 years*

Year	*C.S.Luke (m^3)*	*C.S.Rudanka (m^3)*	*Total production (m^3)*	*l/s*
2008	*1.972.810*	*1.426.164*	*3.398.974*	*107,78*
2009	*2.027.693*	*1.402.313*	*3.430.006*	*100,76*
2010	*2.136.193*	*875.339*	*3.011.532*	*95,50*
2011	*2.014.730*	*910.980*	*2.925.710*	*92,52*
2012	*1.823.691*	*1.054.737*	*2.878.428*	*90,96*
2013	*1.828.081*	*1.041.406*	*2.869.487*	*90,99*
2014	*1.595.625*	*1.018.916*	*2.614.541*	*82,91*
2015	*1.775.721*	*1.164.523*	*2.940.244*	*93,23*
2016	*1.708.503*	*1.053.978*	*2.762.481*	*87,36*
Total	***16.883.047***	***9.948.356***	***26.831.403***	***93,56***
%	*62,92%*	*37,08%*	*100,00%*	

Based on the previous analysis, we can conclude that the consumption of water fairly consistent for the period 2008 to 2016. The average annual consumption for the city of Doboj that it supplies through the public network is 2,981,267 m^3 per year. Due to the sparsely populated and remote rural areas there is no water supply via the city network, we can accurately calculate how much water consumption or the amount of waste water by population. Therefore it can be concluded that the per capita water consumption ≈ 43 m^3 per year. Based on the estimation of the energy potential of waste water in the EU can be concluded that the potential annual per capita is approximately equal to 43 euros [4].

The second part of the analysis refers to the measurement of temperature in the sewage system and waste water management, as well as the temperature of soil and air. The measurements were made using the Data Logger's brand Elitech, accuracy class ± 0.5 °C and control measurements were carried out using a thermal imaging camera brand Flir E4, and thermal imagers Fluke Ti100 Thermal Imager class accuracy +/- 2% or 2 °C. Results are given in Table 2.

Table 2 *Results of measuring the temperature of waste water, soil and air*

Month	*Outdoor temp. 2015/2016*	*Outdoor temp. perennial*	*Ground temperature*	*Waste water temperature*
October	11.41	10.91	11.94	21.44
November	6.88	7.07	8.01	17.01
December	0.76	0.98	4.91	12.61
January	1.06	-0.56	3.31	12.13
February	6.79	1.38	3.78	12.78
March	7.84	6.60	5.87	16.87
April	14.90	10.70	8.20	21.84

Since the aim of the research the possibility of utilization of energy from waste water for heating, analysis was carried out for the duration of the heating season (October to April). Control measurements were made from 2014 to 2017, while precise figures given for the heating period 2015/2016. season. The obvious fact is that the influence of the outside temperature on the soil temperature and the temperature of wastewater large. In proportion to the decrease and increase in temperature. Temperature diagram waste water is higher than the other, which gives a clear picture of the energy potential of waste water. In order to optimize the system and maximize it is necessary to monitor the temperature on a daily basis. Figure 1 shows the results of a random sample temperature of waste water. Temperature variations during the day as a direct result of the use of devices and user habits.

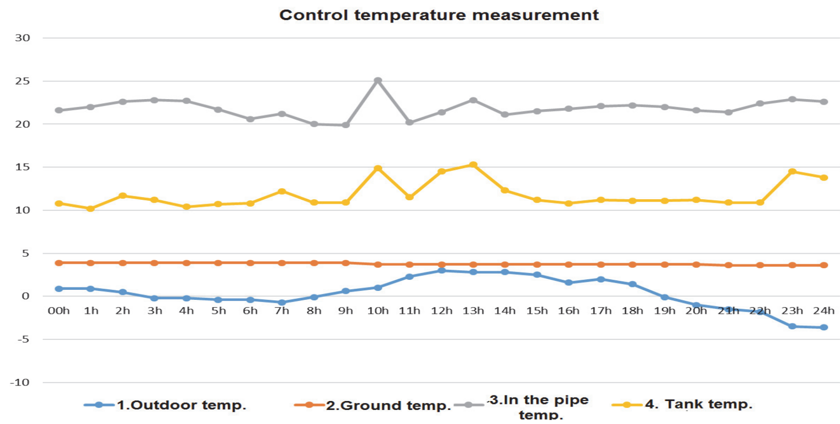

Fig. 1 *Control measurements on a daily basis*

In order to use the thermal energy of waste water, adopts the system with a heat pump, (eng. Wastewater source heat pump, part WWSHP). Energy Efficiency Ratio for WWSHP can be obtained via the following form:

$$COP_{heating} = \frac{Q_{\ hot}}{W_{comp,elect}}$$

where Q_{hot} the amount of heat the heated volume and Wcomp, elect the power consumption of compressors. Furthermore, for WWSHP the theoretical maximum efficiency (Carnot efficiency) can be expressed as:

$$COP_{carnot,heating} = \frac{T_{\ hot}}{T_{\ hot} - T_{\ cold}}$$

where are they T_{cold} i T_{hot} the temperature on the evaporator and condenser. In addition, COP_{Carnot} shows the potential for utilization of heat pumps in percentages:

$$\%COP_{carnot} = \frac{COP}{COP_{carnot}} X\ 100$$

Results of the energy interaction potential of waste water for the city of Doboj, based on previous patterns are shown in Table 3.

Table 3 *Energetic efficiency coefficient for WWSHP for heating season [4]*

Wastewater Source HP- Heating season							
	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Evaporation Temperature (°C)	21.44	17.01	12.61	12.13	12.78	16.87	21.84
Condensing Temperature (°C)	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Evaporator Capacity (kW)	4.15	4.15	4.15	4.15	4.15	4.15	4.15
Condenser Capacity (kW)	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Compressor Capacity (kW)	0.67	0.67	0.67	0.67	0.67	0.67	0.67
$COP_{heating}$	6.19	6.19	6.19	6.19	6.19	6.19	6.19
COP_{Carnot}	16.87	13.62	11.43	11.26	11.50	13.53	17.16
% COP_{Carnot}	36.69	45.44	54.15	54.97	53.82	45.75	36.07

Calculation of COP in the above table is made on the assumption of using heat pumps for low-power, installed on the micro location. The assumption is that heat pump capacity of about 5 kW can meet the needs of a family home. The amount of potential energy from waste water for each case must be analyzed separately. Below will be the energy potential of the area around the town of Doboj.

Designing the system starts by setting WWSHP inlet temperature (T_I) and at the output (T_U) in the system and the fluid flow rate (V_F). The problem consists in the selection of the appropriate heat exchanger and its dimensioning. Thermal power transferred from the waste water (Q_F) through a heat exchanger for liquid fluid is determined using the equation for thermal balance:

$$Q_F = \Delta Tw * \ Cw * \rho w * V_F$$

gdje je: Q_F – thermal power [kW], ΔT_w – temperature drop [°K], C_w – specific heat capacity as 4186 [KJ/ KG °K], ρ_w – density [as 1 kg/l], V_F - flow rate [l/s].

The above formulas shows that the increase in available capacity should increase the flow of fluids or below the temperature drop. In this case, the applied method that was previously done for the city of Bologna in Italy, where water consumption is around 2 l / s (average flow generated 800-1000 inhabitants). This consumption is approximately equal to the consumption of water in the town of Doboj. If water enters the exchanger at a temperature of 16.4 °C (the average temperature of the waste water during the heating season), and if out of the exchanger at a temperature of 8 °C, the temperature drop will be equal to 8.4 °C. Average perennial water consumption in Doboj is 93.56 l / s. Potential energy from waste water based on the above formula for the town of Doboj is approximately 3.29 MW. Potential energy from waste water for the heating season of 183 days is approximately 14.45 GWh [5].

4 CONCLUSION

This paper analyzes the possibility of the use of waste energy from the sewage system in Doboj. The need for thermal energy for heating the building is great. Energy efficiency measures in buildings include improved insulation of buildings and use of renewable sources of energy. Waste water from the building can be used in a system with a heat pump for heating buildings. Measurements taken in the area of Doboj showed great energy potential of the sewage system. Measurements have shown that during the heating season, the highest temperature of the waste water. For example, the average temperature of the waste water in January was 12.13 °C, while the temperature of the soil 3.31 °C, and the air temperature is 1.06 °C. The budget also showed that the COP_{Carnot} in January 11.26 and 17.16 in April. With years of measurements of water consumption, the budget also showed that the energy potential of waste water for the town of Doboj is approximately equal to 3.29 MW, while the potential energy savings for the heating season is approximately 14.45 GWh.

Varying the COP and utilization of potential energy depends on the length of the sewerage network and the flow rate, so that the greatest potential possible with the installation of smaller plants in the city. The great problem is the chemical composition of the waste water and the impact of the heat. Because of this problem is necessary to use the systems for wastewater treatment and storage. Storage of water in the reservoirs would provide a constant temperature on the exchanger. Conducted a lot of research on the few examples in the world where the results approximately coincide with the data obtained from Doboj. This study can serve as a starting point for the possibility of utilization of energy from waste water and sewage. There is a possibility of deviation of the data obtained with other research, due to various conditions such as the number of users, user habits and so on. For this reason, with the possible installation of such a system was necessary to conduct a survey of the relevant site by this model.

REFERENCES

[1] Meggers, F., & Leibundgut, H. (2011). The potential of wastewater heat and exergy: Decentralized high-temperature recovery with a heat pump. *Energy and Buildings*, 43(4), 879-886.

[2] Verstraete, W., & Vlaeminck, S. E. (2011). ZeroWasteWater: short-cycling of wastewater resources for sustainable cities of the future*. International Journal of Sustainable Development & World Ecology*, 18(3), 253-264.

[3] Ekren, O., Araz, M., Hepbasli, A., Biyik, E., & Gunerhan, H. (2016). Design Aspects and Experimental Performance Test of a Wastewater Heat Pump for the Mediterranean Climate. *Journal of Clean Energy Technologies*, *4*(5).

[4] Blagojević, V.Despotović , M.,Božičković, R.,Božičković,S. (2016). Energy analysis of Doboj Municipality*.”Conference on Mechanical Engineering Technologies and Applications ”COMETa2016*, East Sarajevo – Jahorina, p. 485-492.

[5] Cipolla, S. S., & Maglionico, M. (2014). Heat recovery from urban wastewater: analysis of the variability of flow rate and temperature in the sewer of Bologna, Italy. *Energy Procedia*, *45*, 288-297.