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Analysis of Drain Water Heat Exchangers System in Wellness Center

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Drain water heat exchangers worldwide are used since the end of the twentieth century. Different drain water heat exchangers have been installed in Lithuania in last five years. Performance of these systems varies depending on the type of energy users, equipment and design of the systems, as well as their maintenance. The aim of this paper was to analyze different types of drain water heat exchangers and operational systems from the perspective of energy saving and temperature effectiveness. One drain water heat exchanger system in Lithuania was selected for the analysis. Calculation of temperature effectiveness showed that in most cases it is possible to save energy for hot water preparation.

KEYWORDS: drain water heat exchangers, energy savings, domestic hot water

Introduction

Space heating and cooling and domestic hot water supply represent the biggest share of energy in residential buildings (Torio and Schmidt 2010).

In recent years energy efficiency has become one of the indicators of economic development, and the rationalization of its use is the subject of numerous scientific studies (Turner and Doty 2007, Tsioliaridou and Bakos 2006, Schaumann 2007). Around the world, the aim is to minimize the negative impact of energy on the environment.

Evidence that much of the energy utilized in domestic water heating is wasted to the drainage system by applications such showers, tubs, dishwashers etc. For example, a typical dishwashing machine will heat water to over 80 ºC during its sanitation cycle and subsequently discharge this hot grey water to the drainage system at only marginally lower temperatures. A typical washing machine will heat water to 60 ºC and discharge hot grey water in a similar fashion. A typical shower will involve heating water to over 40 ºC, discharging hot grey water to the drainage system at temperatures of approximately 30–38 ºC depending on ambient temperatures (Wong et al. 2010).

The problem of saving the energy used to heat recovery from drain water usage has been observed in many countries such as the United Kingdom (Wong et al. 2010), Ireland (Boait et al. 2012), Spain (Hernandez and Kenny, 2012), Italy (Torras et al. 2016), Netherlands (Cipolla and Maglionico, 2014), Canada (Frijns et al. 2013, Leidl and Lubitz 2009, Picard et al. 2004), Australia (Hobbi and Siddiqui 2009) and Brazil (Beal et al. 2012), where the effectiveness of the use of different technologies, from residential buildings to urban wastewater, for saving energy was analyzed. Studies made in Swiss (Schmid 2009) showed that 15% of the thermal energy supplied to build

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ings is lost through the sewer system; this value rises up to 30% in well-insulated buildings with low consumption. This leads to the fact that, today, sewers represent the largest source of heat losses in buildings (Schmid 2009).

In Lithuania, despite the fact that the costs incurred in the preparation of water at the right temperature is relatively high, the use in residential buildings of heat recovery from drain water still raises a lot of controversy, and drain water heat exchangers are not generally available for sale. This state of affairs may be due to lack of data on the financial performance of the presented investments, as information on cost-effectiveness of a heat recovery system from drain water discharged from sanitary facilities usually comes from the materials from manufacturers. As a result they are not very believable for potential users.

The aim of this paper was to review and analyze different types of drain water heat exchangers, for different types of buildings from the perspective of energy saving and temperature effectiveness as well as to outline the differences of their actual performance.

Review of drain water heat exchangers

Technologies used in order to reduce energy consumption for hot water heating include among others heat recovery from drain water. Current development of technology makes it possible to recover heat from drain water on every stage of its formation, transport and utilization. In a market is it possible to find various types of waste water heat exchangers

(Fig 1): vertical (b), horizontal (c) or build into the shower basin (a). There are lots of other types and combinations, but in this paper, only most popular waste water heat exchangers will be reviewed.

a) Vertical drain water heat exchanger (Fig.1. b) with construction of metal pipe inside the waste water pipe, receives heat from grey water that is usually 30-38°C temperature. Grey water warms up pipe's surface which transmits heat to the cold water (5-8°C), which is circulating in metal pipe. Another version of vertical waste water heat exchanger – metal pipe which is wrapped around grey water pipe. The principle is the same: warm grey water flow heats up the surface of the pipe and the heat energy is transmitted to cold water which is circulating in wrapped metal pipe. The slower flow of grey water, the better effectiveness of waste water heat exchanger (Beentjes et al. 2014). If these kinds of heat exchangers are being installed in public buildings, for example water parks or wellness centers, there should be installed more than one vertical waste water heat exchanger. In this kind of buildings, usage of hot water is relatively bigger than in simple dwelling house. Also, there is usually a group of showers installed instead of only one. Nevertheless

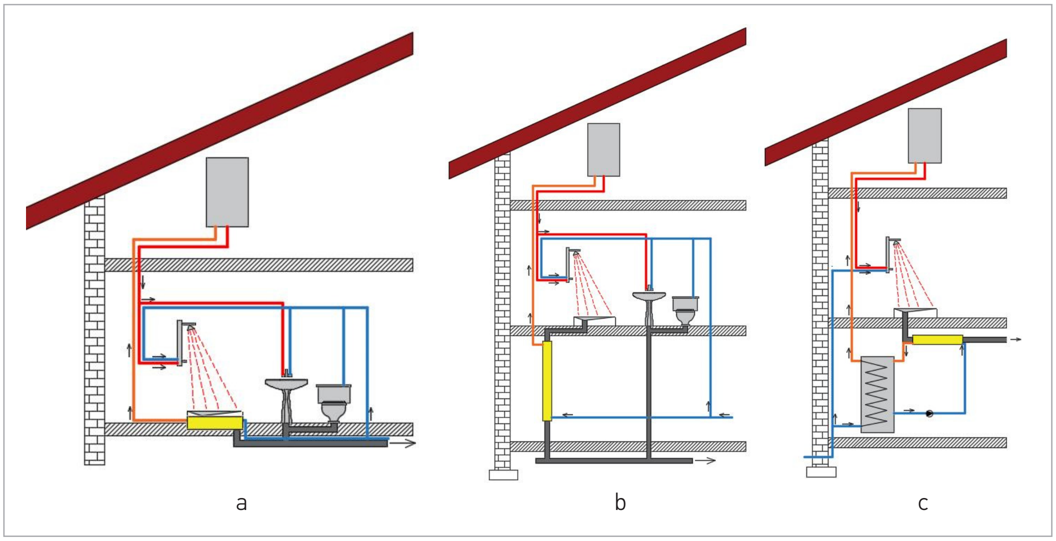

Fig. 1
Different types of drain water heat exchangers (marked in yellow)

choosing this kind of system, the height of storey must be estimated. Also it must be placed in the lowest point of the building, mostly in the basement. Leidl and Lubitz, 2009, Picard et al,. 2004 describe example of this kind of heat exchangers.

b) Waste water heat exchanger build into the shower basin. This flat exchanger is located under the perforated plate constituting the bottom of the basin. The principle of this kind of system is similar to vertical heat exchangers. The heat is transferred through pipe‘s and tray‘s surfaces without using any equipment that requires electricity. Furthermore, there is few ways how these systems can be installed and connected to building‘s hot water systems. First, heated water line after waste water heat exchanger is connected to shower‘s water mixer as cold water line. Also it is being connected to hot water heating tank, as cold water line too. In this case, water heater receives already warm water, so it uses relatively less energy to heat water. Besides, shower tap receives hot water from heater and warm water after heat exchanger, so it uses less hot water to mix a comfortable temperature water (Coopermann et al. 2011).

c) Horizontal type of waste water heat exchanger are more sustainable for public buildings, where hot water usage is relatively high. It uses circulation pumps, storage tanks, rinse machines and other equipment that requires electricity. In this paper, this kind of system will be analyzed. In this type of system, warm water after waste water heat exchanger, accumulates energy in storage tank. Cold water after circulating through storage tank heats up and is being used in showers taps as cold water line. Also, there is possibility to connect water line after storage tank to water heater too.

Methods of analysis

Horizontal type of waste water heat exchanger which was installed in sports and wellness center of Anykščiai city was analyzed in this paper work. There are not much this kind of type waste water heat exchangers installed in Lithuania. Also, none research was made about their effectiveness. On purpose to examine the waste water heat exchanger system in the sports and wellness center of Anykščiai city and its effectiveness, this study has been made.

25 meters long, 6 tracks swimming pool, jacuzzi, sauna, hydro massage baths were installed in the sports and wellness center of Anykščiai. This center organizes sports events, training and health treatments every day from 8 am to 9 pm.

Random week was selected for this research and each day the number of visitors was recorded. From 100 to 270 visitors were recorded every day and in general there was 1350 visitors per week. Fig. 2 shows specific data of visitors every day in a week. It has been observed that the most visitors were recorded at Monday, Wednesday, Saturday and Sunday.

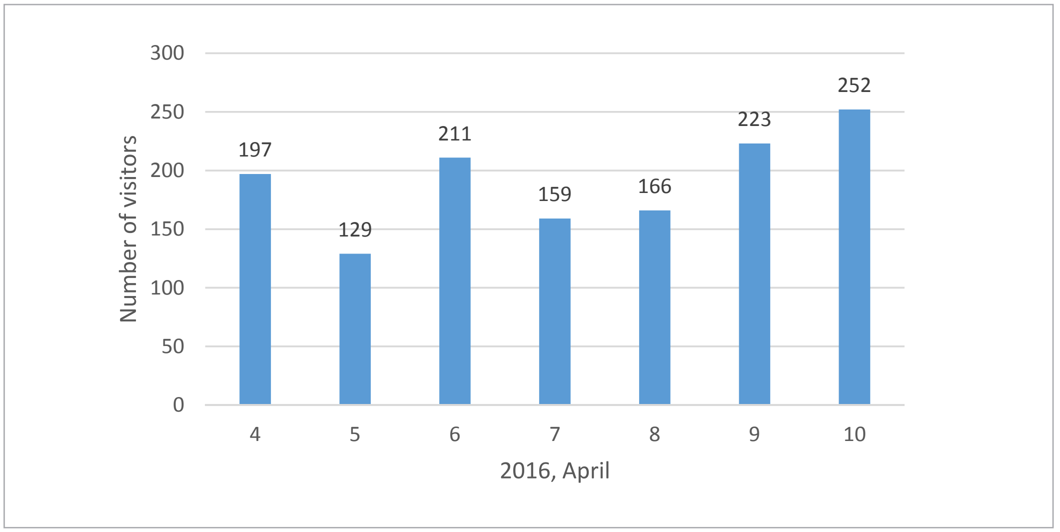

Fig. 2

„Graph of number of visitors in a week“

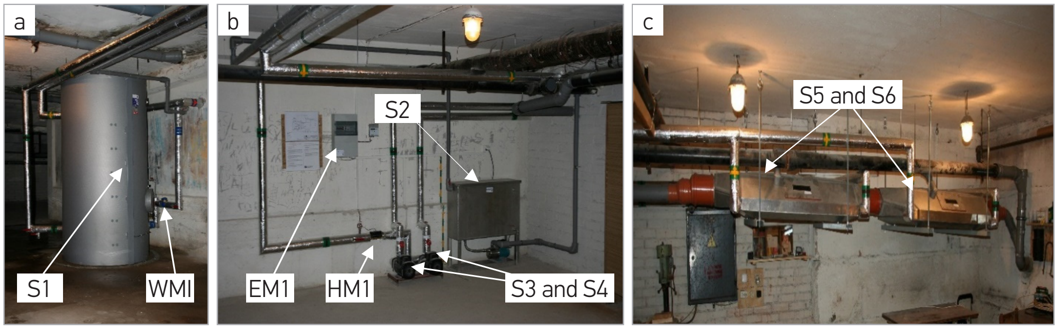

Fig. 3

Waste water heat exchangers system installed in sport and wellness center of Anykščiai city

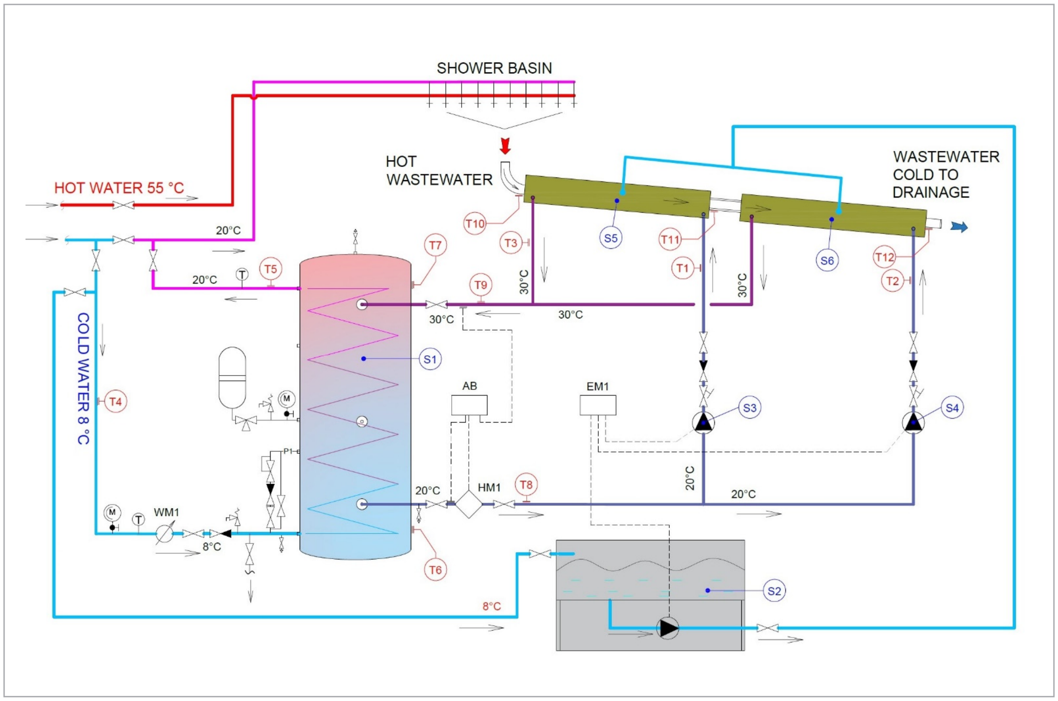

Fig. 4

Schematic representation of the analyzed unit. T1....T12– temperature sensors; S1– storage tank; S2- Rinse tankage; S3, S4- circulation pumps; S5, S6- waste water heat exchangers "

Facility equipped with 8 washbasins and 20 showers. Warm waste water from these appliances are draining through separate pipe which is connected to two waste water heat exchangers (FERCHER Type AWT-928) that are connected in series. After heat transfer, cold waste water is being drained to towns sewer networks (**Fig. 3**). After heat is collected, in a separate circuit, circulation pump transfers it to 1490 liters storage tank (**Fig. 3**, mark S1). In another circuit cold water (8 ºC) passes storage tank, warms up (approx. to 20 ºC) and then passes washbasins and showers mixing valves where it is being mixed up with hot water circuit (55 ºC). Circulation pumps (**Fig. 3**, mark S3, S4) are connected to control box, which is configured to turn on circulation pumps only when the difference between the temperature of warm waste water and water in storage pumps is no lower than 3 ºC. Also, this waste water heat exchangers system uses 150 liters water tankage (**Fig. 3**, mark S2) to rinse inside of the heat exchangers of purpose to increase their effectiveness.

Domestic water that comes into heating system are registered in cold water meter (**Fig. 3**, mark WM1). To register amount of heat being collected in this system, heat meter has been installed (**Fig. 3**, mark HM1). Electricity meter (**Fig. 3**, mark EM1) collects data about electricity use by circulation pumps.

The whole waste water heat exchangers system scheme is shown in **Fig. 4**.

To measure temperatures at different points, 12 temperature sensors (Pt 1000) were installed. Measured values were registered to recorder (LUMEL KD7) every day by every minute.

Results and discussions

All measured points were evaluated for purpose to calculate the effectiveness of waste water heat exchangers by themselves and as the whole system.

This research showed that temperatures were changing depending on the number of visitors in the sports and wellness center (see. Fig. 5). When the number of visitors increases, the demand of hot water increases too. Once the hot water is being used, the warm waste water (up to 32ºC) starts to drain into waste water heat exchangers (temp. sensor T10, T11, T12). Then heat is being transferred to cold water through the wall of heat exchanger (temp. sensor T3, T9). After that, heated water (up to 24 ºC) runs to storage tank and is being mixed up with the total water content. After water temperature drops to 20 ºC it runs back to waste water heat exchangers again (T1, T2), and the cycle is repeated again. Fig. 5 shows that water that is coming into storage tank and goes out, temperature difference is only few degrees. This is because of the size of storage tank. Graph shows that the highest difference is between temperatures of incoming waste water and cold water. The incoming cold water temperature (8ºC) reacted differently. That is obvious because when the usage of hot water decreases or no one is using it, the cold water stays in the pipe. Because of the inside temperature of the room where the systems is installed, cold water warms up by the long time period. That's why sensor T4 shows us the increase of cold water temperature at night time, when sports and wellness center is not working.

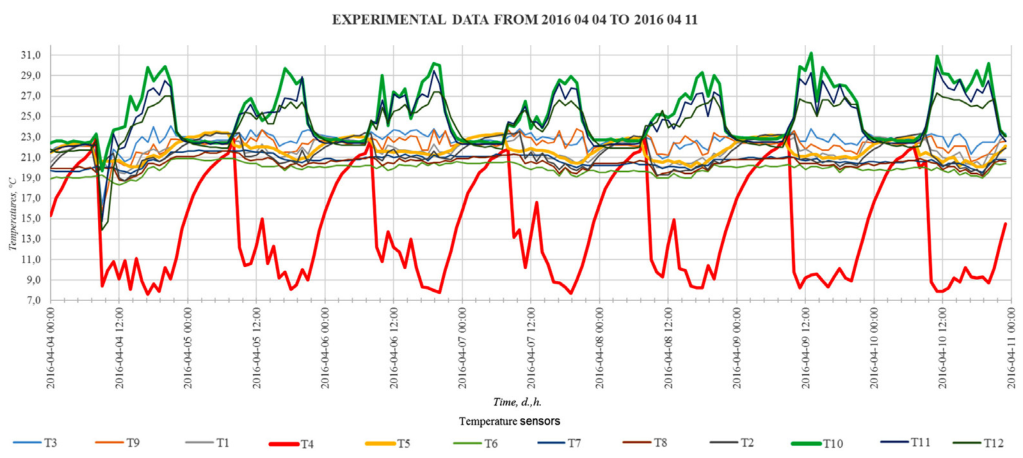

Fig. 5

Graph of all temperature sensors data from one week

T1 – Temp. sensor before first heat exchanger;

T2 – Temp. sensor before second heat exchanger;

T3 – Temp. sensor after first heat exchanger;

T4 – Cold water temp. sensor;

T5 – Warmed water temp. sensor;

T6 – Temp. sensor at the bottom of the storage tank;

T7 – Temp. sensor at the top of the storage tank;

T8 – Temp. sensor before both heat exchangers;

T9 – Temp. sensor after both heat exchangers;

T10 – Temp. sensor of incoming waste water;

T11 – Temp. sensor of waste water after first heat exchanger;

T12 –Temp. sensor of waste water after second heat exchanger."

In purpose to examine the effectiveness of waste water heat exchangers by their own and as the whole system, two graphs (Fig. 7 and Fig. 6) were made from the Fig. 5. Temperatures that helps to examine the effectiveness of waste water heat exchangers as the system is shown **Fig. 6**. Temperatures that helps to examine the effectiveness of waste water heat exchangers by their own is shown in **Fig. 7**.

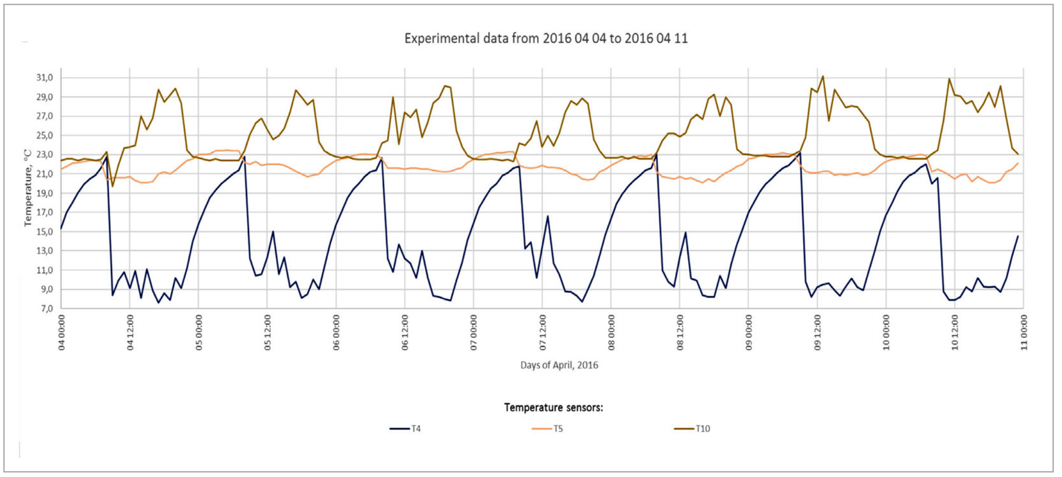

Fig. 6

Graph of temperature sensors T4, T5, T10 from the data of one week. T4 - Cold water temp. sensor; T5 - Warmed water temp. sensor; T10 - Temp. sensor of incoming waste water

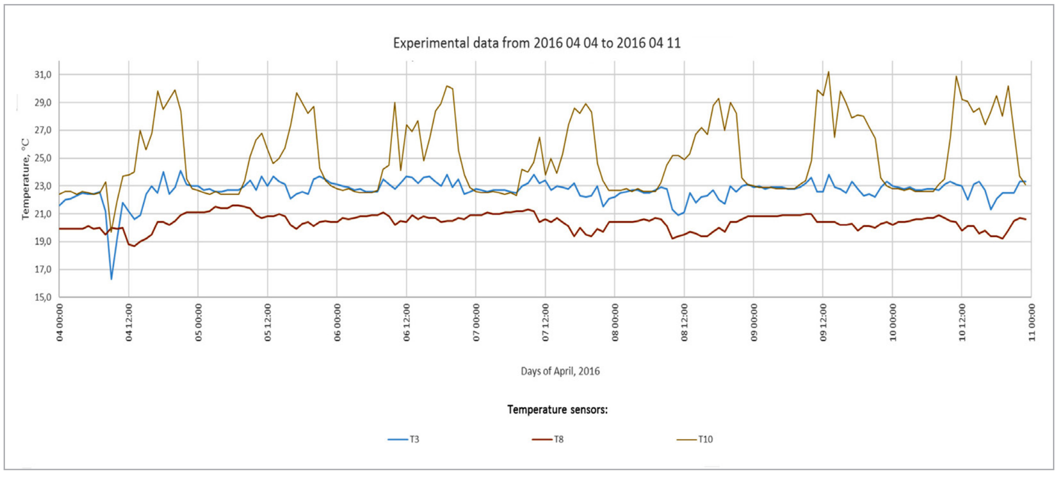

Fig. 7

Graph of temperature sensors T3, T8, T10 from the data of one week. T3 - Temp. sensor after first heat exchanger; T8 - Temp. sensor before both heat exchangers; T10 - Temp. sensor of incoming waste water

The temperature effectiveness of waste water heat exchanger:

$$\varepsilon = \frac{T_{c,o} - T_{c,i}}{T_{h,i} - T_{c,i}} \quad (1)$$

where:

$T_{c,o}$ – temperature of coolant in outlet of waste water heat exchanger, °C;

$T_{c,i}$ - temperature of coolant in inlet of waste water heat exchanger, °C;

$T_{h,i}$ – temperature of waste water inlet of waste water heat exchanger, °C;

Firstly, the effectiveness of waste water heat exchanger by himself was calculated. The average temperature of sensors before and after heat exchanger (T8, T3) and incoming waste water sensor (T10) were evaluated.

It was found, that the effectiveness decreases when the number of visitors increases. There are exceptions when effectiveness increases and the number of visitors increases too. It is assumed that it can be explained by the unknown behavior of the visitors.

Average every day's effectiveness of waste water heat exchanger reliance to number of visitors is shown in Fig. 8. Research showed that every day's average temperature (T10) of incoming waste water related to the number of visitors (Fig. 9). The better attendance the higher average waste water temperature has been observed. This shows that at a greater number of visitors, higher flow rates of waste water drains through heat exchangers and then the waste water heat exchangers exchange less heat to the storage tank.

Moreover, the effectiveness of the whole waste water heat exchangers system was evaluated. For this kind of analysis, temperatures from sensors that are before (T4) and after (T5) storage tank and at the incoming waste water pipe (T10) was collected. Graph of the effectiveness of the whole waste water heat exchangers system reliance to the number of visitors are shown in Fig. 10.

The results of this experiment shows that the temperature effectiveness of the whole waste water heat exchangers system (59,8-69,5%) is higher than temperature effectiveness of the separate waste water heat exchangers (32,2-50,4%).

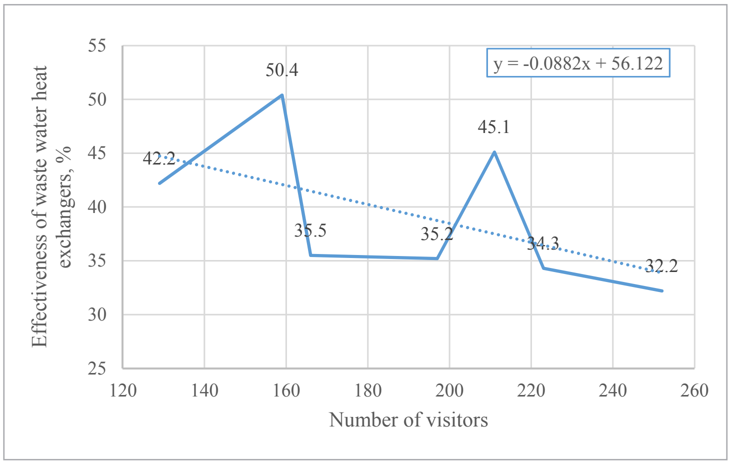

Fig. 8

Graph of effectiveness of waste water heat exchanger reliance to number of visitors

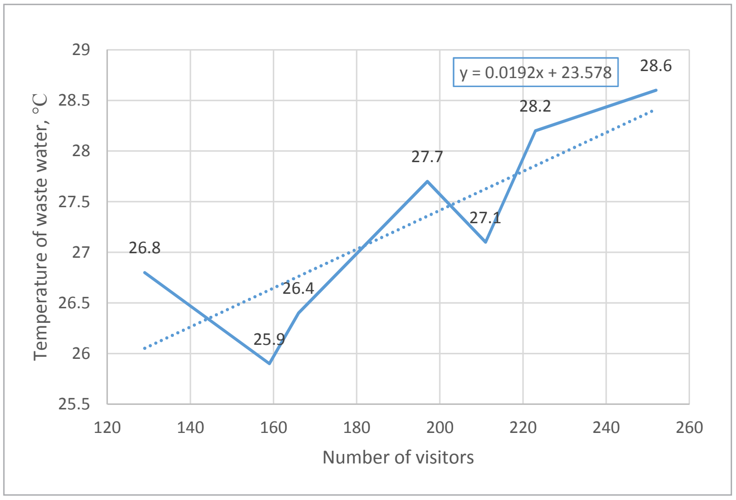

Fig. 9

„ Graph of incoming waste water temperatures reliance to number of visitors"

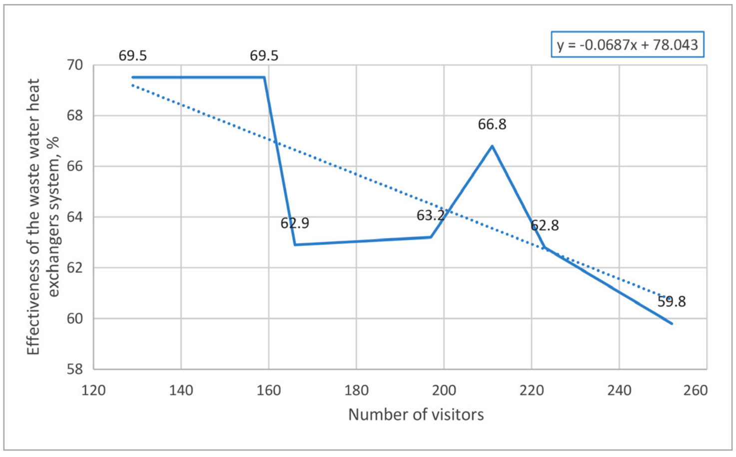

Fig. 10

Graph of the effectiveness of the whole waste water heat exchangers system reliance to the number of visitors"

When the temperature of heated water in the waste water heat exchangers system was recorded, the savings of energy were calculated. The energy that is required to heat cold water (23^{o}C) from waste water heat exchangers system is 61,96 kWh. Energy that is required to heat cold water (8^{o}C) from waste water heat exchangers systems is 116,79 kWh. This shows that waste water heat exchangers helps to save up to 53% of energy that's required to heat water.

Conclusions

Temperature sensors were installed in the waste water heat exchanger system at the wellness and sport center of Anykščiai city. The data from the sensors were collected. After the evaluation of the results it was determined that:

1. The temperature effectiveness of waste water heat exchangers ranges from 32,2% to 50,4%.
2. The temperature effectiveness of waste water heat exchangers system ranges from 59,8% to 69,5%.
3. In both ways, the effectiveness lowers when the number of visitors increases.
4. Installing this kind of waste water heat exchangers system helps to save up to 53% of energy that is required to heat water.

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