Heath Recovery from Waste Recreational Pools Water of Thermal Baths and Medical Sanatoriums

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Abstract. In Slovakia we can find 35 thermal baths and 28 thermal healing sanatoriums that use geothermal or thermal healing water for their operation. After the use of water in these facilities, waste pool water with relatively high temperature is drained out of these facilities. This wastewater has considerable energy potential, which is used in any way. There are number of buildings in the premises of recreational and medical facilities, which are used for various purposes. Whether it is a building used by the staff of the recreational facility or by visitors. We have two options for using the energy potential of wastewater. The first option in the summer is to use waste heat to preheat cold water, which is used together with geothermal water to fill and operate of pools. The second option in the winter is to use waste heat to defrost the sidewalks within the recreational facility or use this heat in the system of active thermal protection of buildings that are part of the complex. The aim of the paper is to present more ways of using the energy potential of waste pool water, which is produced by thermal baths and medical sanatoriums and calculation results of geothermal water volume decreasing.

Keywords. Geothermal energy, thermal baths, wastewater, heat recovery.
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1. Introduction

Geothermal energy is one of the renewable energy sources. Its advantage is that it does not depend on weather conditions or the alternation of day and night. Geothermal sources in Slovakia provide thermal water with a temperature from 30 °C to °30 °C. The possibility of using depends on the temperature of the thermal water. Thermal water with a temperature 110 °C can be used to generate electricity. We do not currently have any thermal power plant in Slovakia, while there are 72 registered in the world. Thermal wells that provide water with a temperature below 100 °C can be used for direct utilization.

"From 114 wells at 74 sites, geothermal energy is used for heating production. Following a long tradition of using geothermal waters, begun in medieval times, the recreation sector remains the predominant use for geothermal waters in Slovakia [4]." World surveys, which are based on information from Slovak experts, show that geothermal energy in Slovakia is widely used in recreational facilities [5].

The most widely used method of direct utilization of thermal water in Slovakia are thermal baths. According to data from the Ministry of Health of the Slovak Republic, we have 213 registered artificial swimming pools in Slovakia with a total of 658 pools. Of these, 461 are filled with non-thermal water and 197 pools are filled with thermal water. It is the recreational and leisure pools that use thermal water with a temperature of up to 40°C for their operation that have the greatest potential for this work. The work is focused on the system of heat recovery from wastewater produced by thermal baths.

1.1 Pool types used in recreational facilities

The following chapter will introduce two basic types of swimming pools that are used in recreational facilities. In both cases, it is possible to use a heat recovery system from the waste pool water. In general, two basic types of pools are used in thermal baths. The first is a flow system that is relatively resource intensive. It is a simple system, where thermal water is fed directly into the pool, if it has the required temperature and a suitable mineralisation. If this is not possible, thermal water must be mixed with cold water to ensure the required pool water parameters. Wastewater flows out of the frow pool without further use. The second type is the circulation pool system, which has a significantly lower composition of thermal water. It is a more technologically demanding system, which is more advantageous and therefore more used. Wastewater does not immediately drain from the circulation pool. Pool water circulates in the system again. The multiplicity of the water exchange on which the volume of water added to the system depends is determined by the body of the hygienic service. From the pool, the pool water flows into a buffer tank, in which thermal water is mixed with cold water. Only after the buffer tank is overfilled does wastewater flow out of the system.

In both cases, the waste pool water, which has a temperature of up to 40 °C, flows out of the pool system. Wastewater with such a high temperature represents a large energy potential that is not used. Another problem with recreational facilities is that the maximum temperature of wastewater that can be discharged into a water recipient is prescribed by the laws and regulations described in the following chapter.

1.2 Legislative requirements

An important factor is the maximum temperature of the waste pool water that can be discharged into the recipient. According to the Regulation of the Government of the Slovak Republic no. 269/2010 of 25 May 2010 laying down requirements for achieving good water status and pursuant to Law No. 364/2004 on waters and on the amendment of the Act of the Slovak National Council No. 372/1990 Coll. on offenses, known as the Water Law, the maximum temperature of waste pool water that can be discharged into the recipient without demanding the environment is set at 26 °C [1, 2]. In most cases this temperature is exceeded. Therefore, the aim of this article is to present the heat recovery system as possibility of cooling the wastewater to a suitable temperature. The heat recovery system has several positive aspects. One of the advantages is the cooling of the waste pool water to a temperature at which is safe to discharge it into the recipient without environmental pollution.

2. Heat recovery system

The wastewater from the pools reaches a temperature of 40 °C. Water with such a high temperature has an energy potential that is not used. Thermal and non-thermal swimming pools use cooling ponds or canals to cool wastewater. It is one of the solutions, but it is necessary to realize that in this way the wastewater is aimlessly cooled, and the energy potential is not used. The heat recovery from the waste pool water is based on a recuperative heat exchanger, which is inserted into the wastewater circuit. Waste pool water flows through the heat exchanger, which transfers its heat to the cold water. This principle is illustrated in the Fig. 5. Preheated cold water can be used in several ways:

- preheating of cold water used to operate swimming pools (yearly),
- preheating of cold water for the domestic hot water preparation (yearly),
- absorption cooling (summer operation),
- snow melting system (winter operation),
- active thermal protection of the buildings.

There are two ways to install a heat exchanger. The first is to install a heat exchanger in the pool engine room. The second option is to install a heat exchanger in the cooling pond or canal. Both options will be described in the following subsections.

2.1 Heat exchanger in the engine room

Each pool has its own engine room, which in most cases is located near to the pool. In the engine room is located the technological equipment needed to operate the pool, such as a buffer tank, sand filter and circulating pump. In the case of using a heat recovery system, where the heat exchanger will be in the engine room, it is necessary to consider the space which is available. The design of the heat exchanger is based especially on this.

The analysis of the suitability of different types of heat exchanger in this system showed that the most positive is the use of a plate recuperative heat exchanger, which can be seen in Fig. 1. Construction of the plate heat exchanger consists of back and front stand between which the plates are places. The plates form the heat exchanger surface where heat is exchanged between heat transfer fluids. Plate heat exchanger advantages are mainly relatively small size and high performance. This system is suitable for preheating cold water, which is used directly in the engine room for mixing with thermal water. Scheme of the flow pool system with heat recovery system is show in Fig. 2 and scheme of the circulation pool system with heat recovery system is show in Fig. 3.

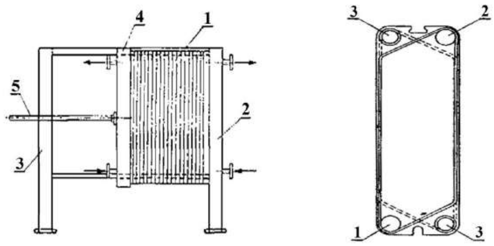


Fig. 1 – Scheme of the flow pool system with heat recovery system. 1 – plate heat exchanger, 2 – back stand, 3 – front stand, 4 – pressure plate, 5 – tightening plate [3]

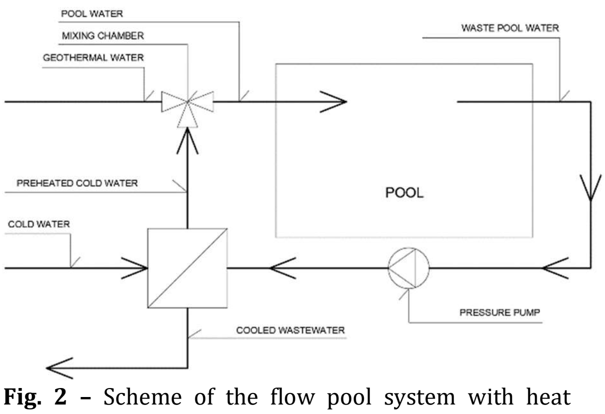


Fig. 2 – Scheme of the flow pool system with heat recovery system.

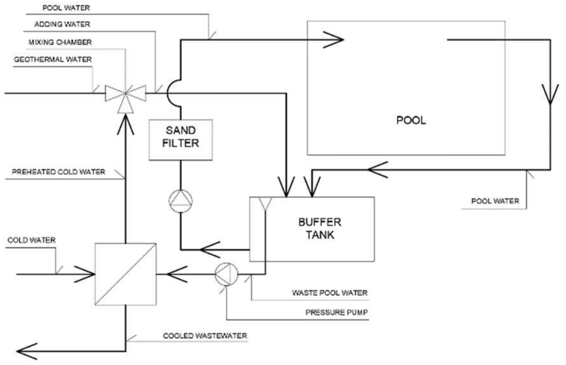


Fig. 3 – Scheme of the circulation pool system with heat recovery system.

The most suitable types of heat exchangers that suit this applications, material, shape, and quality of heat transfer are plate heat exchangers. The heat exchange surface of the plate heat exchangers is formed by parallel, most often vertical plates placed in a rack so that slot channels 3 to 10 mm wide are formed in the interpolate space. Two liquids, ideally in counter current, flow alternately through these slots. The most important element of these heat exchangers is the worktop, which is pressed from thick sheet metal, today most often from stainless steel or titanium. The plates allow the assembly of heat exchangers with a total heat exchange area of up to 600 m^2. Due to the relatively high heat transfer coefficient, they need a relatively small area per unit to output. The operating temperature range is from -10 °C to 200 °C. The advantage of this type of heat exchanger is the good maintenance and accessibility of the work surface due to the possibility of rapid disassembly of the plate bundle for visual inspection [3].

2.2 Heat exchanger in the cooling canal

In principle, this system also consists in the inclusion of a heat exchanger in the wastewater circuit, however, a cooling canal or pond is used. A tubular heat exchanger is installed in the cooling canal, through which cold water flows. Waste pool water with higher temperature flows around the oven, transferring its heat to the cold water. The design of a tubular heat exchanger depends on the properties of the cooling canal, such as its cross-section and water depth. The scheme of the installation of the tubular heat exchanger in the cooling canal is show in Fig. 4.

3. Calculation methodology

One of the advantages of a heat recovery system is the use of waste heat to preheat the cold water which the thermal water is mixed to ensure the required pool water parameters. Because the thermal water is mixed with preheated cold water, a smaller volume of thermal water is needed to ensure the same pool water parameters. This fact was verified by calculation methods.

For the calculation was chosen the pool with parameters based on real data. A recreational pool was chosen, working on a flow pool system. The water area is 295,0 m^2. The depth of the pool is 1,25m and volume is 368,0 m^3. The geothermal well provides water with a temperature of 70 °C, which is mixed with cold water with a considered average temperature of 15 °C, to desire pool water temperature of 38 °C. In this calculation, we considered only the summer operation of the pool, which lasted 70 days. The pool was out of order for 7 days, during which it was drained and refilled.

The calculation must be made separately for the filling and operation of the pool. The reason is that it is not possible to use a heat recovery system during filling, because no wastewater flows out of the pool. The heat recovery system can be used during the operation of the pool, when the waste pool water flows in the recipient.

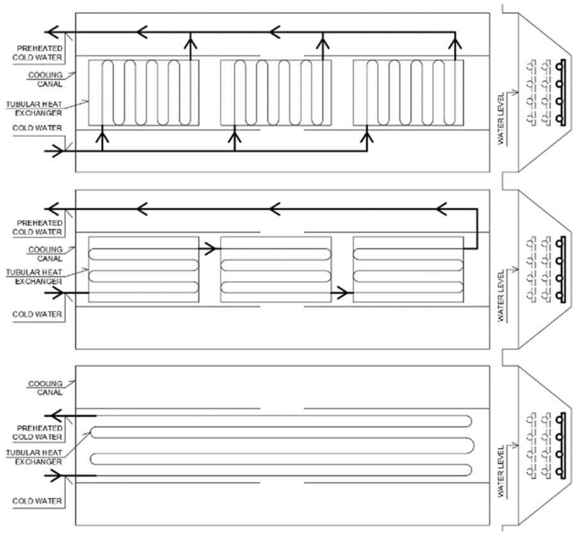


Fig. 4 – Scheme of the installation of the tubular heat exchanger in the cooling canal.

4. Results

The calculation is based on the transfer of heat from the waste pool water through the heat exchanger surface. This process is illustrated in Fig. 4. It is clear from the Fig. 5 that cold water with a temperature of 15 °C and wastewater with a temperature of 38 °C are fed to the heat exchanger. The wastewater transfers heat to the cold water, which is preheated to 27 °C.

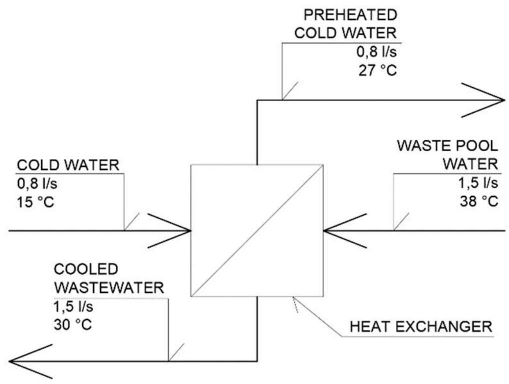
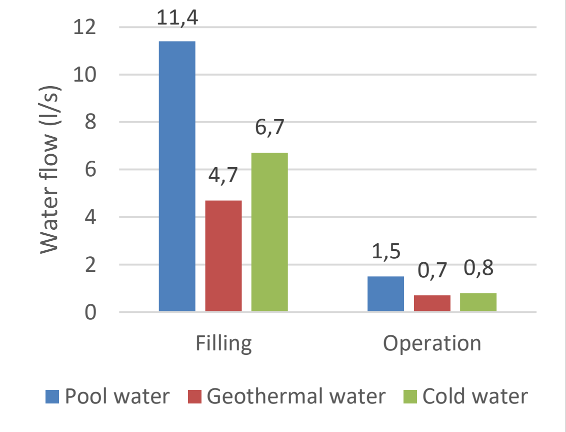


Fig. 5 – Heat transfer scheme in a plate heat exchanger.

The necessary volume of cold and geothermal water to achieve the required parameters of pool water was also calculated. The calculation was made separately for the filling and operation of the pool. The calculation was made for the system without and with heat recovery system.

4.1 Pool without heat recovery system

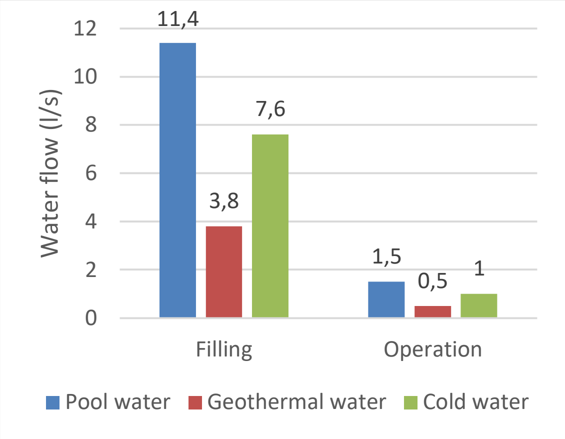
The results of the calculation without heat recovery showed that a pool water flow of 11,4 l/s is required to fill the pool. Pool water is mixed from geothermal water with flow of 4,7 l/s (57% of total pool water flow) and cold water with flow of 6,6 l/s (43% of total pool water flow). During the summer season, which lasted 70 days, the pool will be filled seven times. A total of 2 962,4 m³ is needed to fill the pool during the summer operation. 57% (1 238,8 m³) of the total volume will be cold water, the remaining 43% (1 723,6 m³) geothermal water. The results of the calculation are summarized in Graph 1.



Graph 1 – The results of the calculation of the pool without heat recovery system during filling and operation.

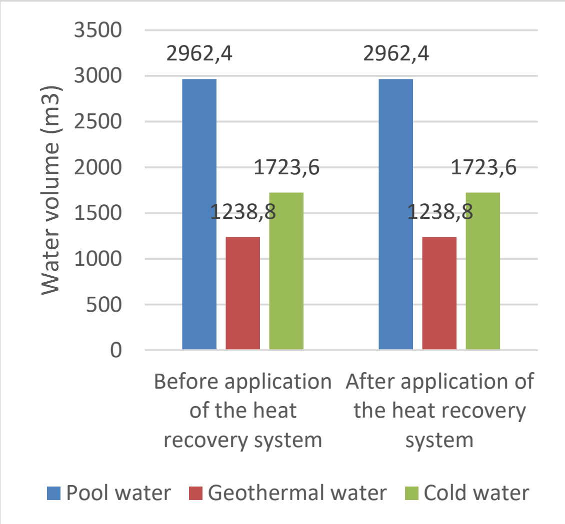
4.2 Pool with heat recovery system

The next step is to calculate the same pool system, but after installing the heat recovery system into the wastewater circuit. The aim of the calculation is to prove that the use of this system brings several advantages. The results of the installation of the heat exchanger, the required flow and the volume of geothermal water needed for the same operation of the pool are reduced. This phenomenon is due to the increased use of cold preheated water that has been preheated using wastewater energy potential. The total pool water flow remains unchanged. The ratio of geothermal and cold-water use is changing. After installing a heat recovery system, the flow of geothermal water decreases and, conversely, the flow of cold water, which is preheated to a higher temperature, increases. In the solved example, the use of cold preheated water increased by 13%. 11,4 l/s of pool water are still needed to fill the pool. The mixing ratio of geothermal and cold water varies. 3,8 l/s (33% of total pool water flow) of geothermal water and 7,6 l/s (67% of total pool water flow) of cold water is needed to achieve the required pool water parameters. The results of the calculation of the pool with heat recovery system during filling and operation are showed in Graph 2. In the solved example, the waste pool water was cooled to 30 °C. The maximum temperature of the wastewater that can be discharged into the recipient is set at 26 °C. If the required wastewater temperature is reached, the use of wastewater energy potential will be even more advantageous.

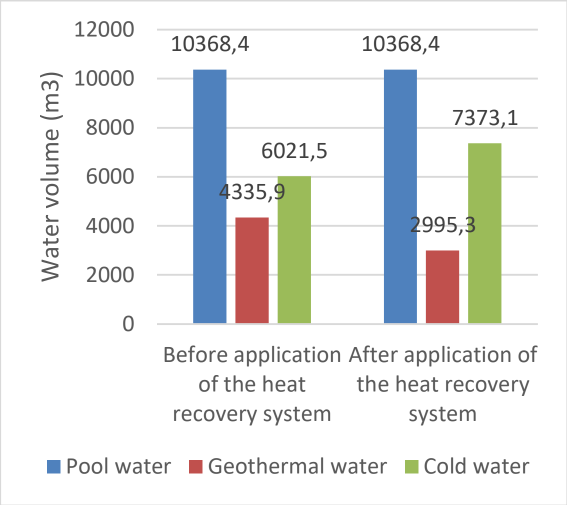


Graph 2 – The results of the calculation of the pool with heat recovery system during filling and operation.

A comparison of the volume of pool, geothermal and cold water is shown in Graph 3 and Graph 4. It is clear from the graph that after the application of the heat recovery system, the consumption of geothermal water decreased during operation of the pool, and the consumption of cold preheated water increased. During the filling, the values are constant because no wastewater flows out of the pool during filling and the heat recovery system is not active.



Graph 3 – The comparison of the volume of pool, geothermal and cold-water during filling of the pool before and after application of heat recovery system.



Graph 4 – The comparison of the volume of pool, geothermal and cold-water during operation of the pool before and after application of heat recovery system.

5. Discussion

The aim of the heat recovery system is to reduce the temperature of the wastewater to a value at which it will not be necessary to face sanctions for environmental pollution. With the help of a heat recovery system using a plate or tube heat exchanger, it is possible to reach a temperature of 26 °C, which is given by laws. The use of a heat exchanger in a heat recovery system can be considered as a one-stage cooling of wastewater. The zero level of water exergy is 15 °C. In the case of the inclusion of the second stage of wastewater cooling in the form of heat pumps, it would be possible to reach this temperature and use the full energy potential of the water [6, 7]. However, it is necessary to consider whether the law provides not only a maximum but also a minimum temperature of wastewater that can be discharged into the recipient. Legislation in Slovakia does not prescribe a minimum temperature of wastewater that can be discharged to the recipient. Another aspect that needs to be considered is the economic aspect. In this case, it is necessary to compare the investment costs for heat pumps, the return on such a system and the fact whether it is necessary from an economic point of view to include the second stage of wastewater cooling.

The significance of this work lies in the use of energy potential, which is considered waste. The idea of heat recovery from waste pool water is not used in any swimming pool in Slovakia. This study is currently under development. The following procedures will also include energy saving potential and resources saving potential, which are not assessed in the current article and have not been the aim of this work. The aim of the work was to prove numerically that thanks to the heat recovery system it is possible to reduce the volume of thermal water needed to operate the pool what is clearly shown in Graph 4.

6. Conclusion

Waste pool water which is largely produced by thermal as well as non-thermal swimming pools, has a great energy potential, which is not used in any way. There are several possibilities of heat recovery from waste pool water. The article focused on the use of waste heat in the cold-water preheating system, which is used in pool management to achieve the required parameters of pool water. Due to the preheating of cold water to a higher temperature, it is possible to achieve a reduction in the required volume of geothermal water, which is needed for the operation of pool management by 13 %. This can be achieved by means of an energy-saving measures as application of a recuperative heat exchanger into the wastewater circuit, or by applying a second stage of wastewater cooling by means of heat pumps. The aim of this system of heat recovery from waste pool water is the possibility to reduce the temperature of waste pool water to a value at which it is safe to discharge it into the recipient without damaging the surrounding environment. In the calculation given in the paper, the temperature of the waste pool water was reduced to 30 °C. By using a heat exchanger with a higher power, it is possible to reach the temperature required by laws. In Another aspect is the reduction in the volume of geothermal water pumped from the geothermal well, which will extend the lifetime of the geothermal source. Finally, it will be possible to reduce sanction for environmental pollution, which depend on the temperature of the wastewater discharged into the recipient.

7. Acknowledgement

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8. References

[1] Regulation of the Government of the Slovak Republic No. 269/2010 of 25 May 2010 laying down requirements for achieving good water status.

[2] Law No. 364/2004 on waters and on the amendment of the Law of the Slovak National Council No. 372/1990 Coll. on offenses (Water Law).

[3] Jelemenský, K. (2021). Heat exchangers – principles, advantages, and disadvantages, iDB Journal, No. 2/2021, ISSN 1338-3337, pp. 34–36.

[4] Lund, J. W., & Toth, A. N. (2021). Direct utilization of geothermal energy 2020 worldwide review. Geothermics, 90. https://doi.org/10.1016/j.geothermics.2020.101915.

[5] Fričovský, B., Černák, R., Marcin, D. et. al. (2020). Geothermal Energy Use, Country Update for Slovakia, European Geothermal Congress 2020, Reykjavik, Iceland, 11-14 June 2019, p. 19.

[6] Nyers, J. (2016), COP and Economic Analysis of the Heat Recovery from Waste Water using Heat Pumps, Acta Polytechnica Hungarica, 2016, Volume 13(5), ISSN 1785-8860, pp. 135-154.

[7] Kassai, M. (2019), Heat Pump Heating System Development of Educational Building based on Energy Economical and Environmental Impacts, Periodica Polytechnica Mechanical Engineering, 2019, Volume 63(3), ISSN 324-6051, pp. 207-213.

Data Statement

The data used in the calculation are provided by the operator of the thermal swimming pool in Slovakia. The calculations are based on real data of the recreational facility.

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