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SEWAGE WATER HEAT RECOVERY: A PROPOSED STUDY AS AN APPLICATION OF ENERGY SAVING IN IRAQ

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Abstract: An Innovative technology is used to recover some of the thermal energy of wastewater released by washing section in a restaurant as one of the energy saving applications to reduce electrical energy consumption for heating, as well as saving money. This research suggests using heat exchanger to recover heat from the sewage hot water (about 45 ^{o}C) to reheat the dining room for a proposed restaurant, and this will supply up to 8 Tons of heating load and will reduce the electrical energy that used to heat the place up to 44%. This technology within the system routes the passive energy conservation and considers another step on the way of sustainability.

Keywords: *Energy saving, Heat recovery, Heat transfer, Sewage water, Renewable energy*

استرداد الطاقة من مياه الصرف: دراسة مقترحة كأحدى تطبيقات حفظ الطاقة في العراق

الخلاصة: تم استخدام تقنية جديدة لاسترداد بعض من الطاقة الحرارية للمياه المصروفة للغسل في المطاعم كاحدى تطبيقات حفظ وتوفير الطاقة للحد من استهلاك الطاقة الكهربائية للتدفئة، فضلا عن توفير المال. يقترح في هذا البحث استخدام مبادل حراري لاسترداد الحرارة من مياه الصرف الصحي الساخن (حوالي 45 درجة مئوية) لتسخين قاعة المطعم المقترح، وهذا سوف يوفر 8 طن كحد اقصى من حمولة التدفئة وسوف يقلل من الطاقة الكهربائية المستخدمة للتدفئة بحدود 44٪. هذه التقنية تاتي ضمن طرق حفظ الطاقة السلبية وتعتبر خطوة أخرى على طريق الاستدامة.

1. Introduction

The use of energy has become a major global issue in recent years because of its environmental aspects and responsibility of carbon dioxide emissions. The energy use in residential and commercial buildings varies according to income levels, availability of natural resources and differences in climate. In Iraq, approximately, it is not less than 60% of the total energy consumed is used for heating or cooling [1]. Hence, there is a great needing for reducing the total energy use in the buildings. In the search for new and sustainable energy sources few people realize that there is an energy source flowing beneath the surface of our cities. Sewage, this abundant, free energy source remains mostly untapped. There are incredibly valuable resources in a wastewater flow: energy, nutrients, other materials and water itself.

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The “Raw Sewage” can be used to heat buildings, cool buildings and provide hot water. This system is an environmentally friendly, energy saving and cost effective solution for multiple unit residential or commercial buildings and energy districts [2].

It is known that low temperature heat still contain a little capacity to do work (Exergy), so the heat is qualified as waste heat and rejected to the environment [3]. Waste heat could be produced by machines, wastewater and industrial processes for which no useful application is found. Various studies have estimated that as much as 20 to 50% of industrial energy consumption is ultimately discharged as waste heat [4].

Applications of wastewater heat recovery include [5]:

- Boiler feed water preheating
- Space heating and domestic hot water
- Power generation

The using of wastewater energy can further be subdivided into three categories, as shown in Fig. 1, depending on where the energy is extracted: In-house energy recuperation, energy recovery from raw wastewater (sewers), energy recovery from cleansed wastewater after the sewage treatment plant [6].

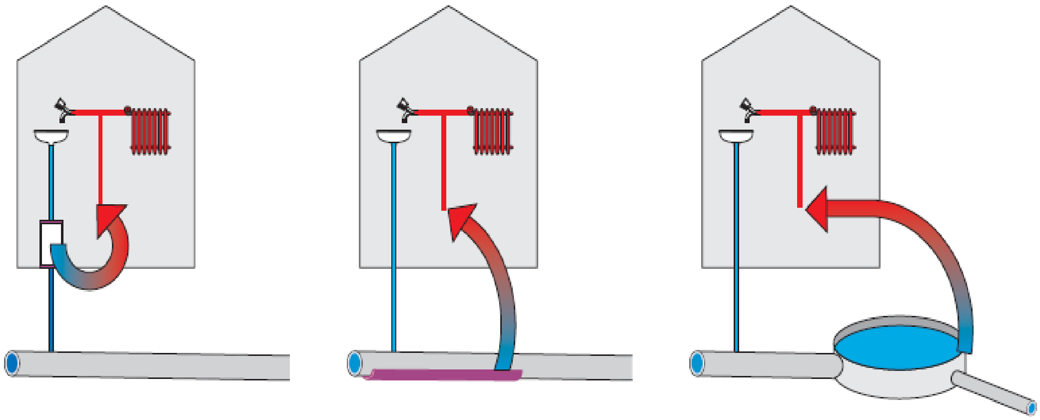

Figure 1. Methods of energy recovery from wastewater [6]

2. Background

Philadelphia Company announced its first project to warm a building with heat from sewage. The building is receiving its heat by direct access and heat transfer from an adjacent sewage channel in its basement. Nova Thermal Energy’s technology will significantly reduce energy use in commercial and industrial buildings. It can provide heat at approximately 50 percent of the current cost in the United States [7].

International Wastewater Heat Exchange Systems (IWHES) implement the "Raw Sewage" method and develop it for several projects through USA. The first system was installed in a multiple unit development in North Vancouver by Adera Developments. The “Seven35” project earned dual LEED certification (Platinum and Green Gold) using the sewage SHARC as a key feature [2].

A project is designed by German Uhrig group together with a group of Romanian specialists from the University in Alba Iulia in order to reduce the heating costs for an apartment building cluster in Pitesti using Therm Liner Method. The heat exchangers will be submerged under the waste water and thus will be able to capture a part of the waste water heat using water-water heat pumps. The water temperature in the sewage is varying from 8 to 18 degrees. The specifications of waste water flow were 15 LPS as minimum and 500 mm diameter of pipe. The advantages are: waste water energy extracted (1-4) kWh/ m and cost saving (40-60) % [8].

Zhou W. and Li J. introduce an analyzing of sewage source heat pump system in China. Through the analysis, they conclude that the system is feasible, advanced in technology and can save the investment. Sewage temperature fluctuates very little and it is related with the amount of sewage, region and season. In North China sewage temperature is no lower than 10 ^{o}C in winter and does not exceed 30 ^{o}C in summer. The total building area in the plant is about 3000 m^2 where the total heating load is about 338 KW [9].

In Northern Ireland, an evaluation study for the potential waste heat recovery within commercial kitchens is done. The study, which involved both numerical simulation and measured data from five restaurant kitchens in Belfast, revealed that heat recovery technology provided substantial economic and environmental savings. Compact devices such as the spiral tube heat exchanger can be utilized as a sustainable solution to retrofit existing hot water systems. They recommend using complementary technologies such as solar panels or modified cookers that would provide a sustainable solution for the catering industry [10].

Northwinds Sailing, Inc. tests the concept of capturing waste heat from kitchen exhaust ducts and using it to preheat the restaurant’s hot water supply. The test site was a small, seasonal restaurant in Grand Marais. The conventional grease filters in the kitchen exhaust hood in the cafe were replaced with an exhaust-to-water heat recovery system. Only one product that met the specifications was available and certified at the time of the installation (Dragon Fire Thermo Recovery Filters). After some initial start-up issues were resolved, this system proved easy to operate and maintain [11].

Heat recovery systems help to reduce a restaurant’s overall energy use. Heat from exhaust hoods and hot drain water can be used to pre-heat air or domestic hot water. The renovated, historic Cambridge Mill restaurant in Ontario, installed an energy-recovery ventilation system that captures 85 percent of the heat lost through the kitchen’s exhaust system and uses it to pre-heat both the building’s makeup air and domestic hot water. Among other benefits, the system, which has an estimated 3.5-year payback period, allows the hot water heaters to use less energy, as they are heating water that is already 95 degrees [12].

An effective way of capturing latent heat in wastewater could be satisfied by heat exchangers. The gravity-film heat exchangers consist of several feet of coiled copper tubing mounted vertically and arranged so that, as the warm drain water flows over the coils, heat is transferred to incoming cold water. There are two units currently on the market — the GFX heat exchanger [13] and the Water Cycle heat exchanger [14].

3. Recent Study

Restaurant is very energy intensive place where using a lot of heat and much of that is wasted through exhaust hoods, down the drain and into the kitchen. A heat recovery system can be installed so that recapture heat and use it to reduce overall energy use. The potential source of energy which can be recovered is the warm water draining from washers, but the volume of hot water drains for small applications is probably insufficient to make heat recovery economically practical. The key is to identify waste heat sources, potential end uses, and times of day the waste heat is available. However, there are some typical sources and uses for waste heat in restaurants:

- Kitchen hood and dishwasher hood heat recovery used to preheat makeup air
- Dishwasher and pot sink drain water used to preheat domestic hot water
- Hot air in the kitchen used by a heat pump to preheat hot water
- Washing section drain water used to warm heating space

This paper encourages the using of thermal energy of released wastewater to reheat a certain space in a restaurant. The restaurant is located in Duz town in the mid-northern of Iraq (35^{o}N, 45^{o}E), where heating is very needy in the winter. The location of the restaurant is a special where it is almost the stop station on the road connecting between the central part and the northern part of Iraq, including 300 km distance as shown in Fig. 2. This makes the rate of water usage and drainage by travelers is very high even in the absence of ordering food.

Figure 2. Geographical location of the Duz town

The restaurant has 120 m^2 floor-area and is affordable for 60 persons. Fig. 3 shows the layout of the restaurant explaining washing space, dining hall and sewage sketch. Heat exchanger unit is placed in the bottom of the dining hall under the floor on the line of drainage. A filter should be installed to separate impurities and to ensure that no sediment and destruction in the tube may be accumulated. Tubes are made of aluminum where the thermal conductivity is very high (150 W/m.k) and the effect of corrosion is minimum. The tubes are installed in an artistic way and coated on the inner side to prevent the collecting of soap and hair inside the heat exchanger. There are 2 stages of heat exchangers arrangements; each stage includes 6 units of heat exchangers. The heat exchanger is consisted from a flat plate connected to the top of tubes and insulated from the bottom. Each heat exchanger tube has 1 in diameter and 3 m long, as shown in Fig.

4.

The theoretical analysis could be presented by calculating the amount of useful heat by several equations and relations dealing with heat transfer [15]. The theoretical heat transfer coefficient could be calculated by:

$$q_{gain} = h\,A\;(T_f - T_w) \qquad (1)$$

Where (A) is the surface area of the tube. The effective water temperature (T_f) is taken as the average temperature of water at entrance and exit of heat exchanger unit. The temperature of tube wall (T_w) is assumed constant. The heat transfer coefficient of the flow inside the tube (h) is given by:

$$h = Nu\,K\,/d \qquad (2)$$

Substitute Nusselt number (Nu) from:

$$Nu = 0.023\,Re^{0.8}\,Pr^{0.3} \qquad (3)$$

Now, the actual heat transfer coefficient which is depending on the efficiency will be:

$$q_{actual} = q_{gain} \cdot \eta \qquad (4)$$

The value of the efficiency (η) could be determined experimentally depending on several parameters like: heat exchanger design, insulation type and system reliability.

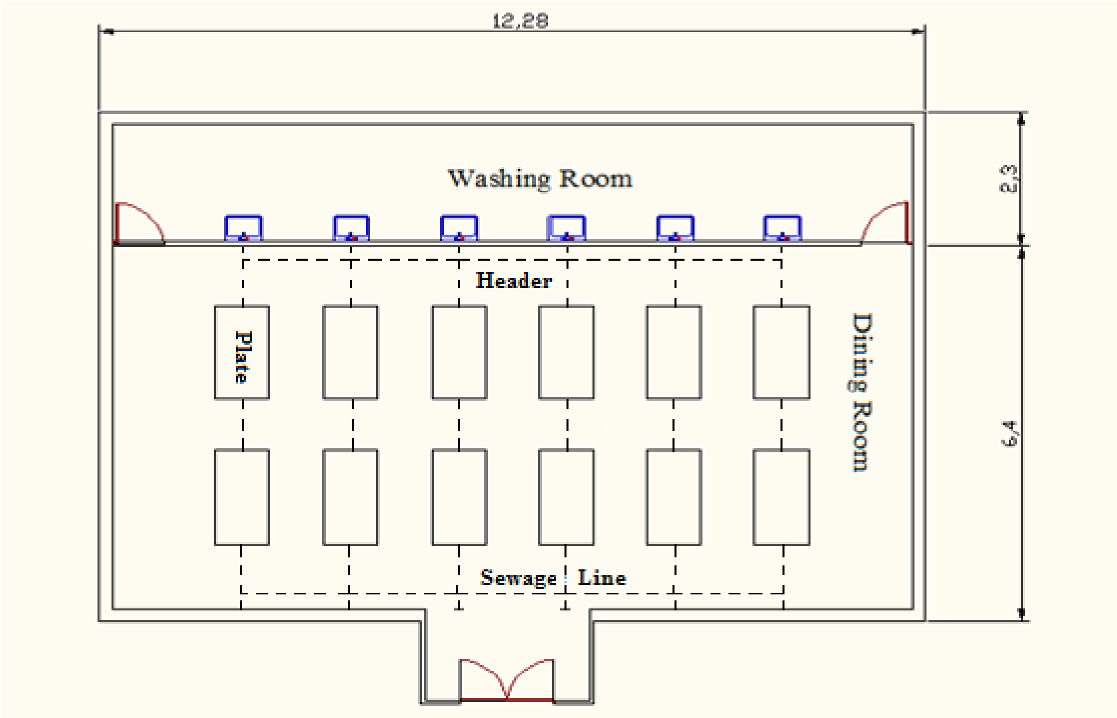

Figure 3. Drawing of the restaurant.

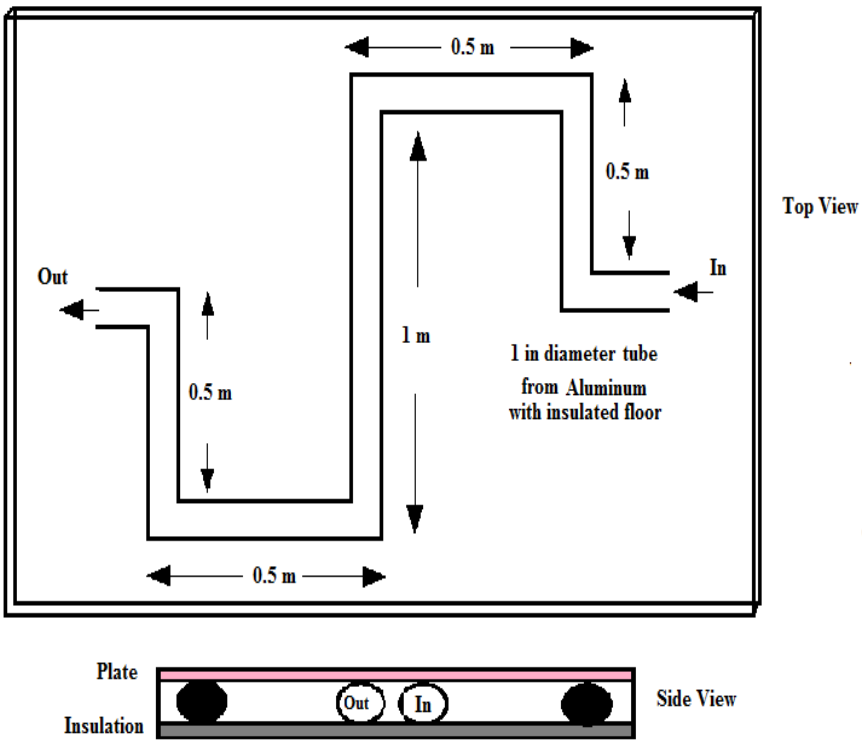

Figure 4. Design of heat exchanger used for heat recovery system.

4. Results and Discussion

The mathematical procedure of the calculation is done using the FORTRAN program where the flow properties at the interface are defined. The main equations were solved for each heat exchanger with its appropriate conditions. The flow properties at the entrance to the upper stage of heat exchanger are shown in Table 1.

Table 1. Characteristics of the fluid flow.

Item	Value
Volume flow rate	5.0E-05 m^3/s
Specific heat (Cp)	4180.0 J/kg.K
Dynamic viscosity (μ)	4.71E-04 kg/m.s
Thermal conductivity (k)	0.651 W/m.K
Density (ρ)	985.0 kg/ m^3
Inlet temperature (Ti)	45.0 ^oC
Exit temperature (To)	20.0 ^oC
Wall temperature (Tw)	20.0 ^oC
Efficiency (η)	0.7

The data is recorded over the winter for several months. Fig. 5 shows the variation of wastewater temperature according to ambient influence during the winter [16]. The temperature of waste water is measured at the entrance to the heat exchanger for several randomly days during the winter season.

Fig. 6 represents the variation of heating load during the winter, where this load is variable according to the ambient conditions. For the existing case, without heat recovery (HR) system, the heating load is measured experimentally depending on the comfortable conditions required by the occupants. It was about 15-24 Tons. While for the proposed case, includes heat recovery (HR) system, the heating load is calculated numerically. It was about 8-19 Tons. There is an acceptable reduction in the heating load by 3-8 Tons.

Fig. 7 represents the value of heating load through the 27^{th} of January 2014. It could say that the load is fluctuated between 24 Tons at early morning to 18 Tons at evening for the case without heat recovery, while for the case with heat recovery system; the load is fluctuated between 15-19 Tons.

Similarly, Fig. 8 represents the value of heating load through the 4^{th} of March 2014. Since the weather is moderate, so the load is fluctuated between 10 Tons at early morning to 7 Tons at evening for the case with heat recovery system.

Fig. 9 represents the value of heat recovery that calculated for the suggested system. Naturally, that the value of heat recovery load is grow up with efficient system. Generally, it is observed that 5 Tons of heating load could be satisfied with an efficiency of 0.7 using suitable system and sufficient insulator down and side the radiator.

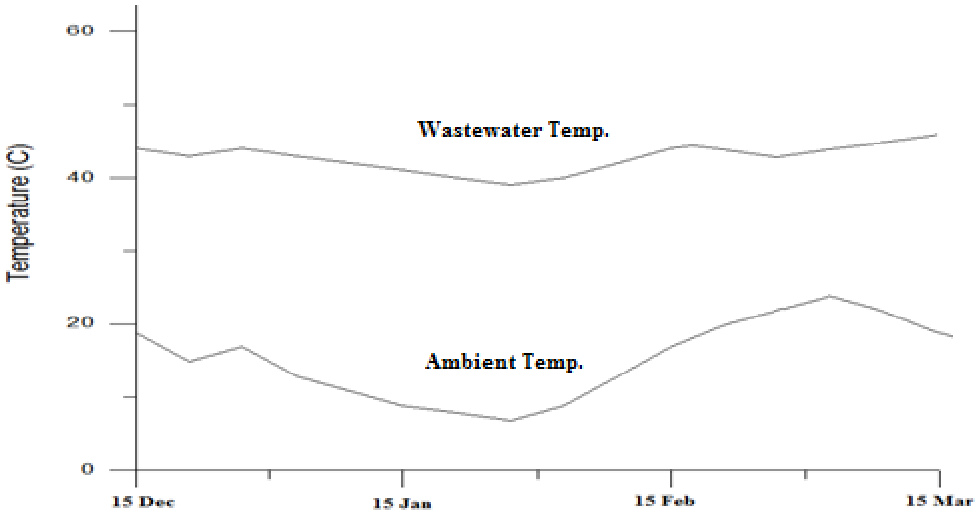

Figure 5. Variation of temperature during winter 2015

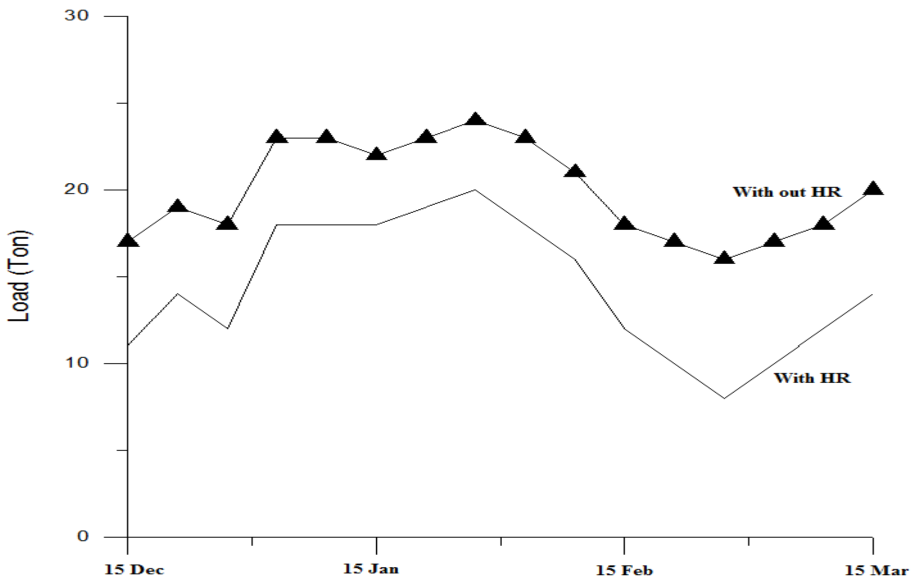

Figure 6. Variation of heating load during winter 2015

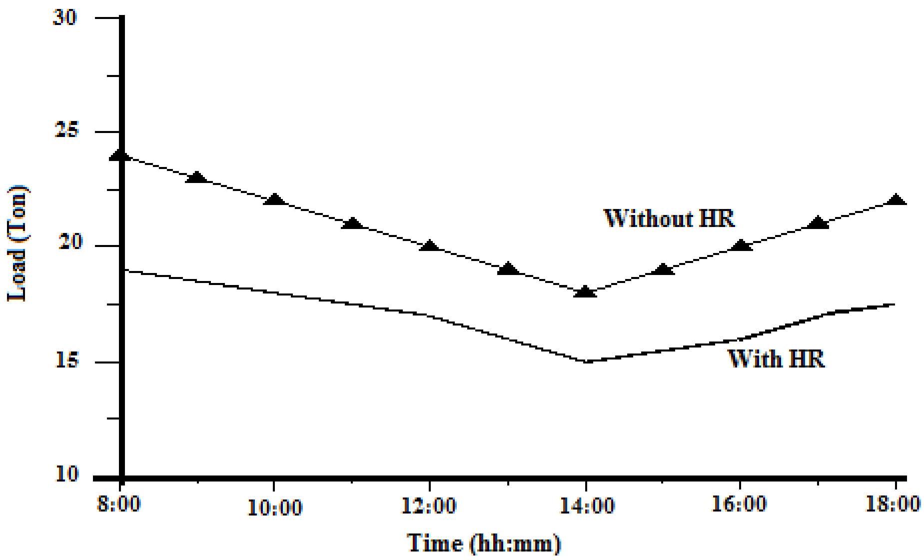

Figure 7. Variation of heating load on 27th of January 2015

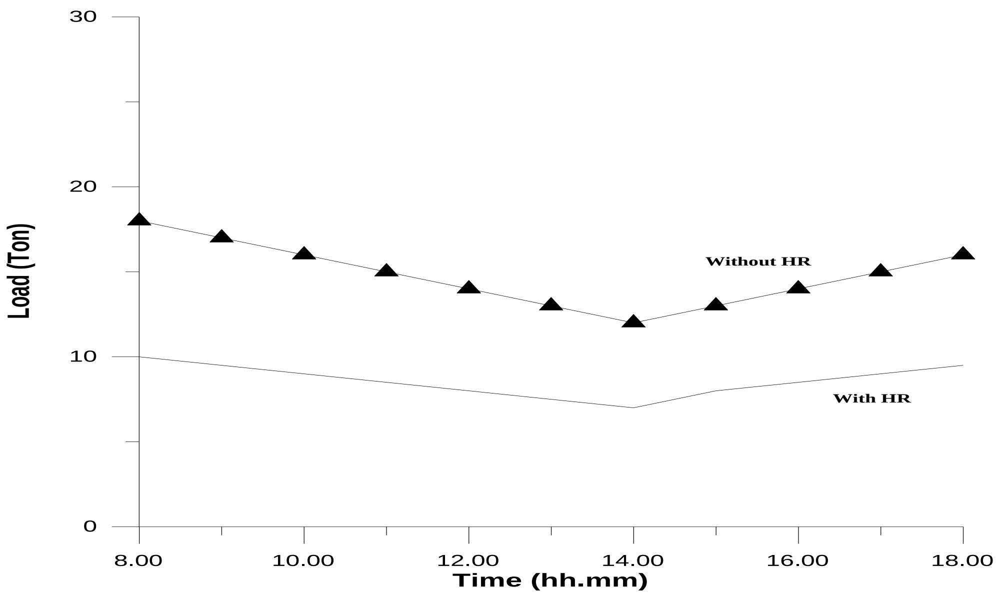

Figure 8. Variation of heating load on 4th of March 2015

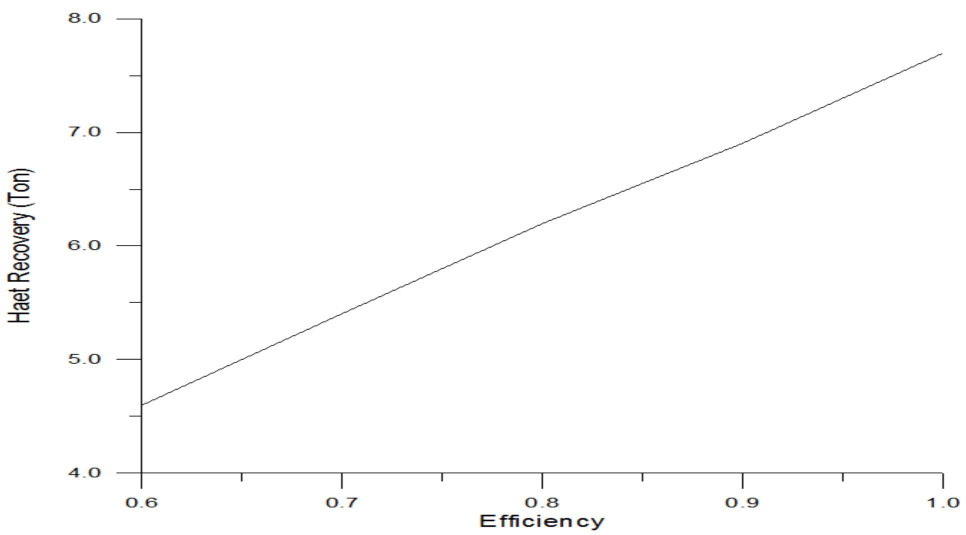

Figure 9. Influence of system efficiency on the heat recovery (January)

5. Conclusions

Generally, there are several results could be noticed from the research

1- The proposed system can be used to heat a restaurant as well as washing place.
2- This system is an environmentally friendly, energy saving and cost effective.
3- This technology within the system routes the passive energy conservation.
4- The proposed HR system can supply up to 8 Tons of heating load and will reduce electrical energy used to heat the place up to 44%.
5- The mentioned values are variables according to the environmental conditions.

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