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Original Research

Exploring the Performance, Simulation, Design, and Construction of a Closed Solar Swimming Pool in Kirkuk City

Fayadh M. Abed [1,*], Hussein Hayder Mohammed Ali [2], Nursan Bayraktar [2]

[1] Mechanical Engineering Department, Faculty of Engineering, Tikrit University, 34001 Tikrit, Iraq
[2] Northern Technical University/Technical College of Engineering, 36001 Kirkuk, Iraq; hussein_kahia@ntu.edu.iq (H. H. M. Ali); nursanbayrakdar@ntu.edu.iq (N. Bayraktar)

* Correspondence: Fayadh_moahmed@tu.edu.iq

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Abstract

Indoor swimming pools are sports or entertainment facilities that require substantial energy to heat the pool water and maintain a comfortable atmosphere in compliance with international standards. However, traditional methods of heating swimming pools using fuels or electricity often result in high operational costs and environmental pollution. To address these challenges, solar water heating has emerged as the most significant and environmentally friendly technology. Consequently, the construction of solar-powered swimming pools has become a prominent issue, drawing considerable attention from governments worldwide. Solar energy is currently being utilized in various applications, with water heating in residential settings being one of the most popular ones. Iraq, known for its high solar energy potential, stands to benefit greatly from adopting and designing solar swimming pools. The proposed design incorporates essential components such as the swimming pool, pump, filter, control valves, and the solar collector. This study explores the influence of flow rate on the solar collector's performance and its relationship with pool size under varying weather conditions in Kirkuk city. The month of February, characterized by lower solar radiation intensity and air temperature, was selected for the investigation. This study provides insights into heating indoor swimming pools using solar energy, examining the types of solar collectors, filters, and pumps involved. By offering guidance in the system design process, our research can be instrumental in facilitating the installation of such systems.

Keywords: indoor swimming pools, solar energy, swimming pool heating, thermal calculations

1. Introduction

Swimming pools are a widely enjoyed leisure activity worldwide, and it is crucial to have indoor pool structures with efficient heating systems for use during winter months, ensuring a pleasant experience for swimmers. The energy required to heat indoor swimming pools is significant, given their role as major sports and recreational facilities. Heating the pool area and providing hot water for other services necessitate addressing heat loss. Therefore, finding a heat source that meets requirements is essential, as traditional heating systems, fueled by either electricity or conventional fuels, are environmentally unfriendly and economically inefficient (Haddy et al., 2021). Moreover, these traditional systems contribute to climate change and dependence on fossil fuels (Li et al., 2021). Recognizing these issues, there is a growing focus on exploring potential renewable energy solutions that can reduce the impact of traditional systems, such as solar techniques, while minimizing carbon dioxide emissions (Natali et al., 2020).

According to the International Swimming Federation, the water temperature in Olympic swimming pools is regulated to 25–28 °C (FINA, 2017). The American Red Cross recommends a temperature between 25 and 28 °C for sports swimming and 27 °C for recreational swimming. Although setting water temperature limits in residential pools is a good practice, these values serve as guidelines for individual preferences and considerations related to human health, well-being, and comfort (Starke et al., 2017).

In indoor swimming pools, a common challenge is not only to maintain an acceptable water temperature but also to ensure comfortable indoor conditions. Water evaporation increases indoor humidity, requiring additional ventilation (Rajagopalan & Jamei, 2015). The primary issue with heating enclosed swimming pools lies in the high expenses associated with conventional heating approaches, such as electrical heaters (Mousia & Dimoudi, 2015). The Spanish National Sports Council recommends a water temperature of 26 ± 1 °C (Consejo Superior de Deportes, 2005). In practice, many public swimming pools operate at 28 °C, which is the temperature considered in this study.

Various technologies are employed to heat indoor pools during winter, including passive and active approaches. Passive solutions utilize thermal insulating covers to minimize heat loss when the pool is covered. Active heat-saving strategies are designed to meet the pool's thermal requirements. Studies on passive strategies have shown that using a cover significantly reduces heat loss in the pool (Yadav & Tiwari, 1987). Additionally, research has demonstrated that transparent covers are more effective than opaque covers in raising water temperature by allowing for increased solar radiation absorption (Francey et al., 1980).

Active approaches include the use of air source heat pumps for pool heating, as demonstrated in a hotel in Hong Kong. The study analyzed the energy savings and life cycle costs of the system, revealing an average energy savings and economic savings ratio of 72.8% and 81.1%, respectively, compared to traditional heating systems (Chan & Lam, 2003; Lam & Chan, 2001). Water evaporation is the primary cause of heat loss in pool heating, accounting for over 60% of the total energy requirement (Zuccari et al., 2017). Even when the facility is closed and not in use, evaporation continues to occur, necessitating a readily accessible power source throughout the year. Furthermore, given that the pool area needs to be warmer than the water, including the pool surroundings, there is a significant demand for heating and domestic hot water for showers. Due to the complexity of thermal mechanisms in indoor pools, specialized expertise is required to enhance energy efficiency and reduce costs (Marín & García-Cascales, 2020).

To determine the impact of different solar collector types on the solar fraction factor for heating an indoor swimming pool in Baghdad, Iraq (located at 33.32° N, 44.32° E), various flat-plate solar collectors were used, including black and selective absorber covers, as well as a pool absorber (polyvinyl chloride - PVC) type (Haddy & Hassen, 2021). The results indicated that the highest solar fraction factor values were obtained when using two selective absorber covers, while the lowest values were achieved with the pool absorber. The experiments were conducted during the winter season (November, December, January, and February). Simulation results for a 10,000 m^2 pool surface area and a mass storage tank with 25 kg/m^2 showed a solar fraction factor of 84% in November using two selective absorber covers, and 50% in February using the pool absorber.

Numerous recent studies have focused on solar swimming pool development, including research on solar heat pumps, thermal losses in solar heated pools, the impact of flow rates on solar collector performance, and the financial feasibility of solar-powered swimming pools. Other studies have aimed to improve the efficiency and performance of solar collectors for both indoor and outdoor pool heating. This current study encompasses the design and construction of a solar heated swimming pool, considering the climatic conditions in the city of Kirkuk, as well as the design and operational factors affecting the system, such as atmospheric temperature, solar radiation, wind speed, wind direction, relative humidity, and sky clarity. The design specifies the type and size of the solar collector necessary to meet the water heating requirements of the pool. It also involves calculating heat loss rates from the pool, selecting the appropriate pump type and size for water circulation, and determining the type, size, and number of filters required for water purification, all tailored to the specific climate conditions of the study site. This paper aims to investigate the economic feasibility, improve, and design a solar heating system for indoor swimming pools. The essay is organized as follows: Section 2 describes the approach used in this study, followed by a description of the system. Section 3 presents the findings and discussions, including the results. Finally, Section 4 concludes the paper by providing a summary of the key points discussed.

2. Methodology

The aim of this research is to design and develop an indoor solar swimming pool for Kirkuk city (latitude 35.5° N, longitude 44.4° E) that utilizes a specialized solar collector to enhance the heating system. To achieve this objective, a solar flat plate with a rotated plastic (flexible) pipe connected to a pump and filter, as depicted in Figure 1, is utilized. This collector transfers heat to two water-filled tanks. The flow rate of water inside the plastic pipe is carefully chosen, and the flat plate is painted black to maximize solar radiation absorption.

To evaluate the heating performance, three different flow rates were selected, and six thermocouple sensors were strategically placed at various locations to monitor temperature profiles. The pump flow rate and filter type and size were chosen in accordance with international swimming pool standards. The effectiveness of the solar collector system was assessed through an experimental investigation conducted in Kirkuk (Iraq), using real-time data.

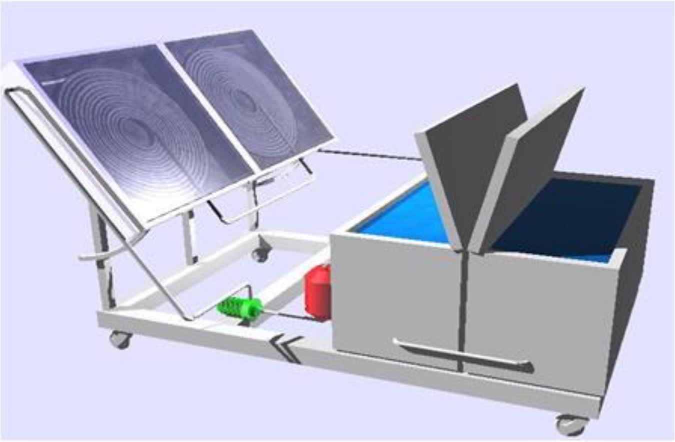

Fig. 1. Schematic drawing of solar swimming pool prototype.

2.1. Description of the system

Figure 2 illustrates the schematic view of the concentrating solar collector integrated with the swimming pool tank, as well as the accompanying equipment such as the pump and filter. A circular flexible pipe is securely attached to the flat plate and covered with transparent nylon to enhance energy absorption within the pipe and minimize thermal resistance in the gap area between the plate and the cover. Aluminum was chosen as the material for the plate due to its favorable physical properties. The distance between the plate and the absorbent cap should range between 0.5% and 2% of the collecting area (Dymond & Kutscher, 1997).

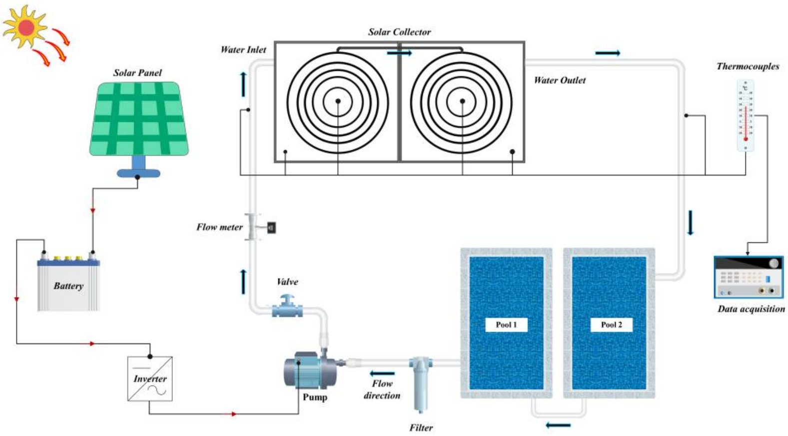

Fig. 2. Schematic representation of solar swimming pool systems.

2.1.1. *Solar collector*

The choice and design of a solar collector for heating pool water are influenced by two factors: the size of the pool and the amount of energy required, which also depend on the desired design temperature. The design temperature should be selected based on the type of pool usage and in accordance with standard criteria, as outlined in Table 1.

The solar collector comprises a 2 cm diameter flexible plastic tube that can be shaped into concentric rings, as depicted in Figure 3. Depending on the site's latitude, the solar collector is installed facing south, inclined at a 45° angle from the horizon, and positioned 40 cm above the ground. The plastic tube, readily available in the local market at an affordable price, possesses efficient heat absorption properties through its walls. The tube's length is 100 meters, a crucial factor in maximizing heat absorption and raising the temperature of the pool water.

The rings of the tube are affixed to a wooden base with dimensions of 260 cm in length and 120 cm in width, painted black to enhance heat absorption. To minimize heat losses, a layer of glass wool insulation is applied on all sides, except for the front exposed to solar radiation. The second layer above the insulation, where the coiled tube is fixed, consists of aluminum foil, matching the dimensions of the wooden box. The aluminum foil is painted with a dark black coating to maximize solar radiation absorption. Aluminum was chosen due to its lightweight nature and relatively low cost.

A polyethylene nylon cover is placed on the inclined surface of the solar collector, with a confined distance of 5 cm between the cover and the absorption surface. This distance is chosen to provide optimal insulation for heat transfer through convection and radiation from the relatively hot absorption surface. The components of the solar collector, including the plastic pipe, insulation, case, aluminum plate, and the method of fixation, are illustrated in Figures 4 and 5.

Table 1. Standards temperature of swimming pool (Garnysz-Rachtan & Zapałowicz, 2018).

Relative humidity, %	Water temperature, °C	Air temperature, °C	Type of pool
Recreational	24 to 29	24 to 29	50 to 60
Therapeutic	27 to 29	29 to 35	50 to 60
Competition	26 to 29	24 to 28	50 to 60
Diving	27 to 29	27 to 32	50 to 60
Elderly swimmers	29 to 29	29 to 32	50 to 60
Hotel	28 to 29	28 to 30	50 to 60
Whirlpool/Spa	27 to 29	36 to 40	50 to 60

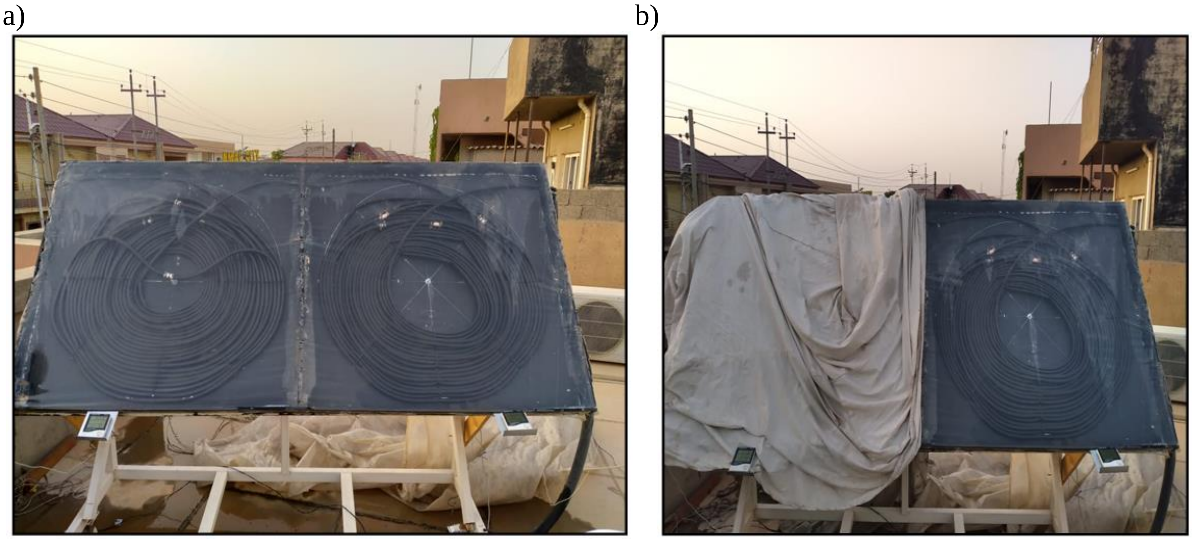

Fig. 3. Solar collector cases: a) 100% used, b) 50% is used.

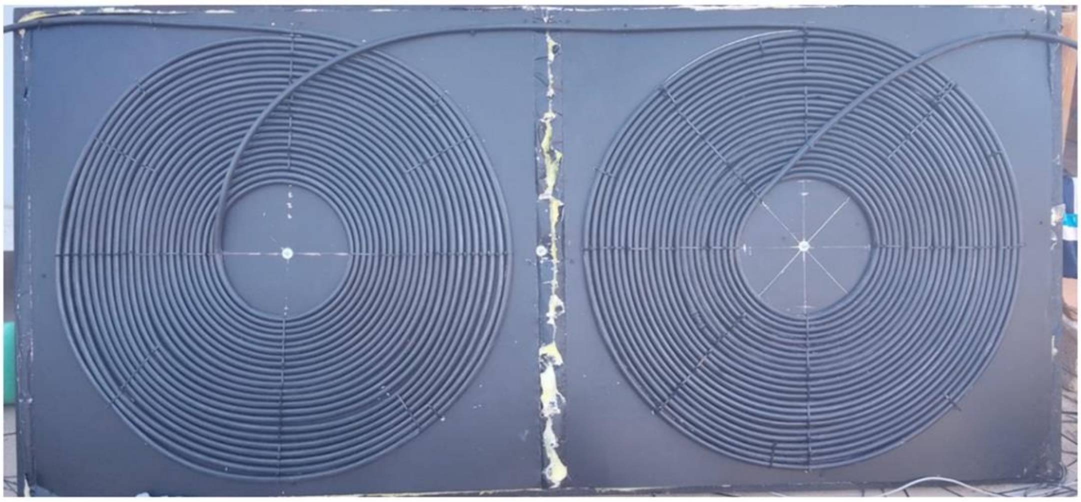

Fig. 4. Type of solar collector (plastic pipe, aminume plate and the way of installing).

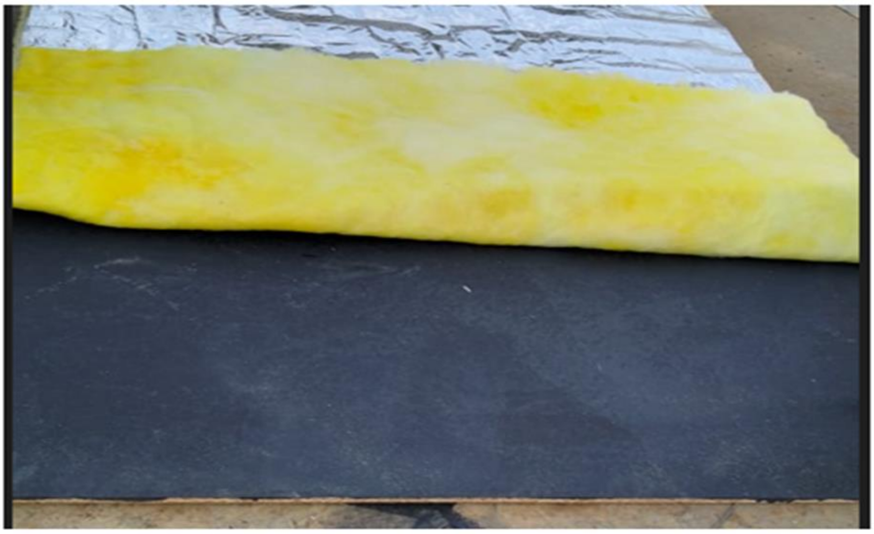

Fig. 5. Case of solar collector, insulation and aluminum plate.

2.1.2. Design calculations for swimming pools

When designing a swimming pool, it is essential to determine its volume, perimeter, and average depth. Additionally, the selection of the turnover period depends on the type of pool, as indicated in Table 2. The subsequent calculations aim to establish the design parameters for operating a swimming pool in accordance with international standards. This includes selecting the appropriate type of solar collectors based on the study area's weather conditions and determining the operational variables. The required collector area is calculated based on the energy needed for heating, followed by determining the operational duration, pump type, filter size, and filter type. The design of the swimming pool takes into account the specific weather conditions of the study area, incorporating measurements such as hourly solar radiation, air temperature, relative humidity, number of cloudy days, and wind speed, as outlined in Table 3.

Table 2. Swimming pool type and turnover period (ASHRAE, 2017).

Type of pool	Turnover period, hr.
Spa	0.1 – 0.25
Leisure water bubble pools	0.1 – 0.33
Teaching pools	0.5 – 1.0
Waterslide splash pools	0.5 – 1.0
Hydrotherapy pools	0.5 – 1.0
Leisure water up to 0.5 m deep	0.2 – 0.6
Leisure water up to 0.5–1 m deep	0.6 – 1.2
Leisure water over 1.5 m deep	1.8 – 2.5
Conventional public pools up to 25 m long with a 1 m shallow end	2.5 – 3.0
Competition pools 50 m long	3.0 – 4.5
Diving pools	4.0 – 8.0
Domestic pools	4.0 – 8.0

Table 3. Weather conditions at Kirkuk city 2021 (RH – relative humidity, Ta – air temperature, GH – hourly solar radiation).

Month	RH, %	Ta, °C	GH, kWh	Black day	Wind speed, km/h
January	69	9.9	2.66	11	11
February	65	11.9	3.15	8	9
March	65	13.7	3.9	9	12
April	61	17.9	5.18	8	13
May	32	28.9	6.98	6	11
June	19	36.5	8.2	0	8
July	19	36.7	8.3	0	9
August	19	37.7	6.4	0	8
September	20	32.6	5.5	2	12
October	32	26.6	3.6	6	10
November	33	17.2	2.6	5	11
December	66	13.1	1.6	8	13

The energy required for heating $Q_{\text{reg.}}$ is calculated based on the mathematical equation for heating as follows (Al Aboushi & Raed, 2015):

$$Q_{\text{req.}} = \frac{\text{volume} \cdot \text{density}\,(\text{T}_{\text{final}} - \text{T}_{\text{initial}})}{860 \cdot \text{hr.}} \tag{1}$$

According to the pool volume and turnover period the pump flow rate is estimated as:

$$\text{Pump flow rate (m}^3\text{/h)} = \frac{\text{Volume of Pool (m}^3\text{)}}{\text{Pool turnover rate(h)}} \tag{2}$$

2.1.3. Sizing filtration and circulation systems

The selection of the filter type and size depends on the circulating rate of the pool system and the filtration velocity. The cross-sectional area of the filter is calculated accordingly, considering the chosen diameter. The filter specifications can be determined based on the pool flow rate and the load surface factor. It is recommended that this factor does not exceed 40 $\text{m}^3/\text{m}^2\cdot\text{hr}$. The pool flow rate Q can be calculated as follows:

$$Q = \frac{\text{volume of pool}}{\text{turnover period}} \tag{3}$$

and the surface load factor is:

$$\text{Surface load} = \frac{Q\,(\frac{\text{m}^3}{\text{h}})}{\text{filter area } A_{\text{f}}(\text{m}^2)} \tag{4}$$

Once the filter area A_{f} has been calculated, the corresponding filter diameter is determined, and the appropriate filter type is selected.

2.1.4. Pump

Solar pool heaters are typically integrated with the plumbing systems of the pool. The heater, as well as lint, hair, and leaf filters, are commonly installed before the pump. This configuration allows the pump to draw water from the skimmer and main drains, pass it through the filter, and return it to the pool. While manual flow control or time clock control methods are simple and affordable, they do have their disadvantages. Therefore, automatic flow controls are often employed. The selection of the pump is determined based on factors such as swimming pool size, filter size, and the turnover period specified in international standards, as illustrated in Table 4.

Table 4. Technical specifications of pump.

Type	**Total head, m**	**Engine net power, kW**	**Maximum output capacity, L/min**	**Engine speed, rpm**	**Maximum operation temperature, °C**
QB60	27	0.41	30	2850	45

3. Real-time experimental investigation

3.1. Meteorological conditions of experimental site

All tests were conducted during sunny winter days in the Kirkuk city region (latitude 35.5° N, longitude 44.4° E), Iraq. Six thermocouples were strategically placed in different locations, as depicted in Figure 6. These locations include the inlet and outlet of the pipe, the surface, middle, and bottom of the tank water, as well as before the pump and after the filter. Ambient conditions such as temperature, relative humidity, and irradiation were recorded from 8:00 a.m. to 5:00 p.m. local time throughout the month of February 2022. Temperature and humidity readings were recorded at 30-minute intervals.

Fig. 6. Solar collector and thermocouple sensor location.

3.2. Experimental error and uncertainty analysis

A digital data logger was connected to a computer to automatically record all the data. The water temperature at various points and weather conditions such as air temperature, relative humidity, and solar radiation were recorded. Solar intensity was measured using a calibrated pyrometer, while capacitive sensors were used for relative humidity measurements. K-type calibrated thermocouples were utilized for temperature measurements. Each modification was calibrated according to the established protocol. The uncertainties of the measuring instruments are provided in Table 5. Through the aforementioned approach, the greatest uncertainty was determined to be less than 5% for all parameters. Assuming that the measured parameters T_1, T_2, T_3, T_m, T_{m+1}, T_n are measured with uncertainties δT_1, δT_2, δT_3, ..., δT_m, δT_{m+1}, δT_n, where n is the total number of measurements. The fractional uncertainty of T can be expressed as (Abed et al., 2014; Islam et al., 2021):

$$\frac{\delta T}{T} = \sqrt{\left(\frac{\delta T_1}{T_1}\right)^2 + \left(\frac{\delta T_2}{T_2}\right)^2 + \left(\frac{\delta T_3}{T_3}\right)^2 + \cdots + \left(\frac{\delta T_n}{T_n}\right)^2 + \left(\frac{\delta T_{n+1}}{T_{n+1}}\right)^2 + \left(\frac{\delta T_m}{T_m}\right)^2} \tag{5}$$

The trustworthiness of the measured data is indicated by uncertainty values in this range.

Table 5. Accuracy of instruments, measurement ranges and maximum error margin.

Instrument	Operational range	Max. error	Accuracy
Thermocouple (K-type)	0 to 1250 °C	3.08%	±1.1
Digital data logger	−250 to 1000 °C	6.19%	±2%
Solar power meter TM-207	0-1999 W/m^2	0.10 W/m^2·°C	±5%
Anemometer testo 425	0-20 m/s	6.58%	±5%

4. Results and discussion

Practical tests were conducted under the weather conditions of Kirkuk city, located at 35.4656° N, 44.3804° E. The experiments took place during the months of February, March, and April. During the summer season, temperatures exceeded 35 °C, resulting in intense solar radiation. The objective of the design was to heat the water in the swimming pool and raise its temperature to the desired limit. This allows for a thorough evaluation of the proposed design's performance. The following sections discuss the impacts of operational weather conditions.

4.1. Ambient condition

Based on data from various sources (Abed, 2018; Al-Douri & Abed, 2016), Iraq's deserts experience a peak power density of 2310 kW/m^2/year. Regarding the geographical location of Kirkuk city, measurements indicate that the average solar radiation ranges from 3.0 to 6.4 kWh/m^2/day. Additionally, the average air temperature falls within the range of 10 to 45 °C, with atmospheric humidity levels ranging from 13% to 44%. Considering these environmental parameters at the experimental study location, all calculations and tests were conducted, as depicted in Figure 7.

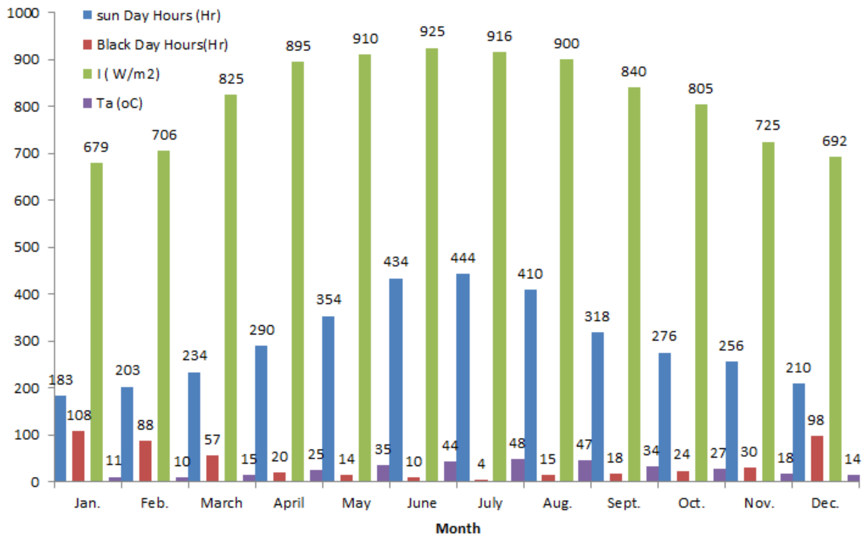

Fig. 7. Yearly data of average weather conditions at site of test 2021.

4.2. The global solar radiation and ambient temperature effects

The year-round ambient temperature and solar radiation data for the test site are obtained from Abed et al. (2014). In September, the maximum daily radiation reaches 25 MJ/m^2, while in January, the minimum daily radiation is 10 kJ/m^2. The maximum and minimum temperatures in September and January are 39 °C and 15 °C, respectively. Figure 8 illustrates the average test data profile of air temperature and humidity in Kirkuk city.

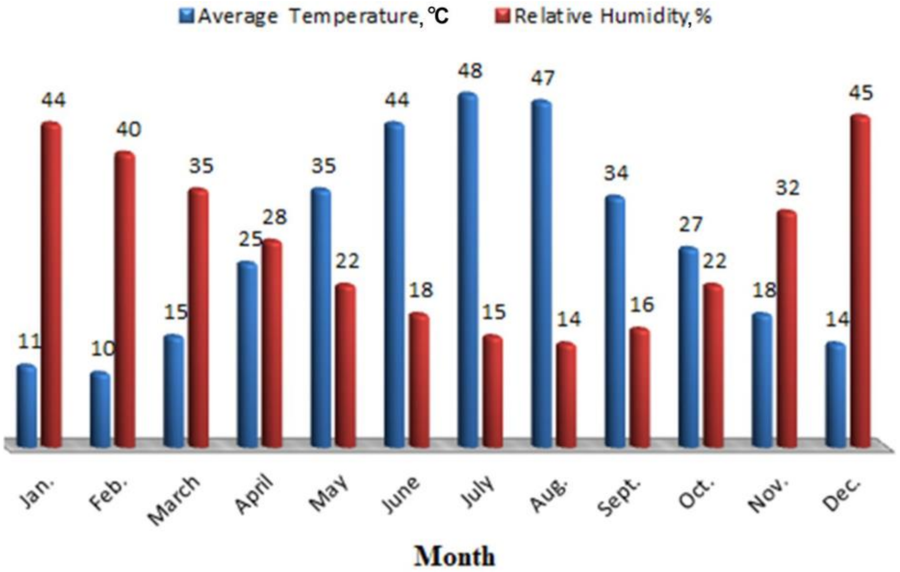

Fig. 8. The Kirkuk area's average monthly temperature and relative humidity.

To assess the impact of operational conditions on the performance of the proposed design for a solar indoor swimming pool, considering the size, type, and area of the solar collector, three cases were examined. The first case involved using both collectors, the second case used only one collector, and the third case utilized both collectors but with coverings. The flow rates tested in all cases were 1, 3, and 7 liters per minute (LPM). The experiments were conducted over a three-month period (February, March, and April) in accordance with the environmental conditions of the study area. These months were chosen to represent suitable conditions for operating winter swimming pools, allowing for an investigation of the amount of thermal energy required to heat the pool water according to international standards for indoor swimming pools.

The study primarily focused on evaluating the performance of the proposed solar collector. Three cases were tested, with the first case fully exposed to solar radiation, the second case partially exposed, and the third case completely blocked. The variables of air temperature and solar radiation significantly influenced the heat gained from the solar collector to warm the water flowing through the pipes installed on the collector plate. To achieve the desired level of pool water heating based on the proposed design, operational variables such as the water flow rate through the pump played a crucial role in achieving this objective.

4.3. The effect of flow rate on the heating of swimming pool water

A series of tests were conducted to examine the impact of flow rate on heating the aquarium water to the desired temperature under the weather conditions specific to the study area. The month of February was selected due to its lower temperatures and solar radiation levels, allowing for an assessment of the heat required to warm the pool water and the efficiency of the proposed solar collector design.

Three flow rate values of 1, 3, and 7 liters per minute were chosen, taking into consideration the relationship between circulation rate, pump volume, purification filter, swimming pool purification criteria, and the water volume in the basin. The collector design plays a vital role in the system, consisting of two interconnected centers as illustrated in Figure 4. For each flow rate, two test cases were conducted: one with both centers uncovered, and the other with a 50% cover placed on the collector. The purpose was to control the rise in heating temperature above the design limit.

Figure 9 demonstrates the effect of different flow rates (1, 3, and 7 LPM) using both collectors on increasing the pool water temperature. The volume of the pool was 685 liters, and the relationship with solar radiation intensity was observed over a 10-hour period throughout the day. The results revealed that the flow rate of 1 LPM achieved the highest increase in pool temperature, followed by the flow rates of 3 LPM and 7 LPM, respectively.

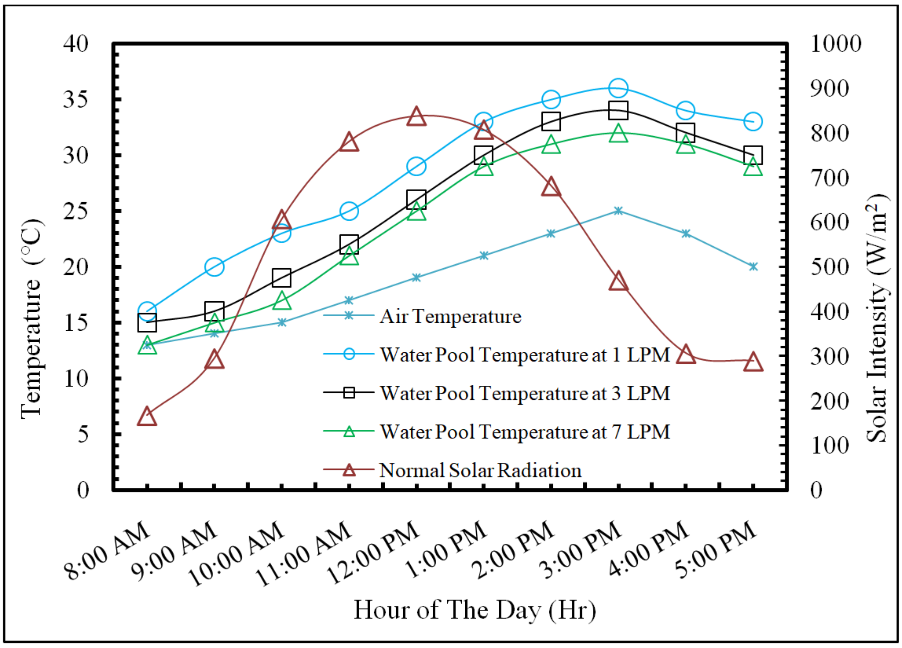

Fig. 9. Profile of the temperature change of the water swimming pool with time at different flow rates (1,3 and 7 LPM), in February 2022, with average solar radiation rate of 550 W/m^2 and an average ambient temperature of 20 °C.

4.4. The effect of the flow rate on the amount of heat gained for the swimming pool water

Figure 10 illustrates the heat capacity needed to warm the pool water using both collectors. The results indicated that lower flow rates corresponded to lower heat capacity requirements for achieving the desired temperature in the swimming pool water. This finding aligns with previous research by

Cunio and Sproul (2012). It is worth noting that the energy requirement is inversely proportional to the decrease in solar radiation intensity and the temperature of the swimming pool.

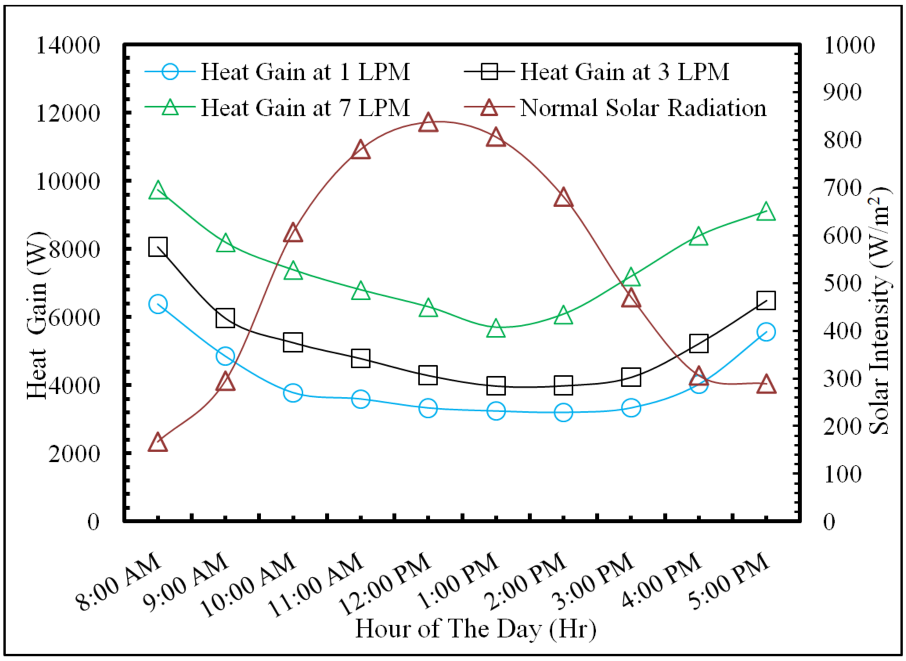

Fig. 10. Profile of heat gain water swimming pool with time at different flow rates (1,3 and 7 LPM), in February 2022, with average solar radiation rate of 550 W/m^2 and an average ambient temperature of 20 °C.

4.5. The effect of the flow rate on the amount of heat lost from the pool water

Figure 11 displays the heat losses experienced by the swimming pool water when utilizing both collectors, with a volume of 685 liters, and its relationship with solar radiation intensity over a 10-hour period. The results demonstrated that the magnitude of heat losses is dependent on the intensity of solar radiation absorbed by the collectors, decreasing as solar radiation decreases. This aligns with the understanding that losses tend to increase with rising temperatures, as observed by Tarrad (2017). Heat loss to the surrounding environment occurs when the pool temperature exceeds the ambient temperature.

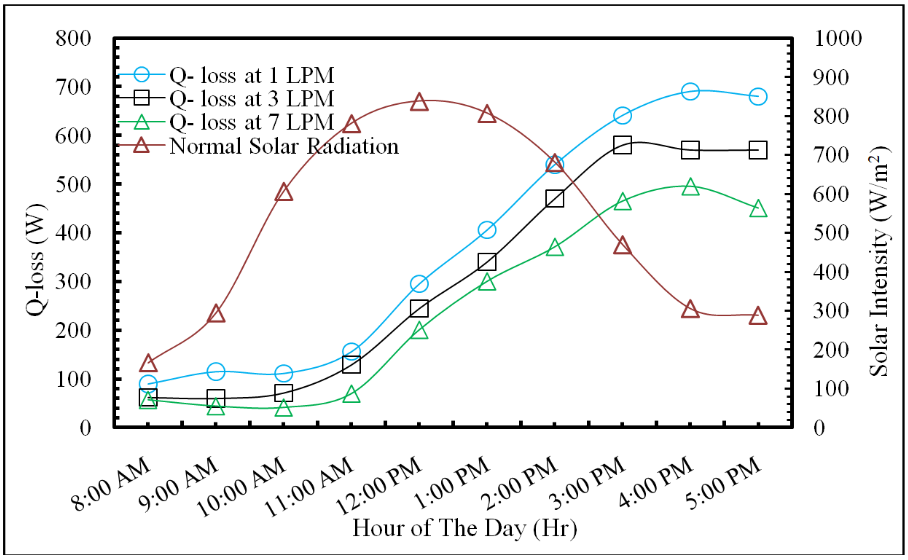

Fig. 11. Profile of heat losses of water swimming pool with time at different flow rates (1,3 and 7 LPM), in February 2022, with average solar radiation rate of 550 W/m^2 and an average ambient temperature of 20 °C

Figures 12a, 12b, and 12c present a comparison between the heat energy gained and lost from a swimming pool water with a volume of 685 liters under specific weather and operational conditions. By examining the curves of these two variables, we can observe the relationship between the quantities. This relationship is influenced by the temperature rise, where a smaller flow rate corresponds to a greater temperature increase but less heat gain. Conversely, a larger flow rate leads to less temperature rise but greater heat loss.

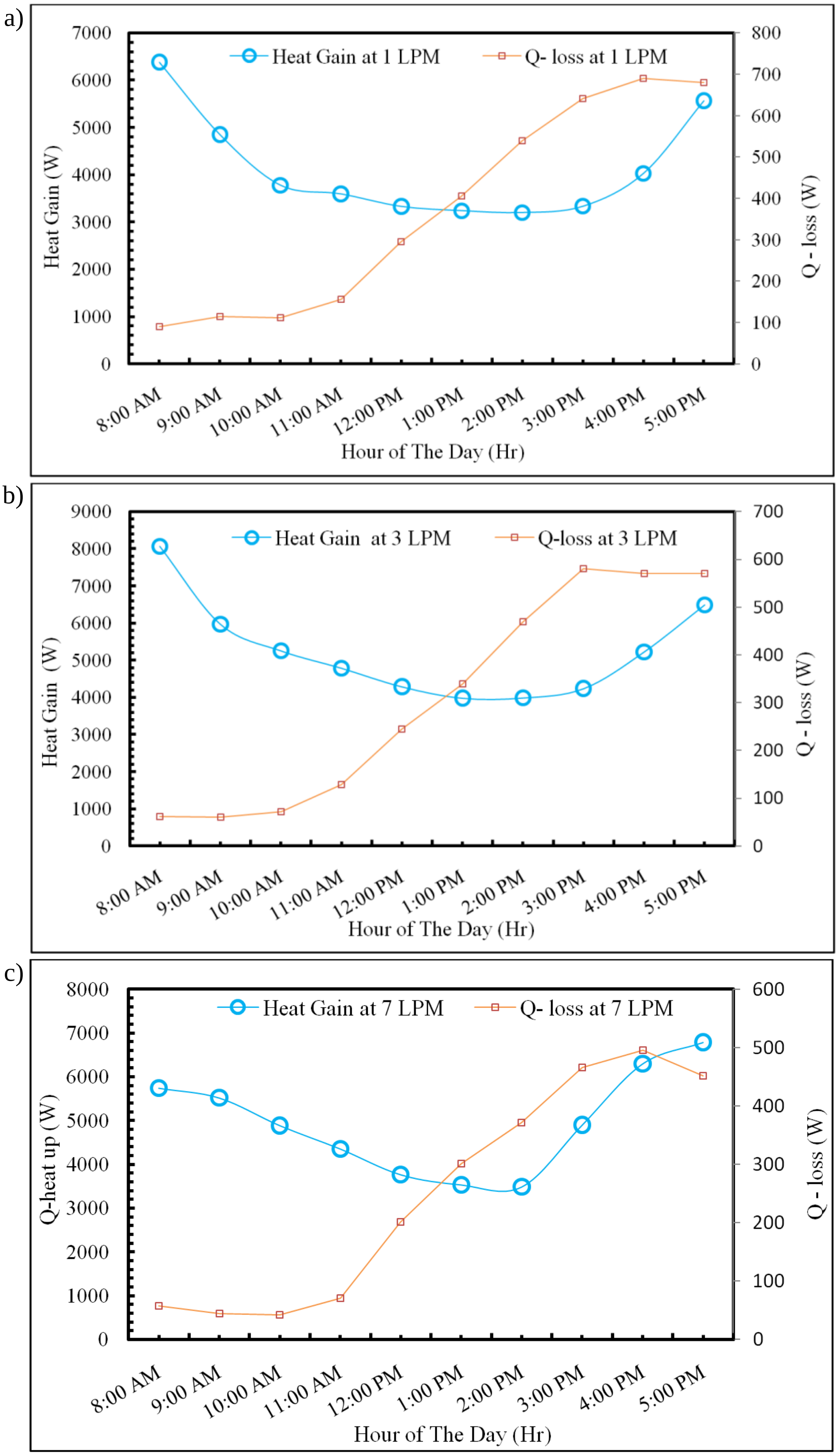

Fig. 12. Comparison of heat gain and losses with time at different flow rates: a) 1 LPM, b) 3 PM and c) 7 LPM, in February 2022, with average solar radiation rate of 550 W/m^2 and an average ambient temperature of 20 °C, without cover.

4.6. The effect of flow rate on the efficiency of solar collectors in heating the water of the swimming pool

Figure 13 illustrates that the efficiency of solar collectors rises with the increase in solar radiation intensity, peaking at 66% between the hours of 1 to 12 in the afternoon. The results also indicate that the efficiency of the solar collector increases as the flow rates decrease, aiming to raise the water temperature. This observation is consistent with the findings of researchers Aldeen et al. (2023), Amroune et al. (2021), Berkache et al. (2022), Poudyal and Bhattarai (2014) and Quader et al. (2023).

On the other hand, with the same conditions but 50% of collector is covered from the sun, the results show that the efficiency is 63% at flow rate 1 LPM and 59% at 7 LPM. As shown in Fig. 14.

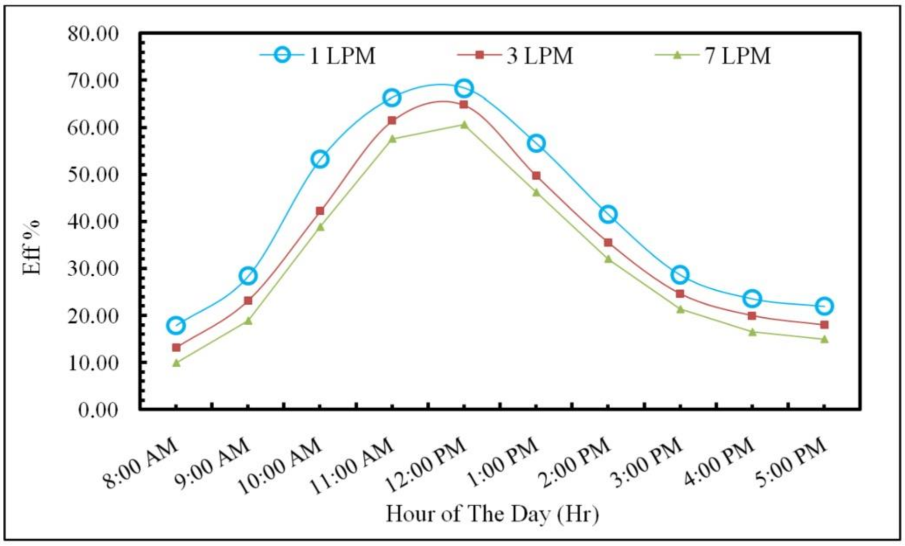

Fig. 13. Profile of collector efficiency time at different flow rates (1,3 and 7 LPM), in February 2022, with average solar radiation rate of 550 W/m^2 and an average ambient temperature of 20 °C, without cover.

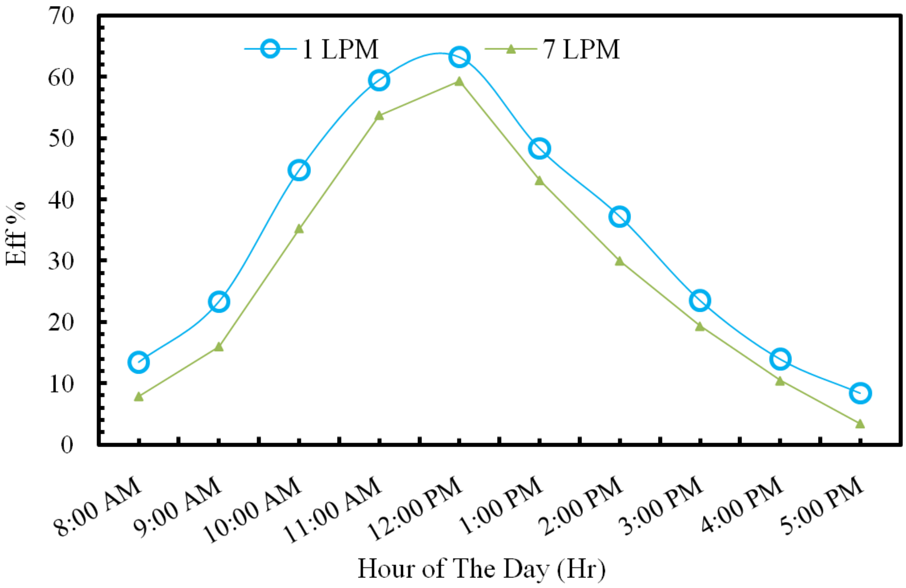

Fig. 14. Profile of collector efficiency time at different flow rates (1 and 7 LPM), in February 2022, with average solar radiation rate of 550 W/m^2 and an average ambient temperature of 20 °C, 50% covered.

5. Conclusion

The proposed design of the solar collector system can effectively fulfill the requirements for heating a swimming pool, offering additional advantages such as ease of construction, affordability, and reliability. When it comes to maintaining warm swimming pools, passive methods are the simplest and most cost-effective approach.

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Badanie Wydajności, Symulacja, Projektowanie i Budowa Zamkniętego Basenu Słonecznego w Mieście Kirkuk

Streszczenie

Kryte pływalnie to obiekty sportowe lub rozrywkowe, które wymagają znacznej energii do podgrzania wody w basenie i utrzymania komfortowej atmosfery zgodnie z międzynarodowymi standardami. Tradycyjne metody ogrzewania basenów za pomocą paliw lub energii elektrycznej często wiążą się z wysokimi kosztami eksploatacji i zanieczyszczeniem środowiska. Aby sprostać tym wyzwaniom, słoneczne ogrzewanie wody stało się najbardziej znaczącą i przyjazną dla środowiska technologią. Budowa basenów zasilanych energią słoneczną stała się ważną kwestią, przyciągając znaczną uwagę rządów na całym świecie. Energia słoneczna jest obecnie wykorzystywana w różnych zastosowaniach, a ogrzewanie wody w budynkach mieszkalnych jest jednym z najpopularniejszych. Irak, znany ze swojego wysokiego potencjału energii słonecznej, może odnieść ogromne korzyści z budowy basenów słonecznych. Proponowany projekt obejmuje podstawowe elementy takie jak basen, pompa, filtr, zawory regulacyjne i kolektor słoneczny. Zbadano wpływ natężenia przepływu na wydajność kolektora słonecznego i jego związek z wielkością basenu w różnych warunkach pogodowych w mieście Kirkuk. Do badań wybrano miesiąc luty, charakteryzujący się niskim natężeniem promieniowania słonecznego i temperaturą powietrza. Wyniki badań dostarczyły informacji na temat ogrzewania basenów krytych za pomocą energii słonecznej z uwzględnieniem różnych rodzajów kolektorów słonecznych, filtrów i pomp. Opracowane wskazówki w zakresie projektowania systemu ogrzewania basenowego mogą odegrać kluczową rolę w ułatwieniu instalacji takich systemów.

Słowa kluczowe: kryte pływalnie, energia słoneczna, ogrzewanie basenu, obliczenia cieplne