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**EXPERIMENTAL INVESTIGATION EFFECT OF USING NANO
FLUID ON THERMAL PERFORMANCE IN SOLAR COLLECTORS**

MASTER THESIS

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PREFACE

The reason for using solar energy as an alternative energy is the perceived scarcity of fossil fuels and their limitations in terms of quantity and region, with their high cost. The State of Iraq is rich in its possession of petroleum energy and its stored reserves among the countries of the region. Nevertheless, we must point out that the solar radiation falling on the geography of Iraq throughout the seasons of the year is also another blessing of God's grace that has not been properly exploited along with other energies. Solar energy is the most economical and environmentally friendly of the available energies. Studies and scientific research have begun in the field of developing and improving the use of solar energy and its applications, especially in the areas of converting it into electrical or thermal energy through nanotechnology. A modest scientific contribution by me to the technology of using Nano silver as a liquid to transfer heat better than traditional liquids hoping to benefit from it in the future.

You have always supported me with great dedication, my distinguished supervisor, Dr. Osama Demir, under his supervision, follow-up, and continuous advice. I also extend my thanks to Dr. Samir, the second supervisor, for supporting me in conducting laboratory work at Soran University, and Azeez Abdullah Barzinjy at Tishk University, and for sending them the results of the work and laboratory results for publication in a solid international scientific journal. And continuous thanks to the presidents of Soran and Tishek universities, Dr. Mosleh, Dr. Idris Hadi, and the head of the central laboratories at Soran University, Dr.Kamal for allowing the space to facilitate administrative, scientific and financial matters.

The first and last support and the great credit for my endurance during the study period is my dear wife and the rest of my family.

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LIST OF SYMBOLS

C_p	: Specific heat, J/kg K
d	: Nanoparticle diameter, m
D	: Tube diameter, m
f	: Friction factor
h	: Heat transfer coefficient, W/m ² K
k	: Thermal conductivity, W/m K
$\dot{m}$	: Mass flow rate, kg/s
ΔP	: Pressure drop, Pa
q	: Heat flux, W/m ²
Q	: Heat transfer rate, W
T	: Temperature, C
Φ	: Volume fraction
ρ	: Density, kg/m ³
μ	: Viscosity, kg/ms

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NANO AKIŞKAN KULLANIMININ GÜNEŞ KOLLEKTÖRÜNDE TERMAL PERFORMANS ÜZERİNE ETKİSİ- DENEYSEL ARAŞTIRMA

ÖZET

Araştırmamızda ilk olarak su ısıtmada tasarım ve performans, düz panel kollektörlerde ısı transferi süreci ve ikinci olarak güneş radyasyonunun hesaplanması açısından güneş enerjisi teknolojileri üzerine odaklanıyoruz ve ardından su kullanan geleneksel güneş enerjili su ısıtıcıları arasında karşılaştırma yapıyoruz. Zayıf termal fiziksel özelliklere sahip bir ısı transfer akışkanı olarak ve komplekslerin termal performansının ve verimliliğinin yükseltilmesine katkıda bulunan yeni yöntemlerin geliştirilmesi, özellikle ince partikül boyutunda (<100) benzersiz ve üstün nanopartiküller içeren nanoakışkanların kullanımına kadar. Geleneksel ısı transfer akışkanlarında dağıtarak termal, elektriksel, optik ve mekanik özelliklere sahiptir.

Gümüş (Ag) nanopartiküller, kristal büyümesi, stabilite ve çeşitli nanoteknoloji uygulamaları için daha iyi şekil ve boyut kontrolü için laboratuvarında kolay, ucuz ve çevre dostu bir şekilde üretildi. Ag NP'leri üretmek için tehlikeli kimyasallar kullanılmadan indirgeyici, kapak kapatıcı ve fiksaj maddesi olarak Petroselinum crispum, maydanoz ve yaprak ekstresi kullanıldı. Biyosentezlenmiş Ag NP'ler, UV-Vis, FT-IR spektroskopisi, X-ışını kırınımı (XRD), dinamik ışık saçılımı (DLS), zeta potansiyeli, diferansiyel kalorimetri (DSC), termogravimetrik analiz (TGA) gibi farklı karakterizasyon teknikleri kullanılarak tanımlanmıştır. Transmisyon elektron mikroskobu (TEM), alan emisyon taramalı elektron mikroskobu (FESEM) ve bitki özü ve biyokompozit Ag NP'lerin optik, termal, yapısal, morfolojik ve kimyasal özelliklerini araştırmak için enerji dağılımlı X-ışını (EDX) analizi.

Bundan sonra, biyosentezlenen Ag NP'ler, güneş enerjisi üretimi için güneş ışığının hasat edilmesinde kullanılmıştır. Koyu renkli yeşil sentezlenmiş Ag NP'ler için Yüzey Plazmon rezonansı (SPR) yaklaşık 450 nm'de ayarlandı. Ag NP'ler SPR'de uyarıldığında, Ag NP'leri çevreleyen yerel kırılma indeksinde bir değişikliğe neden olan büyük miktarda ısı açığa çıkar. Plazmon rezonansının kesin dalga boyunda güneş ışınımı altında Ag NP'lerinden salınan ısı, sulu ortamın sıcaklığını önemli ölçüde artırdı. Ag NP'lerin farklı yüzdeleri suda dağıldı ve daha sonra süspansiyonun sıcaklığını izlemek için güneş ışığına maruz bırakıldı. Ag NP'lerin ağırlıkça %3'ü kullanıldığında sulu ortamın sıcaklığının en yüksek noktasına ulaştığı bulunmuştur. Bu araştırma nadir ve benzersizdir ve az miktarda biyosentezlenmiş Ag NP'lerin kullanılmasının sulu ortamın sıcaklığını önemli ölçüde artırabileceğini göstermektedir.

Anahtar Kelimeler: Güneş enerjili su ısıtıcısı, gümüş nano sıvı, nanopartiküller.

EXPERIMENTAL INVESTIGATION EFFECT OF USING NANOFLUID ON THERMAL PERFORMANCE IN SOLAR COLLECTOR

ABSTRACT

We focus in our research on solar thermal technologies in terms of design and performance in water heating first, the process of heat transfer within flat panel collectors, and the calculation of solar radiation secondly, and then we compare between traditional solar water heaters that use water as a heat transfer fluid with poor thermal physical properties and between the development of new methods that contribute to raising the thermal performance and efficiency of the collectors to the use of Nano fluids that contain unique and superior nanoparticles, especially the size of fine particles (<100 nm) with thermal, electrical, optical and mechanical properties by dispersing them in conventional heat transfer fluids.

Silver (Ag) nanoparticles were fabricated in the laboratory in an easy, inexpensive, and environmentally friendly manner, for crystal growth, stability and better control of shape and size for various nanotechnology applications. Petroselinum crispum, parsley, leaf extract was utilized as a reducing, capping and stabilizing agent, without using hazardous chemical materials, for producing Ag NPs. The biosynthesized Ag NPs were characterized using different characterization techniques, namely UV-Vis, FT-IR spectroscopy, X-ray diffraction (XRD), dynamic light scattering (DLS), zeta potential, differential scanning calorimeters (DSC), thermo gravimetric analysis (TGA), transmission electron microscope (TEM). To investigate the optical, thermal, structural, morphological and chemical properties of plant extract and biosynthesized silver nanoparticles, field emission electron microscopy (FESEM), and energy dispersive X-ray (EDX) analysis are performed.

After that, the biosynthesized Ag NPs have been utilized in harvesting sunlight for solar thermal generation. Surface Plasmon resonance (SPR) for the green synthesized Ag NPs with the dark color were adjusted nearly at 450 nm. Once the Ag NPs are excited at the SPR, a large amount of heat is released, which causes a change in the local refractive index surrounding the Ag NPs. The released heat from the Ag NPs under the solar irradiation at the precise wavelength of Plasmon resonance significantly increased the temperature of the aqueous medium. Different percentages of Ag NPs were dispersed in water and then exposed to the sunlight, to monitor the temperature of the suspension. It was found that the temperature of the aqueous medium reaches its highest point when 3 wt. % of Ag NPs has been utilized. This investigation is rare and unique, and it shows that utilizing a small amount of the biosynthesized Ag NPs can increase the temperature of the aqueous medium dramatically.

Keywords: Solar water heater, silver nano fluid, nanoparticles.

1. INTRODUCTION

The sun is the source of the earth's life energy, if it were not for her, life would not have existed in its current form. Man has realized since ancient times the importance of the sun in his life, and he has spared no effort throughout his history to study its movement and to work continuously to uncover more facts surrounding it, unless after the need to search for energy sources to manage his life, from heating himself in the winter, roasting and heating his food, or lighting his path in the dark times of the night. After the discovery of coal and petroleum, energy sources developed to change the human life towards prosperity, from which electrical energy was produced. But the era of dependence on coal, petroleum and other unsustainable energies as a result of their depletion is no longer the same as the main and only source of energy in our era.

The sun is the source of all energies on the planet since the solar system was formed, whether directly or indirectly, and solar energy is an important reason for the presence of oil, coal and natural gas in the ground and the surface. It is necessary to study and know the history of the uses of solar energy to show its importance, and what prospects it will have if it is dealt with and invested in scientific ways and with high efficiency.

Since the discovery of oil wells in Iraq after the First World War, oil energy has become the primary source of energy and economy in it. Although the geography of the Republic of Iraq is rich in sunshine throughout the four seasons. The Republic of Iraq is among the countries that the sun does not miss with its rich energy, according to official data tables announced throughout the months, days and hours of the day. As a result of these reasons, the search for alternative and renewable energies, such as solar energy, was delayed in order for it to be in the research area of specialists in this field, especially in the scientific universities in Iraq. However, the political and economic crises since the beginning of the seventies, international agreements and international organizations

specialized in oil contracts, and the threats they have created for the economy and its instability, with the increasing human need for sustainable energy, has forced researchers to move towards research in renewable energies, especially solar energy, because relying on electric energy is not satisfied, which depends mainly on sources Petroleum and its derivatives. In this study, we try to shed light on reducing dependence on electrical energy consumption in homes, institutions, and factories by using solar heaters that do not burn a house, an establishment of a factory except that it depends entirely on heating water, especially in the fall, winter and spring seasons, and the consequent reduction in dependence on electrical energy, which drains an estimated one-third of the total supplied electrical energy.

The limited use of solar heaters to obtain hot water in Erbil Governorate, which is in northern Iraq, is due to its high cost and the traditional engineering of house and building designs, not to mention the weakness of planning and strategies at the state level or the relevant scientific institutions.

Therefore, at the beginning of this chapter, we try to shed light on the history of human interest in solar energy and ways of converting it into thermal energy for its various and daily uses, how much solar energy we obtain, and use compared to other common energies such as coal, petroleum, electricity and others. And also we deal with the amount of solar radiation that reaches us during the months of the year, as well as knowing what the individual consumes of electrical energy during t, for this purpose, we put together a set of necessary data regarding the amount of actual he year, what is the benefit for the state's economy in general and the individual's economy in particular if the heating and heating system for homes and institutions is converted from the use of common electric and petroleum energy to the use of solar energy electrical energy production and what is consumed daily, monthly and annually, taken from the Ministry of Electricity, as well as what the electric power stations consume from fuel during the year, after that, we explain the geographical climate of the region and what is the percentage of use of alternative and renewable energies in it, as well as focus on the amount of radiation falling on the ground and the angle of its projection according to the data of the Alternative Energies Directorate in the Ministry of Electricity and the data published in the Global Solar Energy Atlas and the entirety of the data contained therein.

Then we devote a chapter to the study of conventional solar collectors, and the stages of developing the performance and efficiency of conventional solar collectors using water as a heat source liquid.

We devote another chapter on new technologies in the world to increase the efficiency and performance of solar thermal collectors using Nano particles of materials in general and focus on Nano-metal particles to study some of its properties and mix it with fluids to improve the efficiency of the thermal fluid, which in the end leads to raising and improving the performance and efficiency of solar collectors. The physical and chemical properties of the Nano-fluids are studied in a laboratory from the coefficient of thermal conductivity, viscosity, the coefficient of zeta and beta, the shape and size of the Nano scale and touching on some of the necessary and important devices that contribute to determining the chemical and physical properties of Nano fluids.

Nano fluids are liquids that have higher thermal properties than those of a conventional liquid. It consists of metallic or non-metallic nanoparticles with a typical size of less than 100 nm in conventional heat transfer fluids.

In the final chapter, we do some laboratory work on Nano-metal particles, mix it with pure, refined water, study its physical and chemical properties, extract necessary data about it from the shape and size of Nano-silver, as well as extract thermal conductivity coefficients, zeta and beta coefficients, and other characteristics that contribute to diagnosing the thermal conductivity performance of Nano fluid silver and problems. This accompanies it, if any, from corrosion, sedimentation, viscosity, and others.

2. LITERATURE

2.1. Solar Energy

2.1.1. Energy Sources in the City of Erbil, Iraq

In general, energy sources in Iraq are reduced to petroleum and natural gas associated with oil extraction and crude oil derivatives of gasoline and black oil by more than 95%, which is estimated at about 8.000 megawatts, and the rest is produced by hydroelectric power through the water dams concentrated in the northern regions in the city of Sulaymaniyah and Durban Khan and converting it to electrical energy with a capacity of between (100-150) megawatts, depending on the level of water height in the dams. As for the other renewable, clean and environmentally friendly energies from wind, solar, nuclear and geothermal energy, there were attempts to establish the nuclear reactor at the beginning of the eighties of the last century, and the project was not completed due to international and political conditions at the time. As for wind energy, sites rich in wind power in the foothills of Darbandikhan were studied. It is located in northeastern Iraq, but due to the constant turbulence and instability of the wind force, it has prevented the entry of wind turbine construction projects in mountainous areas.

As for solar energy, which is abundant throughout the seasons of the year, Iraqi governments have not paid any attention since their establishment in the 1920s to establishing solar energy projects because of the discovery of oil in them. However, scientific studies and research were presented in sober Iraqi universities in the 1970s and 1980s about the importance of solar energy and its uses in Iraq as an alternative or as an additional energy to oil energy in conditions of its depletion and the depletion of its reserves in the future. These studies have become the main and important sources on which future projects are built.

In 2017, the Iraqi Ministry of Electricity began contracting a project to produce electrical energy from solar energy in desert areas in southwestern Iraq, using an area of 16.000 square meters as a field for solar collectors that produce 400 megawatts of electrical energy, and the project is in progress.

According to the sources that announce from the Ministry of Electricity to the Iraqi government in the years between (2010-2020) that the electric power produced from petroleum, natural gas and associated, and crude oil and its derivatives did not reach 10.000 megawatts, while the actual need of the Iraqi population of 40 million people for electric power To more than 30.000 megawatts. This shows the extent of the need to go to renewable, clean and environmentally friendly energies, on top of which is solar energy that is always and abundantly available throughout the four seasons of the year in different European countries.

In the city of Erbil, which is located in northeastern Iraq, interest in using solar collectors in household water heating started in abundance after 2003, due to the lack of electricity production and the increase in the population therein, forcing some of the houses and factories with high income to go to buy solar collectors for heating household water, in order to increase the cost. Its prices, while the applications of the PV projects produced from solar energy for lighting the main roads remained very few due to the difficulty of maintenance and continuous cleaning that the dust creates throughout the seasons of the year.

Around two million people live in the city of Erbil. The city is equipped with an electrical capacity of 1,785 megawatts from sources of energy produced from raw gas, and it is distributed to residential, industrial, commercial, agricultural and government areas. Studies conducted in the years between (2010-2018) showed that consumption rates increased by (10.5%, 6%, 12%, 20% and 13%) respectively, and the total consumption rate reached 10.8%.

And that what is consumed of electrical energy through various water heaters daily for one consumer reaches 25 kilowatt per hour in the winter season and decreases to 10 kilowatt hours in the spring and autumn seasons until it reaches 15 kilowatt hours in the

summer. Hot water accounts for approximately 25% of the total consumption, and so far the uses of hot water for heating purposes are still limited due to the lack of urgent need for it. In general, population growth is constantly increasing and the number of consumers increases accordingly. This is what leads us to think and present studies and research on sharing the use of solar-powered water heaters to reduce dependence on high-cost electric energy consumption, noting that the cost of consuming natural gas for one megawatt within an hour is \$ 36, \$ 140 for Casawil fuel, and \$ 58 for black oil.

2.1.2. Solar Energy

The demographic and economic growth of our modern society has resulted in a rise in energy demand, which is largely met by the use of fossil fuels (Burger et al. 2019). However, because of its limited availability and the negative impact on the environment, it is important to build technologies that allow for more effective use of alternative energy sources (Cuce et al. 2020). Solar energy, in general, is safe, abundant, simple to obtain, and unlimited supplier. Accordingly, solar radiation energy is one of the most promising sources for meeting future energy demand (Dupont et al. 2020). Similarly, solar energy can be, effectively, transformed into electrical and thermal energy through the photovoltaic and photo catalytic processes (Elumalai et al. 2015).

As it is known, the world population, industries and activities are constantly increasing in all parts of the world, and thus energy consumption increases accordingly. So far, fossil fuel resources are the main source of energy, although it is very limited. Therefore, the development of renewable energy sources has received much attention in recent years (Ahmadi et al. 2019). According to the International Energy Agency (IEA), global energy consumption is expected to increase during 2016-2030 by 44%, and the currently available energy resources are insufficient to meet the demand for its consumption due to technological progress (Cuce et al. 2020).

Solar thermal energy is one of the most widely used renewable energies. Where the sun emits energy at a rate of 3.8×10^{23} kilowatts, of which approximately 1.8×10^{14} kilowatts is intercepted by the Earth, which is about 150 million kilometers from the sun (Thirugnanasambandam et al. 2010).

Solar energy results from the reaction and union of four protons of a hydrogen atom to form one helium nucleus, where the mass of one helium nucleus is less than the mass of the four protons due to its transformation into energy (Duffie et al. 2020).

The average energy density of solar radiation outside the Earth's atmosphere is 1366 W/m^2 as shown in Figure 2.1 Which reaches the Earth is about $1.73 \times 10^{17} \text{ Watt}$. In a study of the amount of global energy consumption during the years 2005-2010, the total annual energy consumption for the whole world was about 500 EJ (Chen 2011).

With this it can be said that a mere 0.01% of the annual solar energy that reaches the Earth meets the energy needs of the entire world.

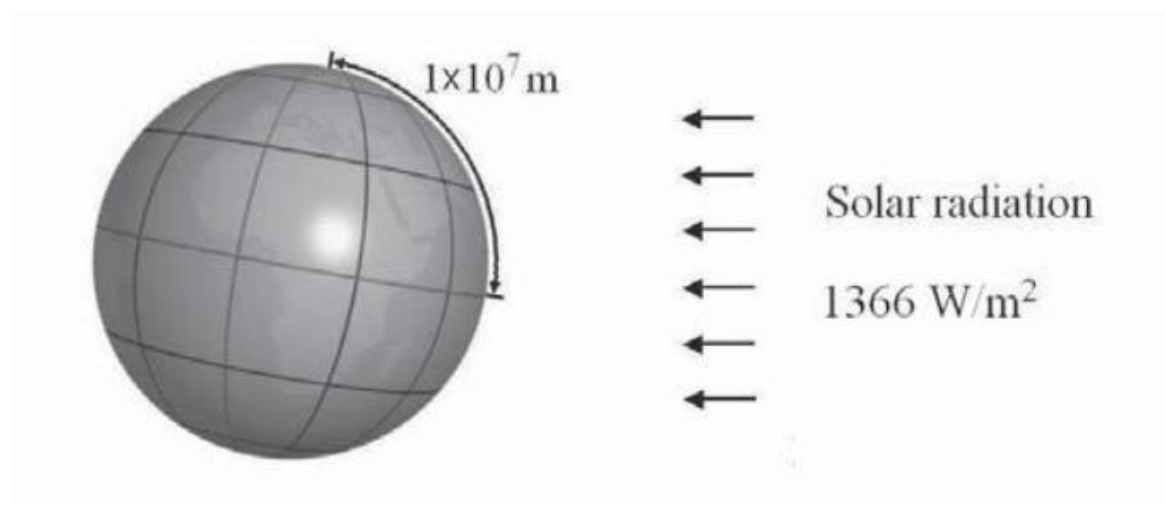


Figure 2.1. The average annual solar energy that reaches the Earth's surface (Chen 2011)

The amount of energy delivered to the earth is equivalent to 15.000 times that of all the inhabitants of the land. Despite the arrival of this huge amount to the surface of the earth and its exploitation by light technological means, its density is highly distributed and varies from one region to another. Also, its severity varies from one season to another of the year. Therefore, dependence on solar energy remains limited, not to mention the limited storage for long periods (Ayyash 1981) (Figure 2.2.).

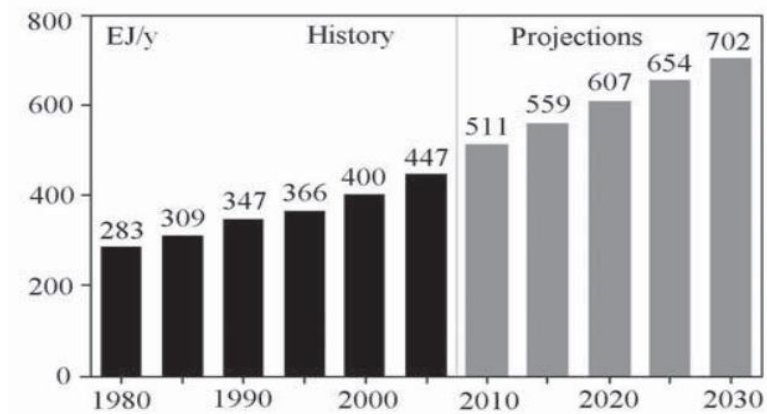


Figure 2.2. Annual global energy consumption in the years 2005-2010 (Chen 2011)

Not all solar radiation on Earth's atmosphere reaches Earth. About 30% of the solar radiation is reflected in space. Clouds and particles in the air absorb about 20% of the solar radiation. Although the Earth's surface contains plains, mountains, seas and oceans, and the areas occupied by water are three times more than the land areas, if 10% of solar energy is used, 0.1% of it can supply the entire world with the required energy.

Some studies conducted in the United States of America in 2006 confirmed that the total annual available fuel reserve constitutes approximately 1.4% of the solar energy that reaches the Earth's surface, as shown in Table 2.1.

Table 2.1. The percentage of different types of energy in the United States in 2006 (Chen 2011)

Type	Resource (EJ/Year)	Implemented (EJ/Year)	Percentage Explored
Solar	2.730.000	0.31	0.0012%
Wind	2.500	4.0	0.16%
Geothermal	1.000	1.2	0.10%
Hydro	52	9.3	18%

2.1.3. Historical Overview

The history of using solar energy goes back to the Chaldean era in Mesopotamia. Also, the pharaohs made a statue of Minnon (1455-1419) BC, which emits beautiful musical notes in greeting to the sunrise in the morning for every day, as the statue contains two

chambers, one containing air and the other droplets of dew, and by the action of the sun's rays the air extends to form pressure on the drops of dew To come out of the holes they made musical sounds Archimedes (287 - 347 BC) was considered the first to use solar rays as a heat source by collecting sunlight with concave mirrors and shining them on the sails of Roman ships besieging Sir Cox to burn them. In (1681 AD), the French scientist Ahengrid used a lens of diameter (76). Poison for melting ceramic materials by focusing the solar rays into the focus of the lens. Whereas the French astronomer Yugus Cassini made in (1747) AD a burning mirror with a diameter of (112) cm to generate a temperature of more than (1000) degrees Celsius sufficient to melt iron bars in a few seconds (Thirugnanasambandam et al. 2010). Claude Boyle (1790-1868) was the first to measure the intensity of solar rays in a unit area by measuring the rise in water temperature (Nagarajan et al. 2014). As for the Greek philosopher Socrates, he said in about 400 BC, explaining the angles of the sun on the earth and the angles of its fall in the seasons of the year from summer to winter: The head and over the roofs, which creates shadows. "In the early seventeenth century, interest in solar energy returned in Europe, as Atana Seuss Kirsch carried out experiments to light a pile of wood with glass mirrors, and there were many experiments focusing on the use of reflective glass mirrors for melting metals, diamonds, ceramics, iron and copper. Solar ovens, the French scientist Buffon created an oven consisting of 360 small mirrors, all of which focus sunlight into one focus. As for the chemist, Lavuzia, he made a solar furnace, with which he managed to obtain a temperature of 1760 degrees Celsius (Ayyash 1981). In the year (1875) AD, a solar-powered steam machine was made to generate steam in turbines or machine ((Thirugnanasambandam et al. 2010). In the last quarter of the ninth century, research and experiments were conducted in the United States by John Erickson by designing a solar collector that tracks the Earth's rotation around the sun, and then scientists went to establish a water distillation device and get fresh water in Las Salinas in Chile, producing 23.000 Liters on sunny days with an area of 4700 square meters for the distillation apparatus. By the beginning of the twentieth century, interest began to produce electrical energy from solar energy by using liquids that evaporate at relatively low temperatures by introducing simple flat collectors (a metal plate painted black inside a box covered with a glass layer) instead Use of reflective mirrors. In the thirties of the same century, interest in solar heaters began as a requirement for homes and dwellings and their need for hot water and solar heating. The state of Japan was at the forefront of countries in the use of

solar heaters due to the lack of other sources of energy in them. The tendency of the scholars of the thirties towards the use of solar energy in heating and water heating is gaining special importance and falls under the heading of thermal energy production with low temperatures that do not exceed (50-100) degrees Celsius. From solar energy. After the fifties of the twentieth century, research focused on generating electrical energy as a result of the flexibility of its use and its conversion to other forms of energy such as thermal and mechanical energy, and as a result of the rapid increase in energy prices of various forms in the seventies of the last century, including coal, gas and oil, not to mention their lack of survival and sustainability in the future, with what accompanies it. From environmental pollution, it has become necessary to search for more permanent energy sources than oil and its derivatives. This has resulted in solar energy being at the forefront to meet human energy needs in the short term and provide future potentials for its development (Ayyash 1981).

Several international conferences have been held in the fields of solar energy use and research due to the active and positive role of the importance of exploiting this renewable energy, including:

- 1- The global conference held at MIT University in 1950.
- 2- The International Solar Energy Symposium held at the University of Wisconsin (1953) to discuss the high potential of energy.
- 3- The World Solar Energy Symposium organized by UNESCO in (1954) in India on solar energy applications.
- 4- Two solar energy conferences were held in Arizona in (1955).
- 5- A special conference was held by Professor Phenix Trump in his laboratories in (1958) in France on the thermal importance of solar energy.
- 6- Holding a symposium in the Economic and Social Department of the United Nations in (1962) on scientific methods of using solar energy.

As for the state of Iraq, some solar energy applications such as heating and water heating were used in (1961) in the field of solar collectors ((Thirugnanasambandam et al. 2010).

2.1.4. The Sun

The sun is one of the stars near us in such a way that we are able to see and study its surface from a distance of 700 km from specific locations of the Earth. It is a ball of burning gas produced by the interaction of different gases that constantly gives the property of gravity. Its average diameter is 1.392 million km and its average density is 1.41 g / cm^3 is 100 times the density of water (Duffie et al. 2020; Chen 2011). And it produces an energy of 3.9×10^{23} kilowatts per second, of which the earth receives about 1.8×10^{14} kilowatts. This amount of energy is equivalent to about 20 thousand times the world's energy consumption, as about 70% of the land surface is covered by seas Unsuitable for exploiting solar energy and other vast uninhabited desert areas. The intense study of the Sun was begun centuries ago by astronomers. Here is some important information about the sun:

2.1.4.1. Distance

The sun is 149.6 million km away from Earth. The distance between the Sun and Earth is measured using triangulation and radar echoes.

The distance between the sun and the earth is not fixed, and it is measured in longitudinal units sometimes, as it ranges from (1.471×10^{11}) m to (1.521×10^{11}) m. And through the time factor, on the other hand, the time it takes light from the sun to the earth is measured

2.1.4.2. The Mass

The mass of the sun according to Kepler's law is 2×10^{30} kg which multiplies the mass of the earth by 333,000 times, and the sun loses its mass annually as a result of the loss of radiation and solar wind.

2.1.4.3. Surface Heat

Despite the different sources about the average surface temperature of the sun, there are those who indicate that the surface temperature of the sun is approximately 5777 Kelvin, while the center of the Sun is estimated to be about 8×10^6 to 40×10^6 K.

2.1.4.4. The Chemical Composition of The Sun

The sun is composed of 85% hydrogen and 13% helium in addition to other elements in the form of impurities shown in Table 2.2. (Chen 2011; Ayyash 1981)

Table 2.2. The elements of the chemical composition of the sun

Element	Z	Molecular Weight	Abundance (% of Number of Atoms)	Abundance (% of Mass)
Hydrogen	1	1.008	91.2	71
Helium	2	4.003	8.7	27.1
Oxygen	8	16.000	0.078	0.97
Carbon	6	12.011	0.043	0.40
Nitrogen	7	14.007	0.0088	0.096
Silicon	14	28.086	0.0045	0.099
Magnesium	12	24.312	0.0038	0.076
Neon	10	20.183	0.0035	0.058
Iron	26	55.847	0.003	0.14

2.1.5. The Solar Constant

The energy intensity of solar radiation is measured through satellite data (Chen 2011).

Figure 2.3. shows the distance between the Sun and the Earth which differs by 1.7%, and the Earth meets the Sun at an angle of 32 degrees.

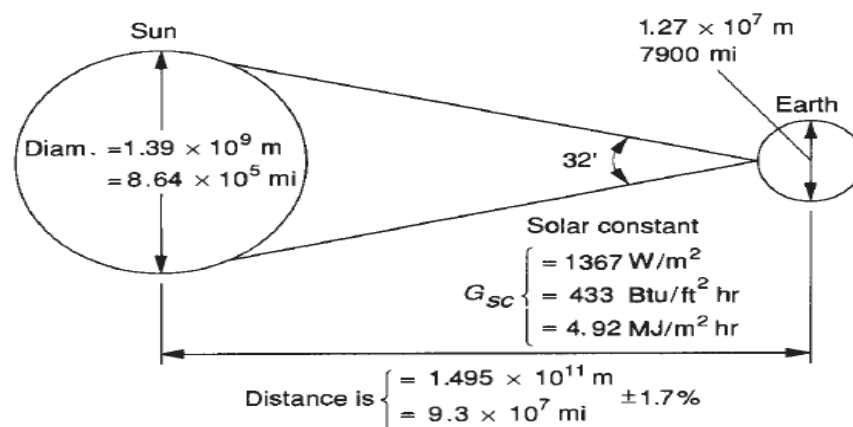


Figure 2.3. Sun-earth relationships (Chen 2011)

This means that there is no greater energy than the solar constant falling on the Earth's surface, whose value ranges between 1322 W/m^2 and 1395 W/m^2 because some of

them are reflected and others are absorbed by clouds and other objects in the atmosphere surrounding the Earth.

The value of the solar constant varies according to the distance between the earth and the sun and according to the length of the seasons (Ayyash 1981). It was fixed at a value of 1373 W/m^2 by Frohlich 1977 based on instrument comparisons with absolute radiometers (Duffie et al. 2020).

2.1.6. Solar Radiation

Earth receives solar energy in the form of radiation, or sunlight, with spectral components mostly in visible infrared, and near ultraviolet rays (Chen 2011). Radiation is the rate at which radiant energy falls on a surface per unit area of the surface. The symbol G is used for solar radiation, with appropriate symbols for beam, diffuse, or spectral radiation.

Solar rays are electromagnetic rays of many wavelengths with different energies and with wide frequencies and have a spectrum mainly concentrated within the spectrum visible to the human eye. And it extends from intense energy gamma rays to very weak acoustic rays (Ayyash 1981). There are many definitions of radiation, which we summarize as follows:

Beam radiation

It is the solar radiation that reaches the earth without losing any of its energy and without being dispersed by the atmosphere and it is also called direct solar radiation.

Diffuse radiation

It is the indirect solar radiation of weak energy that collides with the atmosphere after changing its direction by the dispersion of the atmosphere, and it is also called the solar sky radiation.

Total solar irradiance

It is the sum of the beam and solar radiation scattered over a surface, a horizontal surface, often referred to as the global radiation at the surface.

Solar spectrum

The amount of energy in the solar spectrum determines the value of the solar constant. The solar spectrum is divided according to wavelength into three areas: the ultraviolet field with a short wavelength of 0.4 microns, the visible field (0.4-0.75) microns, and the infrared field with wavelengths exceeding 0.75 microns (Nagarajan et al. 2014).

Absorbency, reflectivity, and transmittance

Three characteristics of solar radiation when it falls on the ground or a piece of material, where part of the radiation is generally reflected from the material to the outside environment, the other part is absorbed by the material, and another part is permeated through materials with window properties such as glass.

2.1.7. Solar Time

The times of the appearance of the sun's rays depend on the latitude and longitude of each region separately and according to the tilt of the solar angle from which it rises to the times of sunset, and the sun's rays are at their peak during noon time (Duffie et al. 2020).

Solar radiation is the main energy source that is used to perform certain tasks. The amount of solar radiation at a location is obtained either through the preparation of tables showing the amounts of solar radiation expected to fall in a region during the year based on the results obtained by means of solar radiation meters or by data from satellites and global solar energy agencies in each spot-on Earth's surface

The number of changes that occur to the solar ray during its passage through the gaseous envelope depends on two factors, which are the absorption coefficient of the atmosphere and the length of the distance traveled by the solar ray inside the gaseous atmosphere.

2.1.8. Solar Radiation in the City of Erbil, Iraq

There are multiple tables, maps, and figures surveyed in Iraq in the years (1967-1978) as study models and continue until now showing the amount of solar radiation received in watts per square meter during each month of the year. The tables, figures and studies show that the highest energy received is in July and August during the noon time, and the lowest energy received is in December and the second during sunset, and that the received energy in the summer is 3-4 times what is received in the winter season.

The city of Erbil is located in Iraq at latitude of 37 north of the equator and a longitude close to 60 east of Greenwich in the far east of Oman. The climatic conditions vary according to the weather factors that affect the formation of its climates, and this effect is reflected in the amount of radiation reaching the ground. The rates of solar radiation in Iraq and the region in the summer are among the highest in the world, as it has an average solar radiation in the summer equal to or more than 7 kilowatt hours per square meter per day (Ayyash 1981). Table 2.3. shows the rate of solar radiation falling on the Hamza Kour site in the city of Erbil for years between 2014 to 2018 and for the different seasons of the year, which shows that the average amount of solar radiation ranges between (1125-1150) watts per square meter under different climatic conditions of pressure Temperature, relative humidity, and wind speed.

Table 2.3. The average incidence of solar radiation at the Hamzakur site in the city of Erbil, Iraq, under different climatic conditions during the years (2014-2018)

Measurement		Oct 2014- Sep2015	Oct 2015- Sep2016	Oct 2016- Sep2017	Oct 2017- Jun2018	Max	Min	Ave
Mean Air Temperature t _{la} [°C]	Max	46	45.9	46.4	31.7	46.4		
	Min	1.1	-1.6	-2.3	3.2		-2.30	
	Ave	22.46	23.27	22.45	16.14			21.08
Mean Air Pressure b _{la} [hPa]	Max	978	977	978	976	978.0		
	Min	947	945	946	952		945.0	
	Ave	961.97	961.29	962.16	965.47			962.72
Mean Global Radiation r _{la} [W/m ²]	Max	1147.26	1125.2	1145.86	1029.52	1147.3		
	Min	0	0	0	0		0.00	
	Ave	206.87	218.27	221.23	142.13			197.13

2.1.9. Solar Angles

The angle of incidence of sunlight on the earth has a great influence on the amount of solar radiation received in any region on the surface of the globe. The greatest energy received is usually at the time of noon on the equator on a clear day, as the rays passing through the atmosphere cross it with their shortest path, while their longest path is at the time of dawn and sunset, which exposes it to diffusion and absorption during the long paths. Determining the angles of projection of the sun's rays on the surface of the earth vertically improves the utilization of solar energy. There are two angles for determining the position of the sun from a point on the surface of the earth, namely the angle of elevation of the sun α_s (Ayyash 1981). The angle between the horizontal and the line of the sun, meaning that it is the complement of the azimuth angle and the solar azimuth angle the angle between the vertical line and the sun (Duffie et al. 2020), That is, the angle from the occurrence of the beam radiation on a horizontal surface that is confined between the line passing at the point on the surface of the earth and heading south and the horizontal projection of the line connecting the point on the surface of the earth and the sun. The angles of the sun's elevation and the solar zenith are calculated through some other angles (Ayyash 1981) as in Figure 2.4.

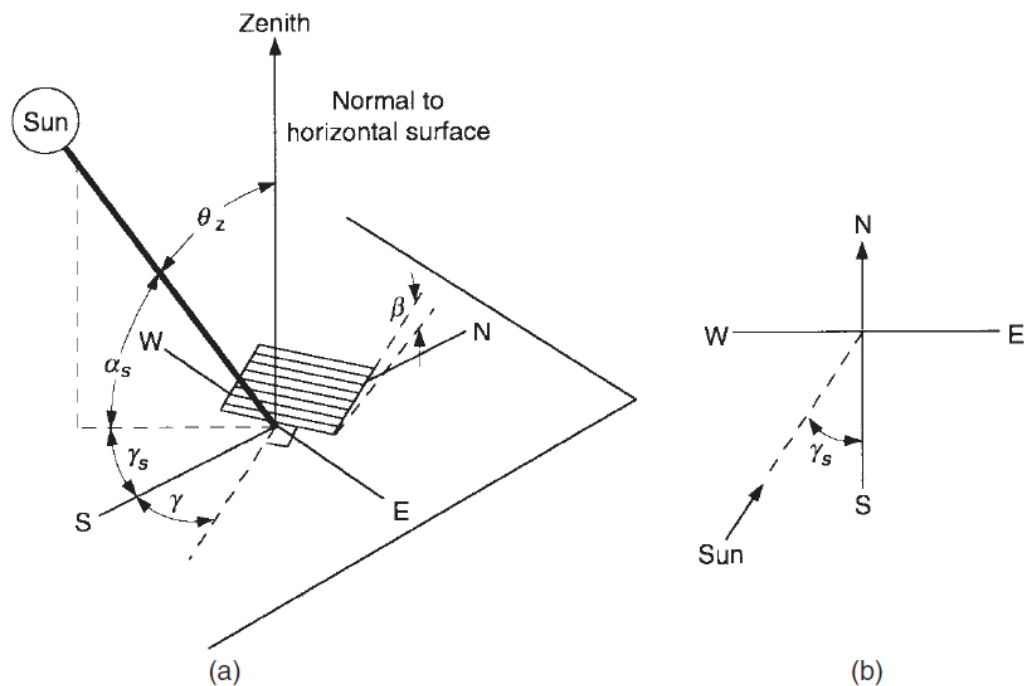


Figure 2.4. Solar angles (a) The azimuth angle, slope, surface azimuth angle, and solar zenith angle of an inclined surface. (b) View a chart showing the solar azimuth angle (Duffie et al. 2020)

ϕ Latitude angular: position north or south of the equator, north is positive:

$$-90^\circ \leq \phi \leq 90^\circ.$$

δ the eccentricity: the angular position of the sun at noon (that is, when the sun is on the local meridian) with respect to the equator plane, north is positive; $-23.45^\circ \leq \delta \leq 23.45^\circ$.

β Slope: angle between the plane of the respective surface and the horizontal; $0 \leq \beta \leq 180$, ($\beta > 90^\circ$ means that the surface has a downward facing component).

γ Surface azimuth angle: deviation of the projection at a normal horizontal plane to the surface from the local meridian, with zero due to south, negative east, and west positive: $180^\circ \leq \gamma \leq 180^\circ$.

ω the hour angle: It is the angle arising as a result of the Earth's rotation around itself at a rate of 15 degrees per hour east or west of the local meridian, so that the value of the angle is negative in the morning times and positive in the afternoon (Duffie et al. 2020).

2.2. Solar Collectors

A solar collector is a type of heat exchanger that captures and absorbs the maximum amount of solar electromagnetic radiation energy and converts it into heat or one of the common forms of electrical, chemical or light energy (Duffie et al. 2020) for use in meeting one or more human needs (Ayyash 1981). The solar collector differs from conventional heat exchangers in the dimension of the radiant energy source to the liquid.

Nicolas Dossosur is considered the first to build a solar Collectors in 1771 and paint it black to heat the water with sunlight to a temperature of 87 degrees. Since that time, numerous research and studies have been conducted to develop solar collectors with high efficiencies and in multiple ways (Ayyash 1981).

Solar collectors are characterized by their durability for long periods of time, some of which may exceed the work of some decades, as is the case for the Collectors that were

built in Florida 80 years ago and still work properly despite being exposed to harsh climatic conditions (Chen 2011).

Designs conventional flat plate collectors for applications requiring power delivery in moderate temperatures, between $(30-100)^\circ\text{C}$ depending on the seasons. They are mechanically simpler in design and require very little maintenance. The main applications of these Collectors are in solar water heating, building heating, air conditioning, and industrial process heating (Duffie et al. 2020).

Figure 2.5. shows a box containing a copper plate with copper tubes welded and painted in black. Thermal insulation of the upper side is usually installed one or two sheets of glass. The water can be heated up to 60°C or 80°C .

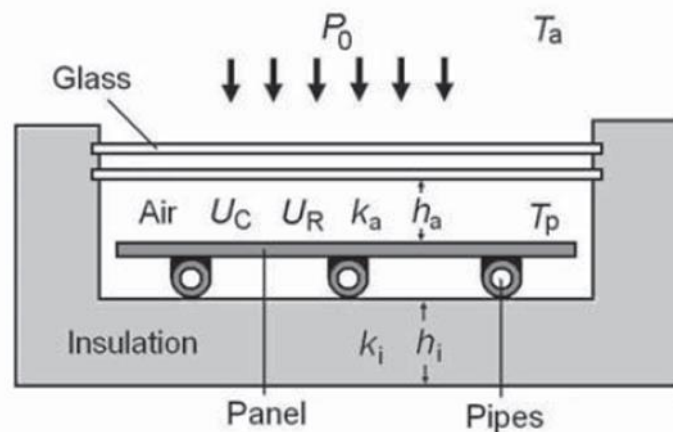


Figure 2.5. Flat solar heat collector. Box, containing copper plate with welded copper tubes, painted in black color. Install two panels of glass for thermal insulation of the upper side (Duffie et al. 2020)

2.2.1. Types of Solar Collectors

One of the most common types of solar collectors in the world, which is used in the field of water heating because of its high reliability, low cost and ease of maintenance.

Solar collectors used in the field of water heating are mainly classified into three categories of flat plates, evacuated tubes and concentrators. In contrast, heating air as a heat transfer fluid is called solar air collectors, which are generally used for drying and building heating as shown in Figure 2.6. (Tang and Li 2017).

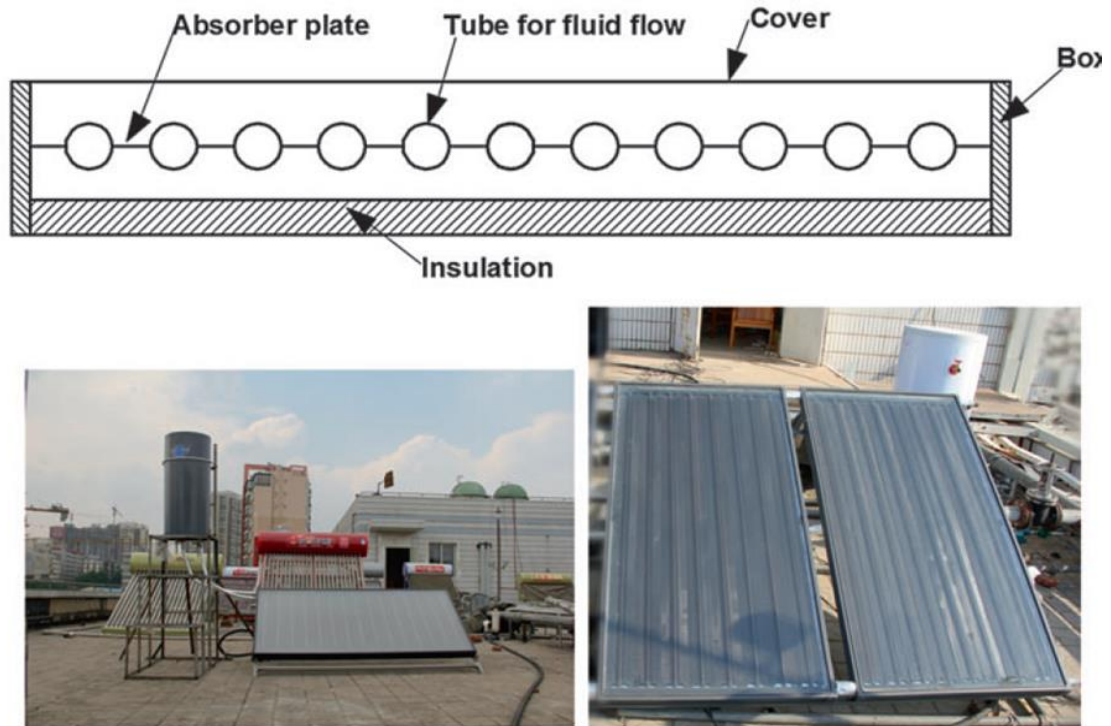


Figure 2.6. Cross-section of a typical flat solar collector (top), collector's image (bottom) (Ahmadi et al. 2019)

2.2.1.1. Thermal Collectors for Heating

Plain water is used in flat plate or vacuum tube heat collectors, in general, to obtain heat energy as low as 100°C above ambient temperature.

Flat plate collectors receive both bright rays and diffuse radiation above the collector surface, and therefore do not require a sun tracker (Tang and Li 2017).

The efficiency of conventional flat-panel thermal collectors for domestic water heating is about 70% which is very high compared to direct solar energy with a conversion efficiency of about 17%.

Recently, nanoparticle fabrication techniques appeared in conventional liquids as a fluid instead of water to improve the thermal performance of thermal Collectors (Nagarajan et al. 2014; Hossain et al. 2011).

2.2.1.2. Solar Collectors That Concentrate Solar Rays

The temperature of solar collectors ranges between a few hundred and up to a few thousand degrees Celsius, and they are called solar radiation capacitors. Concentrator collectors are distinguished by their simplicity of structure and low cost compared to flat collectors, Figure 3.3. (Ayyash 1981; Tang and Li).

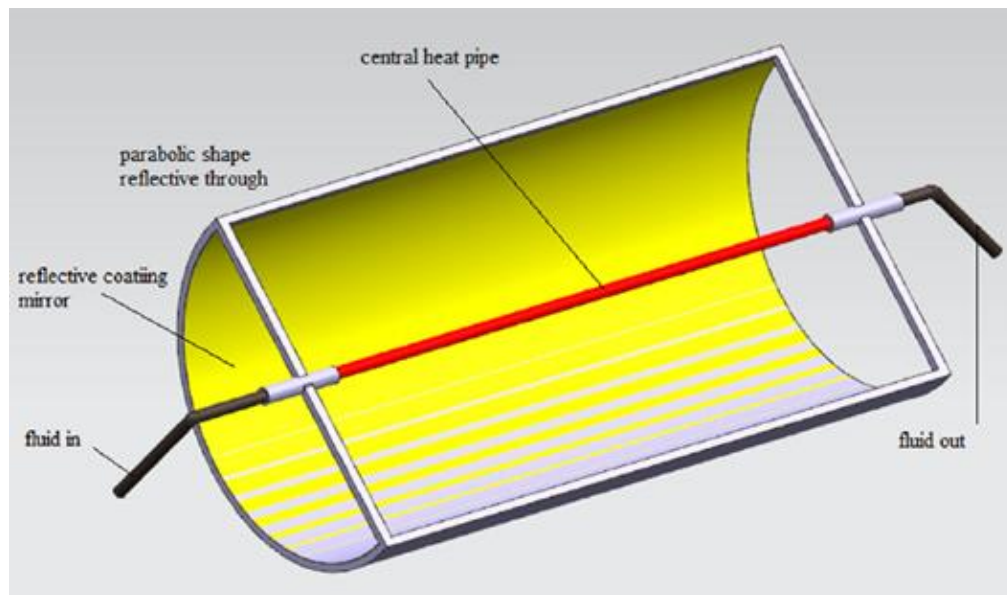


Figure 2.7. General conceptual form of PTC (Ahmadi et al. 2019)

2.2.2. Solar Collector Work

When the sun's rays fall on an object, some of it penetrates the body, some of it is reflected, and the other part is absorbed. And it depends on the nature of the body receiving the rays and its composition and the nature of the rays incident on the body from high-energy ultraviolet rays and rays of low thermal energy.

The solar collector absorbs a quantity of radiant energy falling on its surface and converts it in the form of acquired heat energy into a thermal fluid and transfers that heat to a cooler fluid (usually water or air). Then the thermal fluid is used in heating systems such as pool heaters, or water heating (Ayyash 1981; Hossain et al. 2011).

2.2.3. Thermal Liquid Collector

The panel solar collector consists of an absorbent surface made of copper or aluminum or any materials that have a high thermal conductivity, and is painted black for the best absorption of solar energy. It is covered with a transparent cover such as glass or plastic material that allows the passage of 0-2.5 μm long wave solar radiation and low emission of heat radiation (Tang and Li 2017) as shown in Figure 2.8.

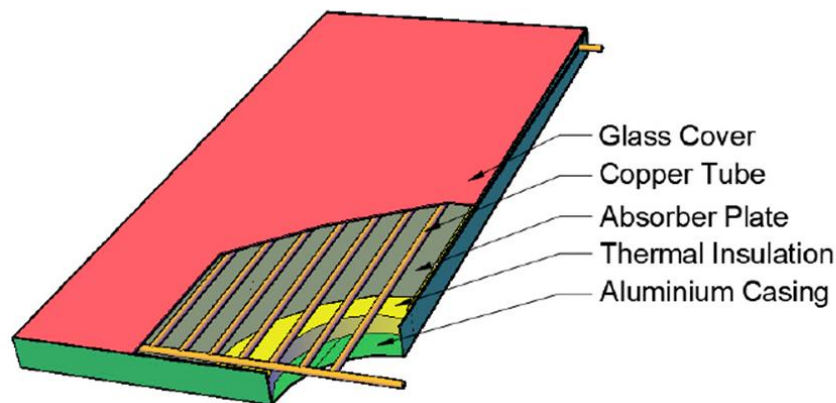


Figure 2.8. Structure of the flat plate collector

The plate absorbs the sun's rays falling on it, and its temperature rises, and the heat of the plate is transmitted to the thermally insulated adhesive tubes that contain the liquid, thus raising the temperature of the liquid, and placing the plate inside a box. With its top cover made of transparent glass with high transmittance properties and the ability to not transmit rays to the atmosphere.

The tube attached to the absorbent plate also acts as a heat exchanger. The larger area of the absorber plate, the greater the amount of heat transferred in the system. A common problem that reduces the performance of flat collectors over time is the effect of dust deposition on the transparent cover, which requires regular cleaning, as well as the problem of overheating, which leads to material deterioration and disruption of system operation, thus Reducing reliability (Shamsulet al. 2020).

here are multiple studies conducted in 2019 on methods to improve thermal performance in surface engineering, the use of selective solar coatings and the flat-plate compound

structure as shown in Figure 2.8. The result was an increase in efficiency, with the thermal efficiency achieved ranging in the range of 50% to 78%. Table 2.4. summarizes the methods used in FPSC studies(Shamsulet al. 2020).

Table 2.4. Summary of the methods studied in improving FPSC thermal performance(Shamsulet al. 2020)

Method	Description
Modifying FPSC Design	Changing the FPSC standard design
Absorber Coatings	Adding a coating to the glass cover to omprove absorbance
Polymer Material	Using polymer as FPSC material to reduce cost
Nanofluid	Adding nanopartical to the working fluid to increase the heat transfer area
Mini and Microchannel	Shrinking the heat exchanger tube to increase the heat transfer area
Phase change material	Store excess energy to be used later
Heat loss reduction	Adding extra insulation to reduce heat loss
Enhancement devices	Adding devices to increase heat capacity turbulences
turbulators	Adding turbulator to increase and promote fluid mixing

2.2.4. Solar Collector Parts

2.2.4.1. Suction Plate and Conduit of Thermal Fluid

The sheet material, its chemical properties, its ability to absorb solar radiation, its abundance, its total costs, and the ease of handling it are important factors to improve the performance and raise the efficiency of the Collectors. The plate is made with a thickness of (0.3-1) mm, and the most common type of plate is copper, which has a high heat conductivity despite its high cost, and other metals such as aluminum or iron.

The plate is designed in different shapes, some of which are like a metal tube attached to the plate with diameters and sizes consistent with the quality of the fluid passing through it or according to the use, so that it increases the efficiency of the collector as shown in the Figure 2.9. (Ayyash 1981).

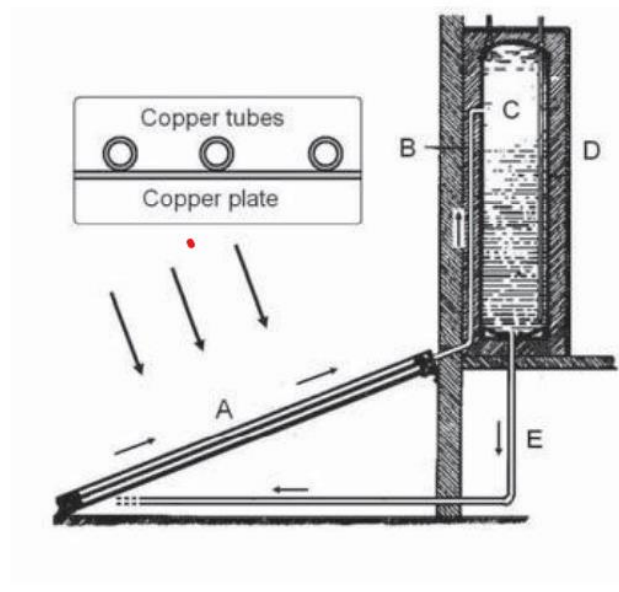


Figure 2.9. Cross section of a plate attached to pipes in the solar water heater system (Chen 2011)

As mentioned earlier in solar thermal applications such as water heaters, the absorbing surface is painted a faded black color to absorb the maximum amount of solar radiation. When the black absorbent surface becomes hot as a result of absorbing solar radiation, it begins to lose its energy by radiation. To reduce the amount of energy loss, the absorbent plate should be designed from materials with high absorption capacity with a wavelength shorter than $2\ \mu\text{m}$ and low emissivity for a longer wavelength.

In order to find out the amount of reflection of solar rays and the amount of absorption by the absorbing plate of different wavelengths, we use the equation $R(\lambda)$ (3.1):

$$R(\lambda) + A(\lambda) = 1 \quad (3.1)$$

The emissivity of the absorbing surface of the plate and its absorption of solar radiation are equal according to Kirchhoff's law, as shown in equation (3.2):

$$E(\lambda) = A(\lambda) \quad (3.2)$$

The results of some tests showed the role that some types of pigments play on improving solar radiation absorption and heat transfer of the absorbent plate, such as selective PVD

coating, and on the thermal performance of flat collectors with absorption higher than 90% and heat emission in the range of 5% to 90% compared to conventional coatings.

The tests also indicated that the thermal resistance of the low absorbent coating increases with higher temperatures, which leads to a decrease in the absorption of solar radiation (Shamsulet al. 2020).

2.2.4.2. Measurement of The Thermal Performance

Figure 2.10. It shows a schematic diagram of the heat flow to the solar collector, where 80% of the heat from the solar thermal energy is absorbed into the collector panel, while the heat loss from the collector surface to the outside environment as a result of radiant heat reflection is estimated at 10-35%.

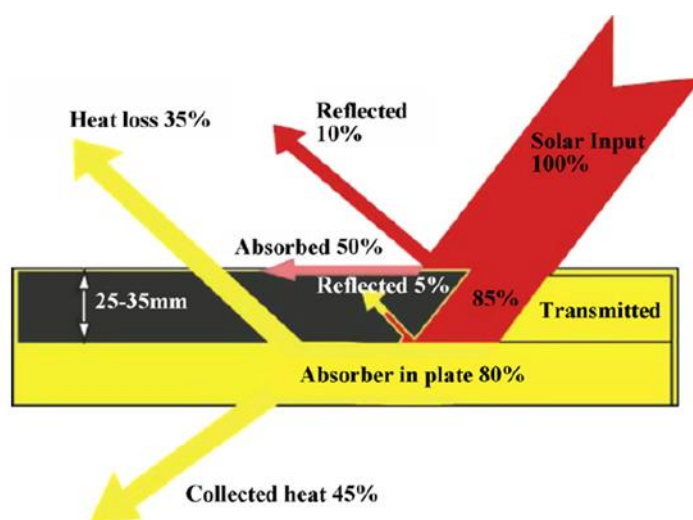


Figure 2.10. Illustrative diagram of heat flow through a solar collector panel (Hossain et al. 2011)

And in Figure 2.11. Shows a simple schematic design of a typical system consisting of solar panels with connecting tubes, storage tank, heat exchangers with control pumps and heat exchangers. To calculate the amount of heat gained from solar radiation, if the intensity of solar radiation is in units of W / m^2 , with the surface area of collector A in square metres, we use the following equation (3.3):

$$Q_i = IA \quad (3.3)$$

where Q_i is the heat energy gained W/m^2 from the collector temperature input. I is the intensity of solar radiation. A is the area of the Collectors (Hossain et al. 2011).

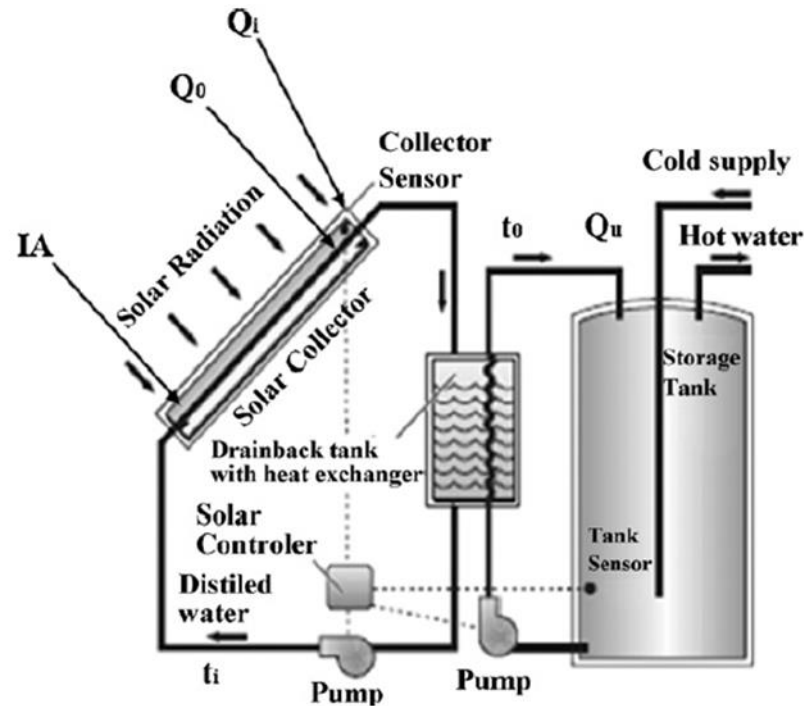


Figure 2.11. A typical solar collector system (Hossain et al. 2011)

In order to achieve the highest performance and efficiency of the plate and the collector and reduce the losses resulting from heat loss and develop it, either by changing the nature of the surface or by coating the surface with certain materials or adding an absorbent layer to the collector, as follows:

- 1- Capturing thermal rays by changing the nature of the surface: This is done by digging the surface of the black plate in such a way that the walls of the protrusions formed become shiny while the bottom remains dark black, which leads to an increase in the yield of the plate by 20-30%.
- 2- Capture the heat rays by coating the black sheet either with special materials such as transparent plastic to allow the rays to pass through to the plate while completely reflecting on its inner surface the heat rays emanating from the plate so as to allow about 96% of the heat rays to pass through and the remaining influence to the air and take on

the high price The plate is coated with semi-conductive materials such as germanium and lead sulfur, so that it allows solar rays to pass through and prevents heat rays from crossing into the atmosphere, but it is also very expensive.

And that the best and cheapest method ever is to scratch the surface of the plate before painting it with black color and cheap zinc oxide, as these grooves increase the effective surface of the plate as well as decrease the amount of heat radiation emitted vertically, and there are other attempts by electrostatic deposition of the surface (Ayyash 1981; Hossain et al. 2011).

2.2.4.3. Transparent Cover

In order for the largest amount of solar radiation to reach the black-colored absorbent surface in the solar collector, a transparent cover with a thickness ranging between (3 - 5) mm made of glass or plastic is placed to prevent the arrival of dust, rain and snow on it, which leads to reducing its performance and efficiency from heat loss factors. Or oxidation of the absorbent surface.

The choice of glass or plastic depends on the characteristics that must be present in them, such as the permeability and absorption coefficient, the transfer of lost heat to the atmosphere, thickness, weight, cost, maintenance and resistance to seasonal thermal atmospheres, while the pure glass that is clear of impurities has good transmittance properties of sunlight to the plate up to 95% and 85% for regular glass and 74%. And when using two glass covers, the absorption of radiation is limited, the heat transfer to the atmosphere is reduced, and it resists seasonal thermal weather with easy cleaning continuously, while the plastic is lightweight, low in cost and more resistant than glass to break(Ayyash 1981).

The normal permeability of the glass cover in most glass covered solar thermal collectors is calculated by the following equation (3. 4)(Chen 2011):

$$\tau = \frac{(4n)^{2N}}{(1 + n)^{4N}}, \quad (3.4)$$

Where the factor N represents the number of sheets of the transparent coating and n is the refractive index of the transparent coating.

Also, one of the functions of the transparent sheets of solar radiation over an absorbent surface is to reduce the atmospheric load and radiation losses and reverse insulation to reduce conduction losses as in the cross section of the solar collector, where the absorbing surface was covered with two layers of transparent sheets as in Figure 2.12.

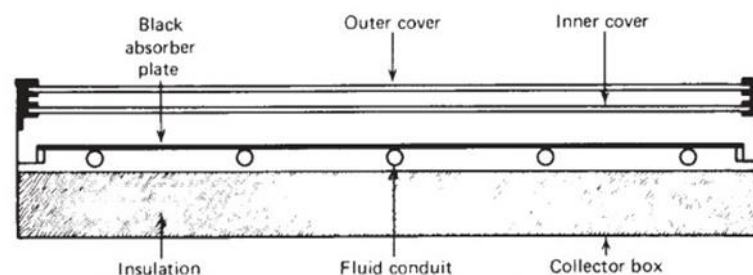


Figure 2.12. Cross section of the solar collector covered with two layers of transparent cover(Duffie et al. 2020).

The time factor is also an important factor affecting the permeability of the solar panel absorber cap. Where the cover absorbs some of the solar radiation, it increases its temperature and loses some others as a result of its reflection, and the high temperature of the cover affects the reduction of heat loss by the absorbing plate.

Dust and smog also affect the permeability factor in a limited proportion, as multiple tests were conducted in the nineties of the last century on the effect of dust and dirt accumulated on the transparent cover installed at different angles of inclination, because the angle of inclination also determines the percentage of dust and dirt accumulation, and the results showed that the proportion of dust Dirt affects the permeability performance by rates ranging between 1% - 8%.

In other experiments, two glass covers were used instead of one by Hottel and Woertz (1942) and found that the percentage of radiation absorbed by the plate was reduced to 3% due to the shading effects of the additional cover. Most modern collector use a cover. One, the unit areas are larger, and both reduce shading effects by 1% (Duffie et al. 2020).

To reduce the heat load losses between the absorber plate and the glass, an insulator is placed from the air cavities to enhance the heat transfer to the collector, and the focus of the highlight transmittance should be higher than 80%, and this means that the high transmittance helps the coating absorb more of the incident solar radiation(Shamsulet al. 2020).

The transmittance of ordinary glass differs from the impurity-free glass. As a result of the impurities in it, ordinary glass shows the transmittance of some spectra of infrared or ultraviolet rays, unlike pure glass. For this reason, ordinary glass absorbs black-body radiation from reflection from the absorbing surface almost completely (Chen 2011).

2.2.4.4. Insulation Materials

The temperature of the absorbing surface and the pipes connected with it increases as a result of absorbing solar energy, and to prevent the transfer of heat into the atmosphere, the absorbent surface is well insulated with an insulating material that prevents moisture and resists high temperatures to the point of combustion, with a thickness limited between (5-10) cm from the bottom and its sides are made of materials Plastic such as sponge (polyurethane) and glass wool. To improve the performance of insulating materials, it is preferable to be covered with a thin layer of aluminum foil that prevents moisture and reflects the heat radiation emanating from the absorbent plate(Ayyash 1981).

The factors that affect the heat loss from the solar collector resulting from the absorption of solar radiation reduce the amount of heat energy gained by the absorbing plate. The waste heat is distributed in the upper, lower and lateral directions of the solar collector in different proportions.

Figure 2.13. shows the temperature distributions in the area between two tubes in flat plate collectors. A quantity of heat is transferred from the absorbent plate to the tubes attached to it, which contain a cold liquid to be heated, and the process of heat loss from the tubes to the outer periphery is gradual.

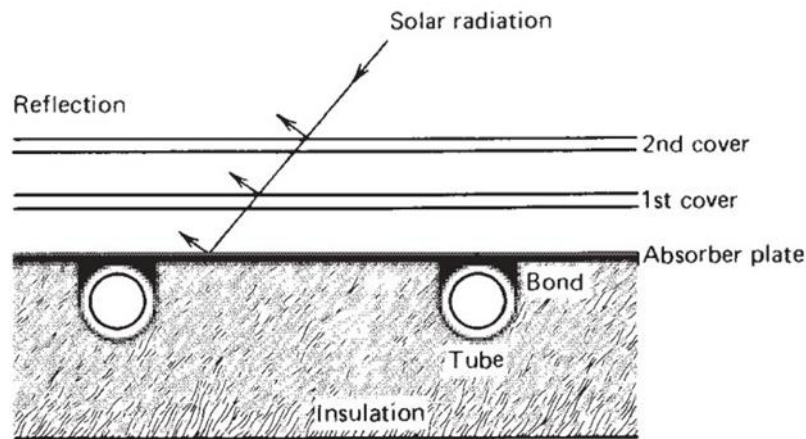


Figure 2.13. Temperature distributions in the area between two tubes in flat plate collectors (Duffie et al. 2020)

The thermal energy loss from the bottom of the solar collector U is determined and reduced by the resistance of the insulating materials R with low thermal conductivity K and of a certain thickness L by the equation (3.5) (Duffie et al. 2020; Chen 2011):

$$U = 1/R = K/L \quad (3.5)$$

In addition, the loss of heat energy due to conduction and lack of resistance through the bottom of the collectors leads to heat loss to the external environment by convection and heat radiation. And that the total heat loss includes the edges of the collectors in addition to the back insulation and can be calculated by the equation (3.6):

$$U_e = \frac{(UA)_{\text{edge}}}{A_c} \quad (3.6)$$

Where U_e is the heat lost from the edges, and A_c is the area of the collector (Tang and Li 2017).

2.2.4.5. Collector Box

The black liquid absorbing solar heating plate, the tubes to transfer the absorbed energy to the liquid, the transparent cover and the insulating material are all placed inside the solar collector box.

And the insulating materials encapsulate the parts of the compound inside a metal box made of light materials such as aluminum, wood or plastic, so that it carries properties that enable it to resist shocks and seasonal weather fluctuations and is tightly sealed so that it prevents moisture from the parts of the collector, with ease of attaching and disassembling it (Duffie et al. 2020; Ayyash 1981; Tang and Li 2017).

2.2.4.6. Safety Valve

A suitable safety valve is connected with its settings and connections for safety purposes at the exit point of the pipe from the collector to the tank to release the excess vapor to the atmosphere and reduce pressure rise with high temperatures that cause sabotage in the collector (Ayyash 1981) (Hossain et al. 2011).

2.2.5. Solar Collector Design

Solar collectors to convert solar energy into thermal energy are designed according to the type of use and the required need, and the size of the collector and the area it occupies varies from an individual to a family to a factory, and according to the designs of the water heating system for buildings or residential collectors (Ayyash 1981).

Accordingly, attention should be paid to the detailed models of the design of the collectors (absorbent plate, how the collectors are connected together, the quality and number of the transparent cover, the dimensions of the background and edge insulation, etc)

The *modus operandi* of the collector affects the design, for example the specification of the design details, and for many it may not be necessary to consider heat capacity at all (Duffie et al. 2020).

Each of the mentioned design methods has advantages and disadvantages. As for the design to increase the collector area may seem easy, but the designers face the difficulty of installation and disassembly and maintenance and it is more vulnerable to vandalism. As for the design of increasing the number of collectors, it is done in a way to connect the collectors to each other through pipes in geometric shapes, so that it gives the highest return of thermal energy, avoiding the difficulty of disassembling and linking and less exposure to sabotage. The problem of the spaces occupied by a group of solar collectors connected to each other, according to their different uses, from converting them into electrical or thermal energy, remains the field of study of researchers. The spaces occupied by solar collectors are a major reason for their limited uses and wide applications (Ayyash 1981).

Thermal performance models for thermal collectors depend on the purpose of their use and their operating conditions. If the operating conditions are highly variable, the models may be more complex (Duffie et al. 2020).

The time and cost factor is also important in choosing designs. The most common solar water heater is the rooftop direct flow system that uses all-glass tube solar heat collectors, due to its low cost, longevity, simplicity of installation and maintenance (Chen 2011).

Weather and weather conditions also have an impact on the quality of designs. For example, the manufacture of collector parts and the selection of their quality differ in cold regions than they are in hot or tropical regions. In most cases, in the winter season, the freezing of the thermal fluid must be taken into account and the use of anti-freezes with the addition of heat exchangers in tanks or Use the reverse flow method for domestic water heaters, which is an effective and simple anti-freeze method. Or by running the pump to circulate hot water in the hot storage tank as the temperature of the water inside the collectors.

As for the designs of collectors in buildings, they may differ from what they are in domestic use, as follows:

As shown in Figure 2.14. there are a group of systems to provide an individual or a family with hot water, such as heaters installed on the roofs of houses with adjoining tanks, or a group of users share in a group of solar collectors installed at the tops of buildings within tanks that store large quantities of water, as is the case in institutions and organizations schools, hotels and hospitals.



Figure 2.14. Individual and group hot water supply systems (Tang and Li 2017)

The relationship of the amount of hot water equipped for use, the available spaces for installing solar collectors, the number of solar collectors, their installation designs and maintenance mechanisms are among the important basic factors that affect the

performance and efficiency of solar collectors in buildings, while in domestic uses, the factors referred to differ to affect the efficiency and performance of the collectors and their systems. As shown in Figure 2.14. (c) (Tang and Li 2017).

He also contributed to the designs of types of active solar water heating systems from the direct circulation system and the indirect circulation system. By adding pumps to the solar collector system to circulate water to treat cold climatic conditions in the direct circulation system and in an indirect circulation system, the pumps circulate a non-freezing liquid to transfer heat through the collectors and heat exchanger, where the pump circulates water only between the heat absorber and the water cylinder, then the hot water flows out Storage tank(Hossain et al. 2011).

Finally, simple and effective methods and tools have been developed by researchers like Belessiotis Mathioulakis and Le Mans to improve solar collector designs such as collector type, number of collectors, heat storage mass, tank temperature, etc. (Thirugnanasambandam et al. 2010).

2.2.6. Solar Collector Efficiency

Collector efficiency is a measure of the performance of a flat plate collector, which is defined as the ratio of the useful energy gain, to the incident solar energy over a given period of time(Hossain et al. 2011), It is the ratio of thermal energy gained from a compound to the energy of solar radiation incident on its surface(Ayyash 1981).

The efficiency of the collector is affected by several factors, including:

2.2.6.1. Intensity of Solar Radiation

The intensity of solar radiation plays an important role in raising the efficiency of the collector (Ayyash 1981). As the solar radiation flows with a relative intensity to the black plate that is constantly absorbed through the transparent cover and heats it to high temperatures, then it begins to lose excess heat to the outside environment through the transparent cover to be a reason to reduce the efficiency of the collector.

This means that there is a direct relationship between the intensity and intensity of solar radiation with the efficiency of the collector, the more intense radiation flows into the collector, the higher its efficiency (Chen 2011).

The radiation intensity varies from one geographical location to another and from one season to another, and it also changes with the change of the angle of incidence of rays on the collector (Ayyash 1981). Efficiency, rate of angle of incidence and time constant can be considered as temperature dependent variables (Duffie et al. 2020).

While it is not possible to control the intensity of the radiation in any place, the angle of incidence of the ray perpendicular to the collector can be controlled so that it is equal to zero (Lambert's law). In order for the collector to remain highly efficient for rays with changing the seasons and geographical locations, a motor must be linked to the collector in order to rotate with the rotation of the sun and sway at an angle with the inclination of the sun in the seasons of the year, and this is practically difficult and costly together. Therefore, after several researches and studies, they found that to keep the solar radiation falling vertically, the collector must be oriented parallel to +10 degrees latitude to the southern side of the northern hemisphere throughout the seasons, especially in winter. Places separated from the collectors reflect an additional amount of radiation and direct it towards the collector (Ayyash 1981).

2.2.6.2. The Effect of The Collector Temperature Difference from The Ambient Temperature

The efficiency of the collector is affected by the difference in the temperature of the external environment to the change in the temperature of the collector over time. As due to the loss of heat emitted from the absorbing surface while constantly capturing the solar rays to the outer periphery through the transparent cover, which leads to a loss in the acquired energy of the absorbing plate, so that it reaches a stage where the efficiency is negative due to the ratio of heat loss to the amount of solar energy gained (Chen 2011). The thermal radiation emission of the collector to the outside environment increases as the temperature difference between the collector and the surrounding atmosphere increases, and thus the collector efficiency decreases (Ayyash 1981).

2.2.6.3. The Effect of Isolating The Collector From The External Environment

As a result of the high temperature of the collector from the outside environment, part of the heat escapes into the surrounding atmosphere, either by radiation, and this constitutes the largest part or through the transfer of heat. Therefore, the collectors are well insulated from all contact with heat transfer objects (Ayyash 1981).

Calculating the performance of the collector depends on the factors that are affected by the amount of solar energy gained and the amount of thermal energy lost, by knowing the temperatures entering and leaving the collector and the fluid flow rate in the transmission pipes, as in the equation (3.7):

$$Q_u = \dot{m}C_p(T_o - T_i) \quad (3.7)$$

In addition, the radiation on the collector and the ambient temperature and wind speed on the collector are also recorded and thus, two types of information are available: data on heat exit and data on the conditions leading to this thermal performance.

It is also possible to write an equation for the thermal performance of the collector based on the amount of incident radiation operating under constant conditions, as follows:

$$Q_u = A_c F_R [G_T (\tau \alpha)_{av} - U_L (T_i - T_a)] \quad (3.8)$$

where $(\tau \alpha)_{av}$ is the product of transmittance and absorption, defined according to the ratios of beam, diffused radiation, and ground radiation reflected back to the collector. The two equations below can be used to determine the instantaneous efficiency:

$$\eta_i = \frac{Q_u}{A_c G_T} = F_R (\tau \alpha) - \frac{F_R U_L (T_i - T_a)}{G_T}$$

$$\eta_i = \frac{\dot{m} C_p (T_o - T_i)}{A_c G_T} \quad (3.9)$$

FR represents the ratio of the actual heat transfer of the collector to the heat transfer to the thermal fluid without any heat loss to the ambient (Duffie et al. 2020).

Thermal performance is affected by the thickness of the absorbent board and the thermal conductivity of the absorbent board material. For example, the coefficient of thermal conductivity of copper is twice the coefficient of thermal conductivity of aluminum. As a result, we need only half the thickness of aluminum in copper when it is installed in solar collectors. But the cost of copper plates doubled aluminum three times (Tang and Li 2017).

There are various studies on the mechanisms of improving thermal performance to achieve efficiencies ranging from 50% to 78% in different ways, including the use of nanofluids instead of traditional fluids, including improving the quality of the absorbent plate coating, the quality of the insulating material, and others.

There are other methods that some researchers resorted to by improving the integrated corrugated absorbent surface instead of the flat surface, which increased the thermal efficiency values of the solar collector. The researchers also studied that adding insulation to the compound contributes to addressing heat loss to some extent.

Some experiments also proved that adding an additional absorbent coating layer to the absorbent plate leads to a higher absorbability of solar rays, and thus increases its efficiency. As for the tests, studies and laboratory work on the shift from using water as a heat transfer fluid to adding nanoparticles to the fluid, heat transfer increases thermal conductivity and its performance. In the next chapter, we will discuss this topic in detail (Shamsulet al. 2020).

2.2.7. Solar Collector Mass

The smaller mass of the collector, the faster the heating of the collector begins. And it is better if the glass panels, absorbent plate and pipe walls are as thin as possible. In addition, the volume of thermal fluid in the tubes located under the absorber plate is limited to no more than 3 liters per square meter of the collector, and all these factors

affect the final cost of the parts of the collector, which was the field of research of researchers such as. Filipović and others, by using polymer and wood material as a box to contain the components of the collector and prevent leakage and heat loss (Ayyash 1981) (Shamsulet al. 2020).

2.2.8. Solar Energy Storage

The development of solar energy storage is no less important than the development of the performance of solar collectors, if they are the main supply. In order to benefit from the solar energy continuously and sustainably at all times, because the rays of the sun that reach the earth are not equal throughout the seasons of the year nor at the hours of the day. In the summer, the intensity of the sun's rays is definitely stronger than it is in the winter season, not to mention the blocking of the rays during The night. Because solar energy is intermittent, energy storage is a necessity that must be stored just as any product or material is stored to meet the needs related to it from its applications in multiple fields. Hence the importance of developing methods of storing heat from the solar collector for use when needed, especially in solar heater applications, the constant need for hot water, home heating, and many other areas of solar energy exploitation (Duffie ET AL. 2020; Chen 2011; Ayyash 1981).

The peak effective solar radiation occurs when they are awake in the middle of the day, and since the need for heating and hot water persists throughout the day. Some kind of energy storage system is needed when there is no sunlight at night or lack of it in some seasons of the year, such as winter review on solar water heater collector and thermal energy performance of circulation tubes (Hossain et al. 2011).

The goal of thermal storage is to take advantage of them in times of need. Thus, the period of time during which storage losses occur are when they are not used, and losses occur in the summer months when there are no systems with sufficient storage capacities to arrange the days of the year (Duffie ET AL. 2020; Chen 2011; Ayyash 1981). Solar thermal energy can be stored easily and inexpensively compared to other energies. It is of two types: thermal energy that does not change from its properties at different temperatures, and another that moves from one phase to another, so that it retains the

largest amount of energy while it is still standing and stable at temperature and pressure, liquid or solid, by a thermodynamic process (Chen 2011).

2.2.8.1. Heat Storage Principles

There are principles of energy storage, and methods for calculating its capacity, so as to enhance the useful solar energy gains to meet its needs at the necessary times. Energy is stored either in the form of apparent heat or chemical to preserve materials, or it is stored in the form of latent energy as a result of mechanical processes.

Since all bodies in nature have the ability to store energy, but with different capacities. Therefore, the process of developing energy storage depends first on the heat capacity of each material, meaning the amount of heat absorbed by one cubic meter to raise its temperature by one degree Celsius, and on the range of temperatures that can be worked with without any physical or chemical shift in the storage material. The field of storing water, for example, ranges between (0-100) degrees Celsius without any change. Finally, the factor of time required for the process of storage and discharging speed is also important for developing energy storage performance. Solar process products, such as storing distilled water from a solar system, can be stored in tanks until needed, and electrical energy stored as chemical energy in batteries. As for storing energy in the form of latent heat in latent heat tanks, it is still in the research and development stage, which depends on the melting and freezing energies of each material, but it has several advantages, including the use of relatively small tanks to store a certain amount of energy, and also the amount of heat loss from the reservoir as a result of radiation. Thermal to the outside environment few (Duffie et al. 2020; Ayyash 1981).

2.2.8.2. Thermal Energy Storage Properties

1. Possible amount of storage per unit volume.
2. The amount and rate of temperature at which heat is added to and removed from the storage system.
3. How to add or remove heat and temperature differences associated with the storage system.

4. Stratification of temperature in a volume.
5. Energy needs to add or remove heat.
6. The type of tanks associated with the storage system.
7. Mechanisms for controlling heat losses from the storage system
8. Economic cost needed storage system.

There are several factors involved in knowing the amount of stored, lost and transmitted heat between the solar collector, the storage place and the external environment, and it is expressed by the equation (3.10):

$$T_c - T_d = \Delta T_{c-s} + \Delta T_{s-in} + \Delta T_{s-loos} + \Delta T_{s-out} + \Delta T_{s-a} + \Delta T_{a-in} \quad (3.10)$$

Where T is temperature, c is the collector, d is the delivery, s is the storage, and a is the applications.

Diagram 3.11 below illustrates the model of the storage and transmission mechanism for the collector and the field of application referred to in equation (Duffie et al. 2020):

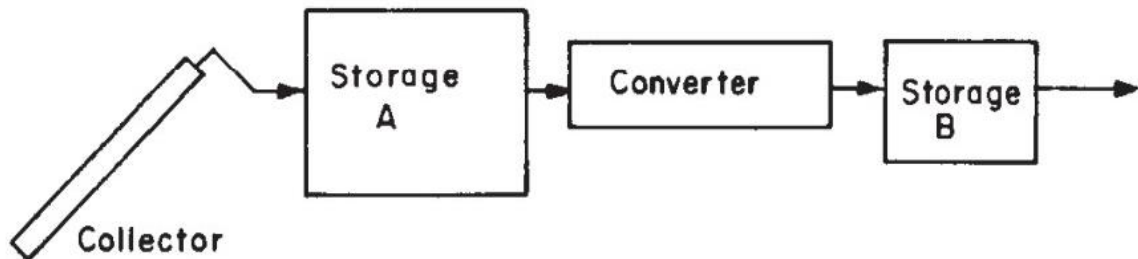


Figure 2.15. Schematic diagram of storage and transfer model in A or B (Duffie et al. 2020)

2.2.9. Tank Construction

To preserve the amount of heat coming out from the solar collector as a result of converting solar energy into thermal energy, a tank is designed to store the storage material coming out of the solar collector. There are multiple designs for tanks designed according to the type of stored heat (apparent heat, latent heat). Most of the current and

future studies and research are directed towards raising the efficiency of storage of various types and sizes (Ayyash 1981).

There are several ways to improve the storage capacity of the tanks, one of which is the design of the tank in the form of multiple layers as shown in Figure 2.16. Where the temperature at the top is hotter than at the bottom, the tank is divided into a group of nodes in which energy levels are regulated in a balanced manner. Each level in the tank layers has a size that matches the entrances and exits and the flow rate.

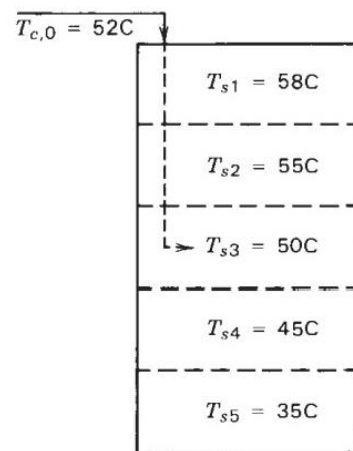


Figure 2.16. Model of a hypothetical five-node tank (Duffie et al. 2020)

The problem of storage in large quantities may remain with many researchers, so some designers directed to study the exploitation of storage capacity in caves and groundwater or water-filled pits in the ground. In this case, there will be more room in the stratification at different temperatures, which leads to heat loss or thermal coupling with the Earth. Therefore, the earth components of sand, rocks, etc. are used by adding some heat transfer fluids as a large reservoir to provide thermal energy (Duffie et al. 2020).

2.2.10. Short Term Storage Tanks

They are tanks made of materials that can hold storage materials such as hot water or warm air for a short period such as hours or days for domestic use in winter. The tank is made of a material with good storage capacity, it does not react with the storage material

at temperatures and bears pressure. It is insulated from the outside with an insulating material to prevent the amount of energy leaking from the tank. The storage material in the tank is continuously transferred to the solar collector, where it is heated and back to the tank under constant pressure (Ayyash 1981).

Storing hot water and protecting it from heat loss and preventing it from corrosion and rust It is preferable to use materials either glass and plastic or steel and concrete lined with materials that resist rust and corrosion.

2.2.10.1. Advanced Heat Storage Methods in Tanks

1- Adding a heat exchanger to the tank: where the storage material coming out from the solar collector enters the tank that may contain another storage material that is not similar to the storage material of the solar collector in order to raise its temperature. The two storage materials do not mix with the heat exchanger, and it is not a condition that the pressure of the solar collector is equal to Tank pressure in this case.

2- To extend the storage time for longer periods, it may also be added to the tank with the presence of the heat exchanger, an electric or petroleum heater that works automatically when the temperature in the tank drops below the required level at all times of the day and night and days of the year, regardless of the weather, the extent of sunrise and the intensity of its rays.

3- Adding an additional tank to the original tank increases the storage efficiency so that the total volume of the two tanks remains equal to the volume of one tank. In this case, the storage material that gained thermal energy from the original first tank enters the additional tank after its temperature has been raised to the required temperature. The cost of the two tanks and the transfer of heat from the surface of both tanks to the outside environment is greater than one tank, and stopping taking the storage material from the additional tank for a period of time creates problems in the entire system and falls within the disadvantages and disadvantages of using the two tanks.

4- Design of a tank with two floors separated by a bulkhead equipped with one or several openings. As the heating material in the tank is heated in the lower layer and its temperature is raised by the solar collectors, and thus it is raised to the upper layer.

2.2.10.2. Long-term Storage

It means storing solar energy for several months from summer to winter. There are continuous designs and research for the purpose of storing the surplus of solar energy in the summer to winter season, some of which have come into application, such as building insulating basins to fill with storage material, whether the material is hot water or other materials in the basement of buildings depending on the storage of apparent heat, with sizes (40- 100) cubic meters. However, the loss of thermal energy during the long storage period reached 50% of the stored energy. Therefore, research is moving towards latent heat storage and chemical storage as solutions to the issue of long-term storage (Ayyash 1981).

Independent chemical reactions that are not subject to other reactions and that produce energy or absorb energy from them are considered ideal ways to store thermal energy (Duffie et al. 2020).

2.2.10.3. Characteristics of Storage Materials

In addition to the above mentioned factors, high density, low vapor pressure, low reactivity with the storing vessel and the cost must be provided in the storage materials. Perhaps one of the most difficult problems in finding a suitable storage material is in achieving some of the following characteristics in a storage material:

- 1- The energy to transform matter from one physical state to another must be great.
- 2- The heat conductivity of the material is good, whether in a solid or a liquid state.
- 3- The change in the volume of a substance due to the transformation from a solid to a liquid state is small .
- 4- The incapability of a chemical reaction between the material and the storage container.
- 5- Its costs are low.

2.2.11. Water Storage

Due to the abundance of water and ease of obtaining it, it is the ideal material for storing heat in the tank and using it when needed. Energy is added and removed from this type of storage unit by conveying the storage medium itself, thus eliminating the temperature drop between the transmission medium and the storage medium. The typical system in which a water tank is used is shown in Figure 2.17.

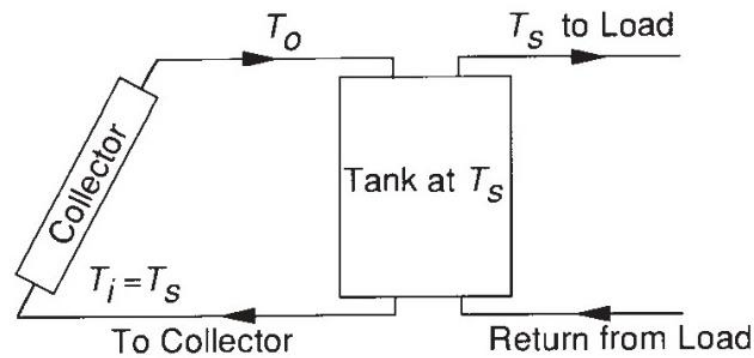


Figure 2.17. Schematic model of water storage and carrying (Duffie et al. 2020)

The heat capacity for energy storage of a water (or other liquid) storage unit can be found at different temperatures as follows:

$$Q_s = mC_p (T_s - T_l) \quad (3.11)$$

Where Q_s is the total heat energy stored in the tank for a complete loading cycle to and from the tank via the solar collector, T_s is the storage temperature of the usable tank and m is the mass of water per unit time, c_p is the heat capacity of the storage material and T_l is the temperature of the load entering the tank (Duffie et al. 2020).

In the Table (2.5) below, it is clear that the heat capacity and thermal conductivity of water is higher than that of metals and other liquids such as ethionyl, glycerine, and others.

Table 2.5. Thermal properties of some liquids

Materials	Density ρ 10^3 Kg/m^3	Heat capacity c_p $\frac{10^3 \text{ J}}{\text{Kg} \cdot \text{K}}$	Product ρc_p $10^6 \text{ J/m}^3 \cdot \text{K}$	Temperature Range ΔT $^\circ\text{C}$
Water	1.00	4.19	4.19	0 to 100
Ethonal	0.78	2.46	1.92	-117 to 79
Glycerine	1.26	2.42	3.05	17 to 290
Canola Oil	0.91	1.80	1.64	-10 to 204
Synthetic Oil	0.91	1.80	1.64	-10 to 400

The volume, area, and thickness of the tank has a direct relationship with the storage capacity. The loss of storage capacity and temperature is directly proportional to the size and storage space of the tank. For cylindrical tanks, the diameter and length of the tank plays an important role in determining the storage energy loss and temperature, and the ideal design for low temperature and storage lies when the length and diameter of the cylinder are equal. If we take into account an insulated tank with a thickness of 5 cm and dimensions of 1 meter, the time period to reduce the temperature of one degree Celsius needs 8 hours as in Figure 2.18. (Chen 2011).

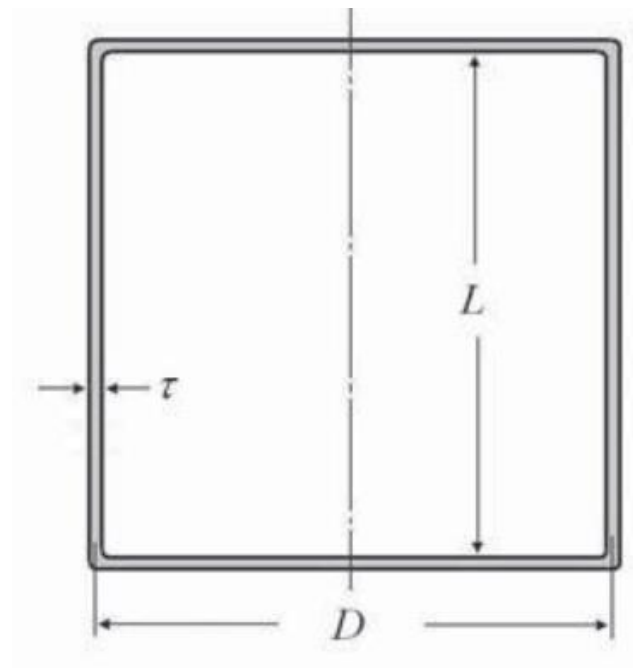


Figure 2.18. Dimensions of a water tank and its thickness to reduce the temperature(Chen 2011)

The average consumption of hot water in domestic water tanks ranges between 20-30 gallons / day / person. Similarly, the rate of hot water supply for a family consisting of four people should range between 80-120 gallons / day / family (Hossain et al. 2011).

2.2.12. Solar Preparation of Hot Water

The exploitation of solar energy in the preparation of hot water is of particular importance because it constitutes about 40-50% of the total energies consumed on the surface of the earth, which are consumed in the form of heat at temperatures less than 100 degrees Celsius. Most of the solar hot water preparation devices use both flat and evacuated solar collectors, Which has an efficiency of about 70% which is suitable compared to direct solar inverters which have an efficiency of about 17%. These collectors are environmentally friendly and meet household needs and in some industrial fields.

Hot water of low density is transferred from the solar collector through the tubes to the tank either automatically by (siphon) process, due to its light weight under constant air pressure due to, as in Figure 2.15. or by pumps where the movement of thermal fluid between the solar collectors and the tank is regulated by a pump Small, connected to an electronic regulating device that regulates its work, pumping between (90 - 120) liters per hour and per 1 square meter of solar collectors with a power of 5 watts. With the pump, the tank can be placed anywhere and works with all solar collectors, despite its cost and the need to provide an electrical source close to it (Nagarajan et al. 2014; Ayyash 1981).

In the heat exchanger heating system, the hot water is separated inside the tank. Water or any anti-freezing fluid enters the vacuum-type heat collector and is useful in areas with freezing temperatures, as the fluid is pushed by a pump regulated by a controller that connects outside the accumulator so that it helps to regulate the temperature of the fluid. Another temperature gauge is placed to measure the temperature of the tank as shown in Figure 2.19. (Duffie et al. 2020).

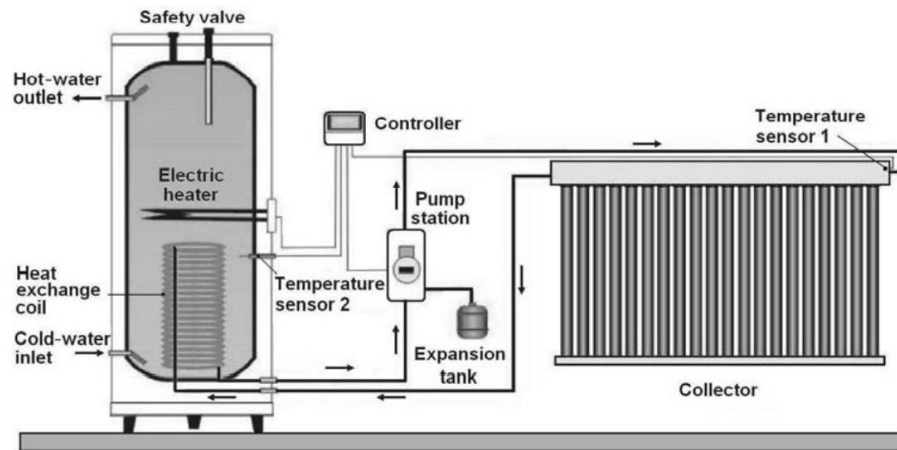


Figure 2.19. Parts of a separate solar heat exchanger heater (collector, tubes, pump, tank, thermometers) (Duffie et al. 2020).

Mono solar water heating systems are generally classified on the basis of the force of water pushing from the tank to the collector through the pump and circulating it from a negative or forced natural cycle or on the basis of freezing point to direct and indirect systems.

In the natural circulation system, the tank is located above the solar collector. When solar energy is converted into heat energy by the absorbing surface, the temperature of the thermal fluid from the tubes in the collector rises and its density decreases. As a result, the liquid rises from the bottom of the collector to the top and then moves to the tank by Siphon operation as shown in Figure 3.16. (a) (Tang and Li 2017).

The direct circulation system that uses pumps differs from the indirect circulation system in that it operates in fixed climates so that the fluid circulation is not subjected to freezing. The pumps in the indirect circulation system circulate a non-freezing liquid to transfer heat through the collectors and the heat exchanger and push the liquid into the tank as shown in Figure 3.16. (b) (Hossain et al. 2011).

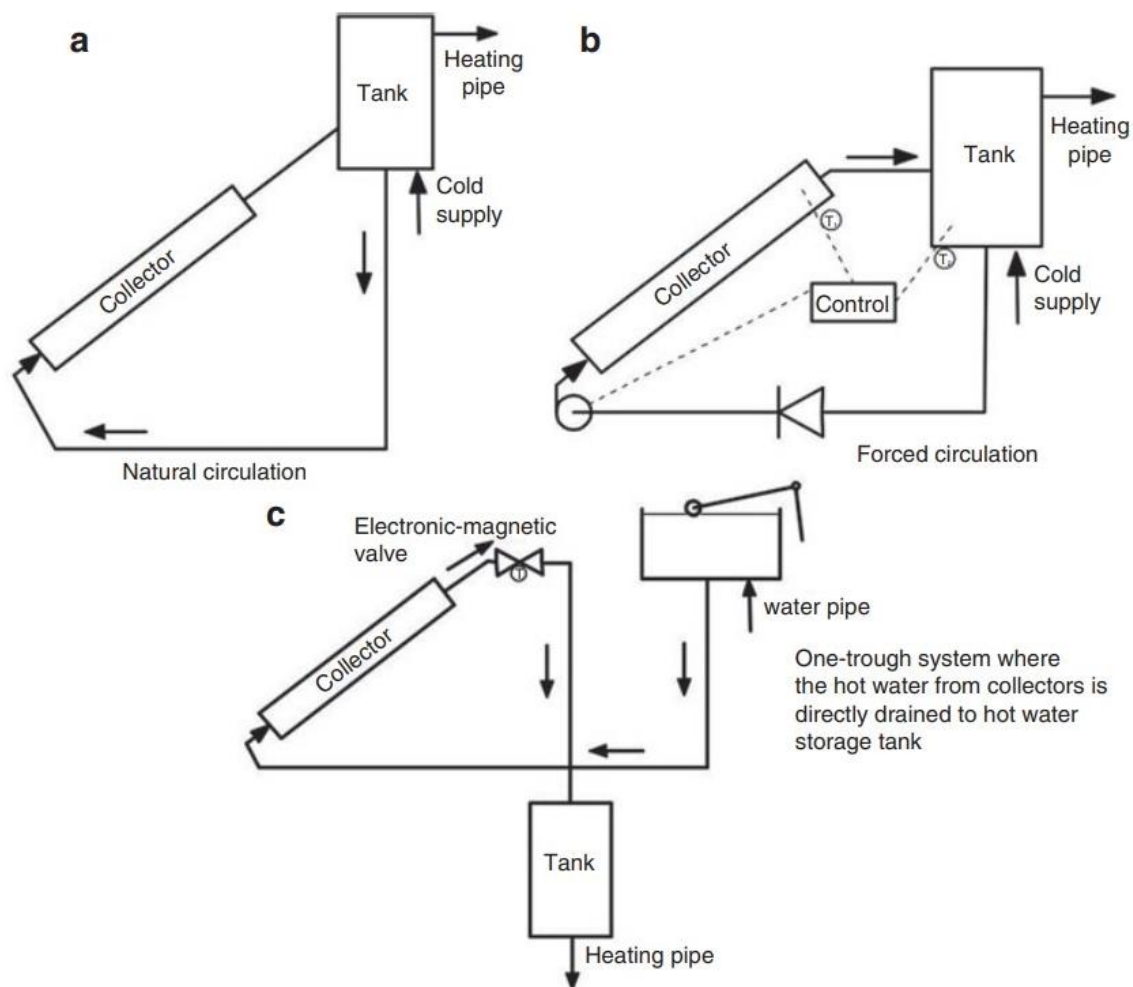


Figure 2.20. Diagram of liquid circulation in natural or pump solar energy systems (Tang and Li 2017)

In Figure 2.21. (a) natural circulation appears by the siphon process, but for the water to remain at the exit temperature from the collector, a heat exchanger needs to be added to be placed in the tank. As in Figure 2.21. (b) a forced circulation system appears, in addition to a thermostat that operates the pump at different temperatures at the top and bottom to ensure stability control. Another valve will be added to prevent reverse circulation and nighttime heat loss from the collector.

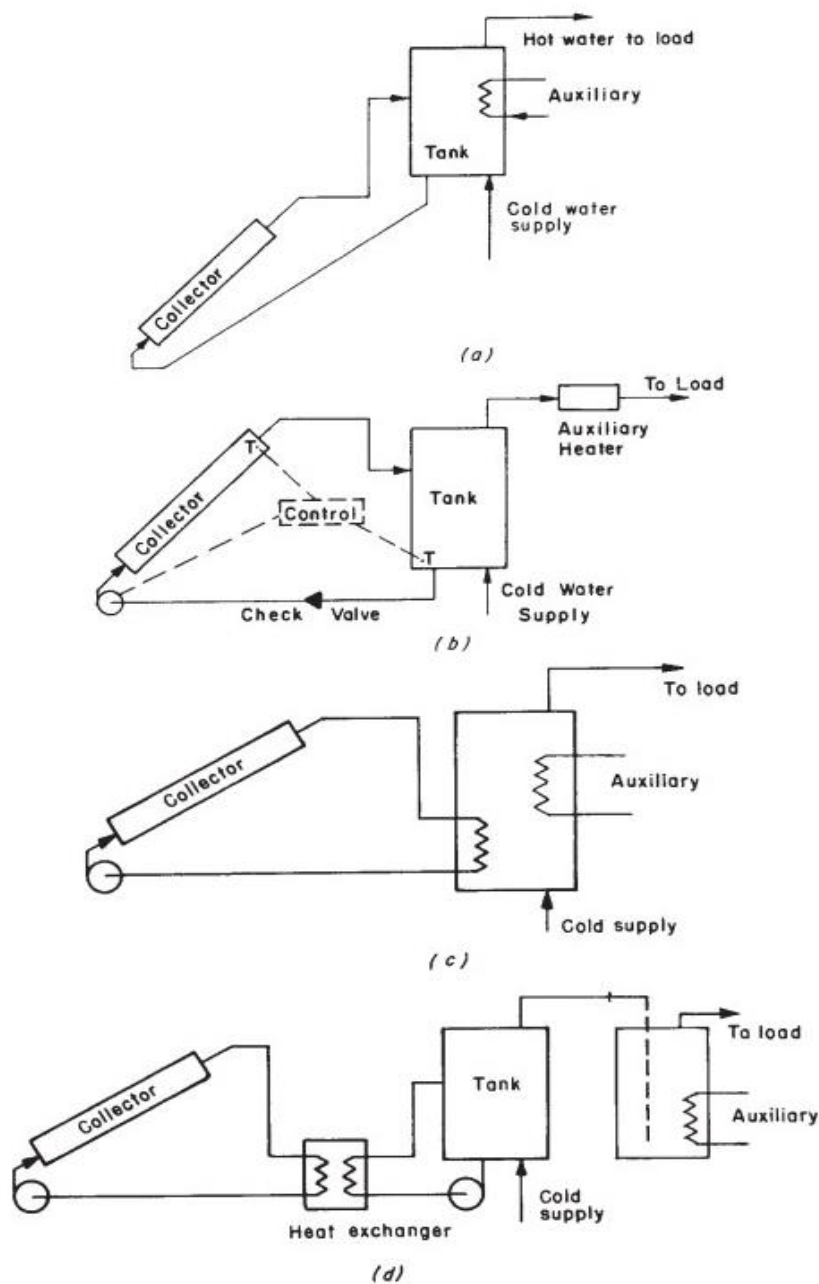


Figure 2.21. Schematic diagram of the placement of heat exchangers in natural and forced water heater systems(Tang and Li 2017)

In Figure 2.21. (c), instead of adding a thermostat in Figure b, the heat exchanger is placed in the storage tank. In Figure 2.21. (d), a standard electric water heater has been added, in addition to the tank to which the hot water from the solar collector is directed.

Figure 2.22. shows some real pictures of solar collector systems to heat water for homes, buildings and hospitals for a Swiss city, showing the ways of connecting pipes to each

other at distances ranging from 0.10 to 0.15 meters made of copper, steel or aluminum materials.



Figure 2.22. Solar water heaters with natural circulation for domestic use and hospitals, and the method of connecting pipes in the cities of Australia. Image source: Affiliated Engineers

2.3. Fluids

2.3.1. Thermal Fluids

In solar energy applications in general, traditional working fluids with poor thermophysical properties compared to solids such as water, ethylene glycol and heat transfer oil still play an important role in industrial processes and chemical production from power generation and conversion to heating, cooling, nuclear system, space, defense, transportation and microelectronics. But what is taken on conventional liquids, as they have low thermal conductivity and do not reach a high level of temperatures (Cuce et al. 2020; Gupta et al. 2017; Mahian et al. 2013).

Generating high thermal energy is an important requirement for equipment, processes and industrial needs, so speeding up the enhancement of meeting technologies by obtaining high temperatures is a reason to reduce stress on heat transfer equipment (Duangthongsuk and Wongwises 2010).

The introduction of materials with thermal conductivity in liquids contributes to improving the physical properties and affects important factors in particles (size, shape, etc.), and thus it can be incorporated into solar energy applications such as refrigerants in heat exchangers in cars.

Initial studies focused on mixing solid particles in liquids to increase thermal conductivity in millimeter or micrometer sizes to modify thermophysical properties to enhance heat transfer, but the size of solids and their suspension in the liquid at these sizes caused clogging of the channels and weakened their stability and suspension. For these reasons, a trend has been made towards the development and improvement of the technology of solids with high thermal conductivity compared to traditional materials (Gupta et al. 2017).

Nanoparticles and nanofluids have effectively contributed to technological developments by improving their thermal and optical properties, especially in solar energy applications, thermal energy storage systems, and in the fields of automobile and heat exchangers.

Finally, it aims to achieve the best performance of solar energy systems and increase their production efficiency (Cuce et al. 2020; Nagarajan et al. 2014).

In addition, the superior thermal behavior of nanofluids can support a wide range of commercial, transportation, power generation, micromanufacturing, thermotherapy for cancer treatment, chemical and metallurgy sectors, and production of nanostructured materials for engineering collector fluids to clean oils from surfaces (Paceet al. 2011; Mahian et al. 2013).

The liquid plays a prominent role in energy conversion and transfer, and water is one of the most common fluids in solar energy applications, as mentioned earlier in the second chapter, with its low ability to conduct heat. Nanofluids act as an alternative to water as a conventional liquid, in order to improve thermal transfer and thermal conductivity (Cuce et al. 2020; Verma and Tiwari 2015).

The term "nanotechnology" has been in circulation since 1974 when Norio Taniguchi, a researcher at the University of Tokyo, Japan coined the process of engineering materials with precision at the nanometer level. Its aim was to develop electronic construction device tools and the accuracy of its miniaturization in terms of size dimensions to reach 40-70 nanometers for a silicon thinner, and thus it has wide applications in the memory of computers, components and semiconductors. "Nanotechnology" is the application of science to control matter at the molecular level (Vaidyanathan et al. 2009).

At the end of the last century, developments began in nanotechnology, and particles of materials with a size (less than 100 nanometers) were scattered in basic fluids instead of micrometer-sized particles, called nanofluid.

The introduction of the new technology also initiated improvements in particle properties and advantages of better stability, suspension and greater thermal conductivity (Duangthongsuk and Wongwises 2010).

The new technology of nanofluids has attracted many researchers and students in the electronic, mechanical and health sciences and sectors, in addition to the optical,

electrical and thermal properties, and traditional fluids have been mixed with nanofluids to obtain new and advanced physical and thermal properties (Gupta et al. 2017).

Therefore, metal-based nanomaterials are the most common photoactive materials capable of performing the processes described above (Wei et al. 2019). Nanoparticles (NPs), in turn, which are particles with one or more dimensions within the range of 100 nanometers or less, have attracted great interest due to their unique and attractive features and their irreplaceable usage over their analogues bulky materials (Khan et al. 2019).

Metallic nanoparticle NPs, in general, possess several advantages. First, their optical properties can be easily controlled, practically they are perfect optical absorbers (Khan et al. 2020). Second, they can be utilized in multifunctional applications to accomplish some specific purposes such as rapid thermal response (Coronado et al. 2011), corrosion resistance (Yan et al. 2009), recyclability (Astruc et al. 2005), etc. Last but not least, through the doping of metal-based materials, heat loss can be effectively reduced (Myers et al. 2016).

Photoactive nanomaterials, composed of novel metals, are capable to convert solar energy into thermal energy (Kamat 2007). In recent times, the synthesis of metallic NPs is an important area of research, due to the diverse application of NPs (Salem and Fouda 2021). When the particle size goes to the nanoscale, it's catalytic (Hvolbæk et al. 2007), optical (Khan et al. 2020), thermal (Eastman 1999; Li et al. 2020), mechanical (Guo et al. 2013), electronic (Löberg et al. 2013) and magnetic activity (Kolhatkar et al. 2013) will improve significantly.

2.3.2. Nanofluids

It is a type of homogeneous fluid suspensions of nanoparticles containing nanoscale materials (1-100 nm) that enhance the improved thermophysical and rheological properties of the particles dispersed in the solution and have thermal conductivity of bulk solids with higher amounts than the base fluids, which makes them more suitable for solar energy systems. The heat transfer properties are much better than conventional liquids depending on the nanoparticles used, the size of the nanoparticles, and the

concentration of the colloidal suspension. It is a new class of heat transfer fluids engineered by dispersing metallic or non-metallic nanoparticles (nanoparticles, nanofibers, nanotubes, nanowires and nanopods) into base fluids.

Improving the size, shape and concentration of nanoparticles effectively contributes to determining the behavior of nanofluids and the thermophysical properties, especially when mixing a group of nanoparticles with hybrid characteristics such as nanostructures, and it has a significant and direct impact on the efficiency and thermal performance of the solar collector.

Despite the good characteristics and advantages of suspended nanoparticles, it remains to determine the potential risks of using it to ensure liability. One of the challenges faced by researchers and scientists is the toxicity of nanomaterials and their complex effects and the weakness of the technical method in environmental systems (Paceet et al. 2011).

2.3.3. Applications and Uses of Nanofluids

Applications of nanoscale fluids in solar energy enhance the efficiency and performance of solar thermal systems in collectors and solar water heaters. In addition, they also enhance thermal energy storage, solar cells, and solar trailers. More recently their thermophysical properties, such as heat capacity, thermal conductivity, viscosity, latent heat and critical heat flux have been extensively studied in comparison to those of basic fluids such as oil or water. The heat transfer fluids and volumetric solar receivers show great potential for the current high-efficiency and low-cost systems.

Accordingly, metallic NPs can be used in different areas of applications. Figure 2.23. shows some real pictures of applications and uses of nanofluids such as absorption of the light spectrum (Singh et al. 2020), water purification (Singh et al. 2020b), antimicrobial activity (Singh et al. 2020b), biomedicine (Długosz et al. 2020), sensors (Khurana and Jaggi 2021) and many others.

The great use of nanoscale applications in the manufacture of dyes, cosmetics, catalysts, foodstuffs, paints, screens, batteries, catalysis, pharmaceuticals, energy, agriculture,

refrigerants, and stain resistant textiles is due to their physical properties of accurate size, distribution and dispersion (Cuce et al. 2020; Nagarajan et al. 2014; Wang et al. 2016).

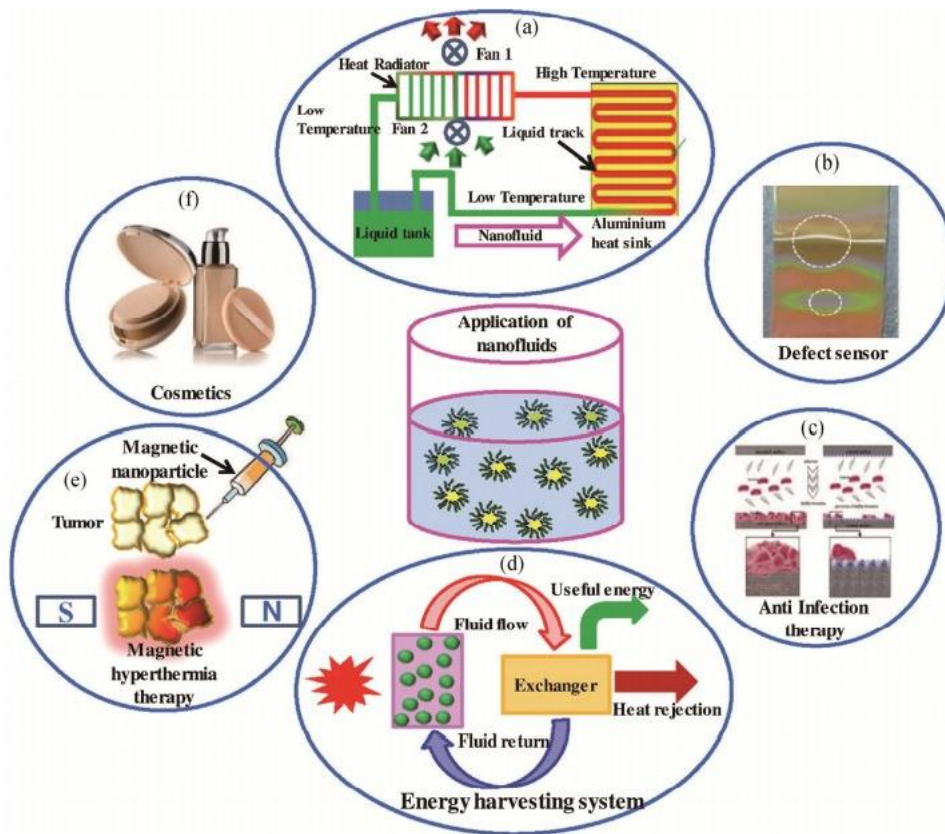


Figure 2.23. Schematic diagram of typical applications of nanofluids (Cuce et al. 2020)

2.3.4. Types of Nanofluids

Nanofluids are divided according to the metal atoms contained in them, some of them are metallic and non-metal.

Liquids containing metallic particles such as Cu, Fe, and Ag etc. have enhanced thermal conductivity and temperature-dependent effects, compared to non-metallic nanofluids containing non-metallic nanoparticles. Such as aluminum oxide (Al_2O_3), silicon carbide, semiconductor (TiO_2), carbon nanotubes, and composite materials such as nanoparticles that make up the shell of the polymer core. Studies and research are conducted on it to find out the physical properties that contribute to raising its performance and efficiency to enter the areas of practical applications (Nagarajan et al. 2014).

2.3.5. Nanoparticle Devices Technologies

To analyze the concentration of nanoparticles, see their shape, measure their weight, and determine their ability to absorb solar rays, advanced devices and technologies must be present that extract data, and in the light of these data, the physical and chemical properties of nanoparticles are known.

Among these techniques are transmission and scanning electron microscopy, atomic force microscopy, Fourier transform infrared spectroscopy, X-ray spectroscopy and others.

There are techniques that only know the time and intensity of light that can calculate the size of nanoparticles. However, some complications remain in some of the physical properties of the shape of nanoparticles that prevent obtaining accurate data under some natural conditions (Brar and Verma 2011).

2.3.5.1. Particle Concentration Analysis Technique

It is also known as inductively coupled plasma mass (ICP-MS). The traditional method for measuring the concentration of metals in samples, this technique analyzes the ultra-concentrated elements (ng/L). Where the meter detects the metal ions of the charged blocks to read their density related to the amount of metal detected during a limited period of time. Then, based on the concentration of known metals, and from the titration curve associated with the density extract the value of the concentration of metal particles in the sample.

2.3.5.2. Light Scattering Techniques

It uses light scattering techniques to measure nanoparticles, an important technology in the field of various industrial, chemical and physical applications, as well as knowing their toxicity levels to reduce damage to the environment and their food uses. Conventional techniques available for colloidal particles have limited certainty, such as (microscopy, spectroscopy, resonance, and modern additives). Here are some techniques

that contribute to better knowledge of the important properties of nanoparticles than conventional techniques:

2.3.5.2.1. Working Principle of Light Scattering

The principle of the process of scattering light on nanoparticles suspended in liquids is to find the dimensionless size parameter α for nanoparticles by means of the equation below:

$$\alpha = \frac{\pi D_p}{\lambda} \quad (4.1)$$

where πD_p = circumference of the particle, and λ = wavelength of the light. Because the nanoparticles interact with the viscous liquid and are suspended in it, a random movement called Brownian motion occurs. The Brownian motion, temperature, electric charge, and particle size are linked through the following relationship:

$$D = \frac{k_B T}{6\pi\eta r}$$

$$D = \frac{\mu_q k_B T}{q} \quad (4.2)$$

where D = diffusion constant, q = electric charge of a particle, μ_q = electric mobility of a charged particle, k_B = Boltzmann's constant, T = absolute temperature, η = viscosity, and r = radius of spherical particles.

When highlighting the optical movement of suspended particles using DLS technology at a specific speed and time, the particles light up due to frequency shifts and light propagation, which helps in determining the function of the particle diameter and refractive index and knowing the relationship between the interaction of nanoparticles and the phenomenon of gravity, as shown in the Figure 2.24.

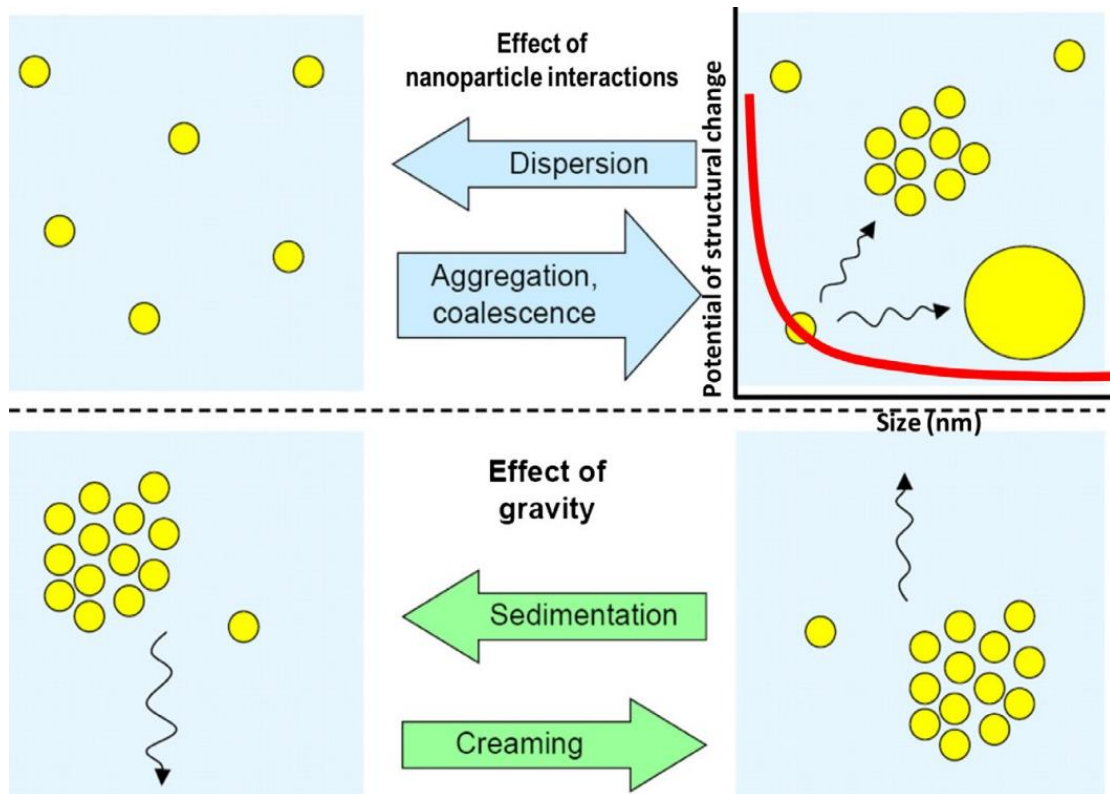


Figure 2.24. Light scattering technique on suspended nanoparticles in viscous liquids

2.3.6. Sample Preparation Techniques

In the experimental conditions for the preparation of nanofluid samples consisting of nanoparticles dispersed in ordinary basic liquids, the mixing must be appropriate to stabilize the particles and suspend them in the liquid. Sample parameters (eg quantity, temperature, pressure and viscosity) are determined by selecting the sample cells. Light scattering method used to measure the size of nanoparticles (NPs)(Brar and Verma 2011) shows in Figure 2.25. For most off-line measurements of aqueous or non-aqueous solutions of scattering NPs or polymers, quartz glass cylindrical cuvettes are used. And it must be taken into account when mixing the particles with the liquid that the sample is diluted to prevent interactions between the particles, which may lead to interferences and agglomerations between the particles.

There are three methods for controlling and stabilizing the particles, unloading dispersed nanofluids, and not accumulating and depositing them, so as to achieve a change in the surface properties of the particles:

- 1- Controlling the pH value of the suspensions.
- 2- Addition of surfactants.
- 3- Using ultrasonic vibrations (Duangthongsuk and Wongwises 2010; Wang et al. 2016).

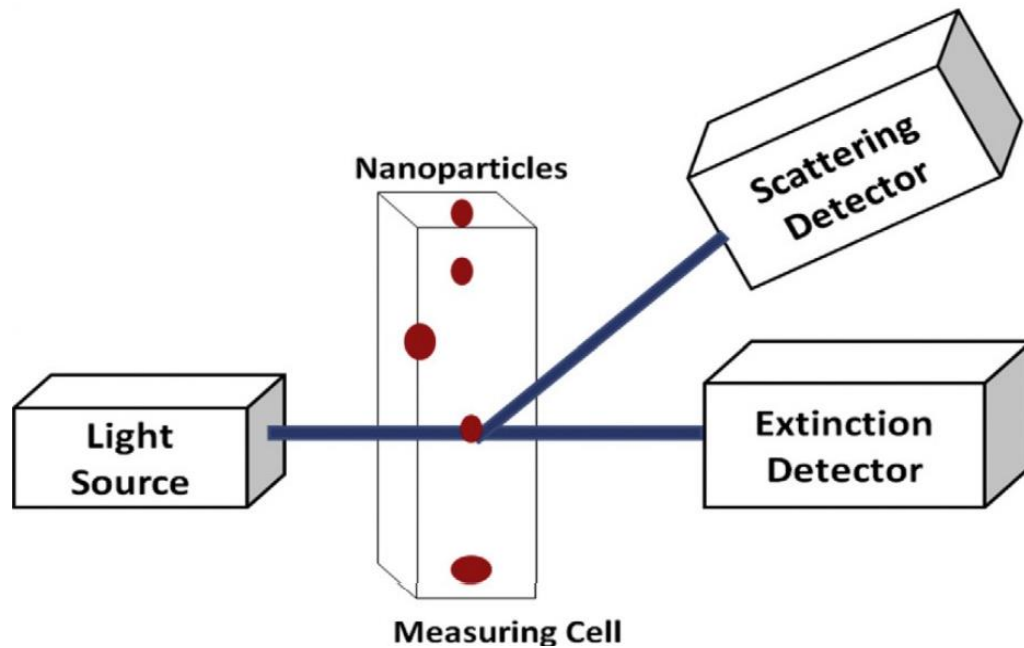


Figure 2.25. Set up a typical light scattering method to measure the size of nanoparticles (NPs)(Brar and Verma 2011)

2.3.7. Thermophysical Properties of Nanofluids

To change the physical properties of traditional basic fluids such as water, it is mixed with nanoparticles to give new improved thermal properties (conductivity, specific heat, viscosity, heat transfer coefficient, emissivity and optical absorption). All these properties depend on the size and shape of the particles, the level of purity and the type of nanoparticles in the liquid. Thus, improving the physical properties increases the performance of solar collectors compared to conventional collectors that rely on water only in different operating conditions of pressure and temperature. Therefore, it is necessary to select a suitable nanofluid to achieve the highest efficiency and performance. Table 2.6. shows that the value of the thermal conductivity factor for nanoparticles suspended in liquids is higher than the value of the thermal conductivity factor in conventional liquids (Nagarajan et al. 2014; Verma and Tiwari 2015).

Table 2.6. Thermal conductivity of various solids and liquids (Nagarajan et al. 2014).

Material	Specification	Thermal Conductivity W/m-K
Metallic Solids	Copper	401
	Aluminum	237
	Silver	429
Nonmetallic Solids	Silicon	148
	Alumina	40
	CNT	2000
Nonmetallic liquids	Water	0.613
	Ethylene	0.253

2.3.7.1. Thermal Conductivity

The experiments conducted by the researchers proved that the addition of nanoparticles in liquids of different types increases the thermal conductivity due to Brownian motion that controls the thermal behavior of nanoparticles suspended in liquids on the one hand, as shown in Figure 2.26. On the other hand, the interfacial nanolayer was formed near the surface of the solid particle in the form of multilayered structures, as shown in Figure 2.27.

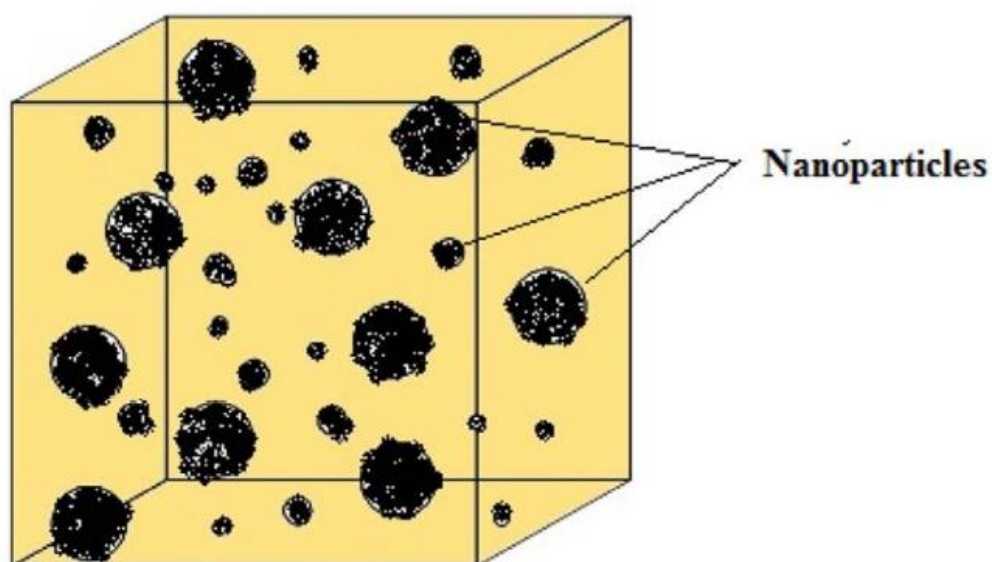


Figure 2.26. Brownian motion of nanoparticles suspended in liquids

After measuring the thermal conductivity of nanofluids with different techniques, it was found that the thermal conductivity of nanofluids is higher than that of conventional

fluids such as water, kerosene, ethylene glycol, and others. However, the problem of pressure drop to some extent during flow as a result of the new physical properties remains an obstacle for researchers and scholars to find appropriate solutions in the future.

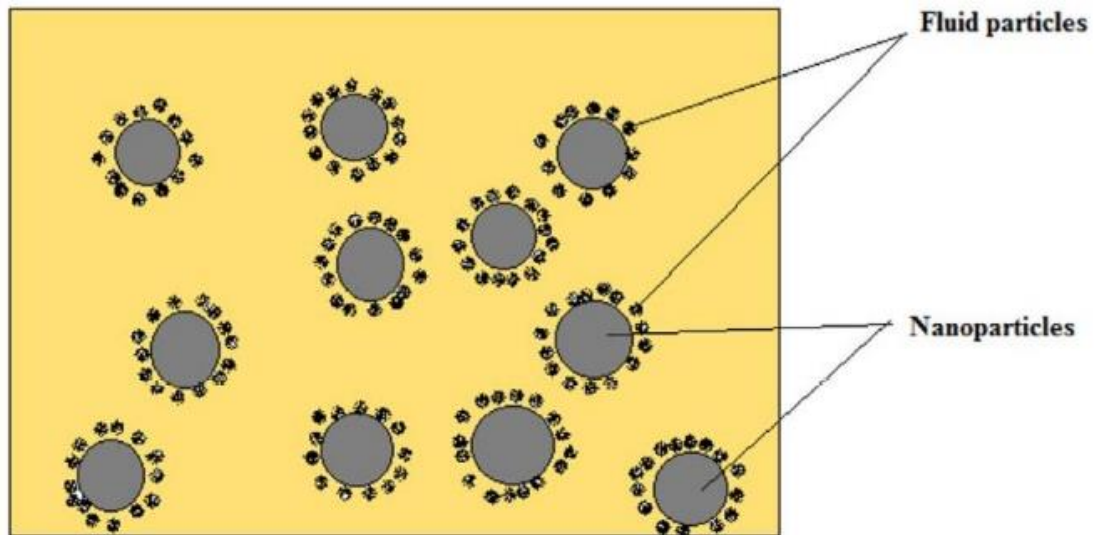


Figure 2.27. Nanoparticles suspended in liquid with nano-layers around the particles

In another test by Jiang et al., it was found that the coating formed by the fluid particles around the nanoparticles suspended in the fluid effectively increases the thermal conductivity (Cuce et al. 2020; Verma and Tiwari 2015).

2.3.7.2. Base Fluids

They are the base fluids that mix with nanoparticles to attach to them and give better thermal conductivity than traditional fluids such as water, ethylene glycol and others. The following are some of the tests conducted by researchers on some base fluids and the extent of improvement in the thermal conductivity of each separately:

Nanofluids containing Al₂O₃, Cu particles:

When testing the base fluids with Al₂O₃ and Cu particles there was an improvement in thermal conductivity of 60% compared to oil/aqueous HE-200, but the improvement with water/ethylene glycol was 20%.

The iron-based nanofluid:

However, with another test for dispersion of iron nanoparticles in ethylene glycol liquid, it did not give promising results for thermal conductivity (Nagarajan et al. 2014; Verma and Tiwari 2015).

The effect of pH on thermal conductivity:

The effect of pH is obvious on improving the thermal conductivity, a test was conducted on Al₂O₃ - H₂O nanofluid and the results showed the correctness of the prediction.

2.3.7.3. Effects of Different Factors on The Thermal Conductivity of Nanofluids

The thermal conductivity of nanofluids is affected by several factors as shown in Figure 2.28. such as the size and shape of the particles, the underlying liquid material and temperature:

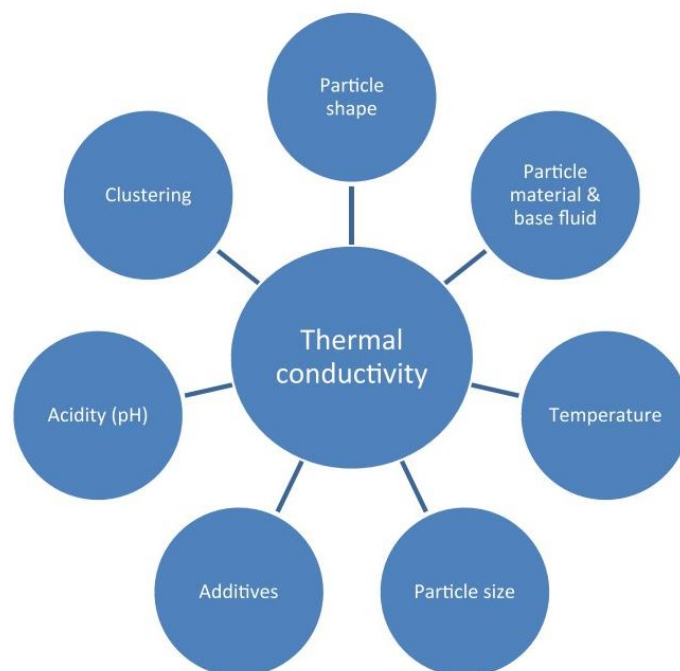


Figure 2.28. Scheme of the relationship of factors affecting thermal conductivity

Particle size:

The change in the size of nanoparticles in liquids affects the thermal conductivity. Some laboratory experiments have shown that the thermal conductivity has a direct relationship with the fraction size (Cuce et al. 2020; Verma and Tiwari 2015).

Particle shape:

Nanoparticles are formed either in the form of spherical or cylindrical or in the form of wires and filaments, but most researchers directed their tests to deal with the shapes of spherical and cylindrical. The cylindrical shapes of nanoparticles have a large ratio of length to diameter. In one of the tests on TiO₂ nanoparticles in the form of rod and spherical dispersed in nanofluids, the experimental results showed that the thermal conductivity in cylindrical shapes is more improved compared to the spherical shape.

Particle matter and basic fluid:

To prepare nanofluids with a high conductivity of heat transfer, some materials such as oxide ceramics, metallic carbides, and others are sometimes used in the preparation of nanofluids.

Temperature of the nanofluid:

The temperature of the nanoparticles and the nanofluid is an important factor in increasing the thermal conductivity.

In some tests conducted on some nanofluids such as (zinc oxide nanoparticles, ZnO-EG, TiO₂- water) and it was shown that the thermal conductivity of nanofluids increases with increasing temperature.

Additions:

The additives are used to enhance the thermal conductivity, in addition, it has the benefit of keeping the nanoparticles suspended and stable. And prevent particles from agglomerating inside the nano-liquid.

Acidity (pH):

The relationship of acidity in nanofluids with thermal conductivity is an inverse relationship, the higher the acidity of the nanofluid, the lower the thermal conductivity.

Clustering:

The agglomeration of some nanoparticles occurs in the nanofluid after a period of time, and it is negatively reflected on the thermal conductivity of the nanofluid. So that the thermal conductivity decreases with any agglomeration that occurs inside the nanofluid. Fe₃O₄/aqueous nanofluids were tested and verified that the accumulation and alignment of nanoparticles was largely responsible for the increase in thermal conductivity.

2.3.7.4. Viscosity

Viscosity is an important factor and an essential thermophysical property of nanofluids (Nagarajan et al. 2014). It provides the fluid adjacent layer with abrasion resistance against shear stresses. It plays an important role in turbulent or laminar flow (Verma and Tiwari 2015). Increasing the size of solid nanoparticles in liquids increases the nonlinear viscosity and linearly due to the increase in the nanoparticle size concentration (Gupta et al. 2017). The relationship of viscosity with temperature is an inverse relationship, as the temperature increases, the viscosity decreases due to the lack of cohesion between the particles.

For example, the viscosity of Al₂O₃ / water was tested, and it was found that the viscosity increases with increasing volume concentration, and the reason was the interaction between particles from the nonlinear relationship between viscosity and volume concentration (Verma and Tiwari 2015).

On the other hand, the researchers performed multiple tests on the types of viscosity of base fluids such as 1- water 2- ethylene glycol 3- other alkaline fluids (gear oil) with the volume fraction of nanoparticles, and they found that the viscosity of gear oil with the volume fraction of the particles is close to three times the viscosity of the base fluid, While it decreases significantly with increasing temperature.

The concentration, particle size, morphology, shear rate and temperature all affect the viscosity of the nanofluids as shown in schematic Figure 2.29. The viscosity of the liquid increases with the increase in the particle concentration. According to some laboratory experiments, it was found that the formation of morphology affects the viscosity of fluids and their pumping force in some cooling systems in terms of shape and volume.³ -The shear rate does not fluctuate with temperature The viscosity of nanofluids decreases with increasing temperature (Gupta et al. 2017).

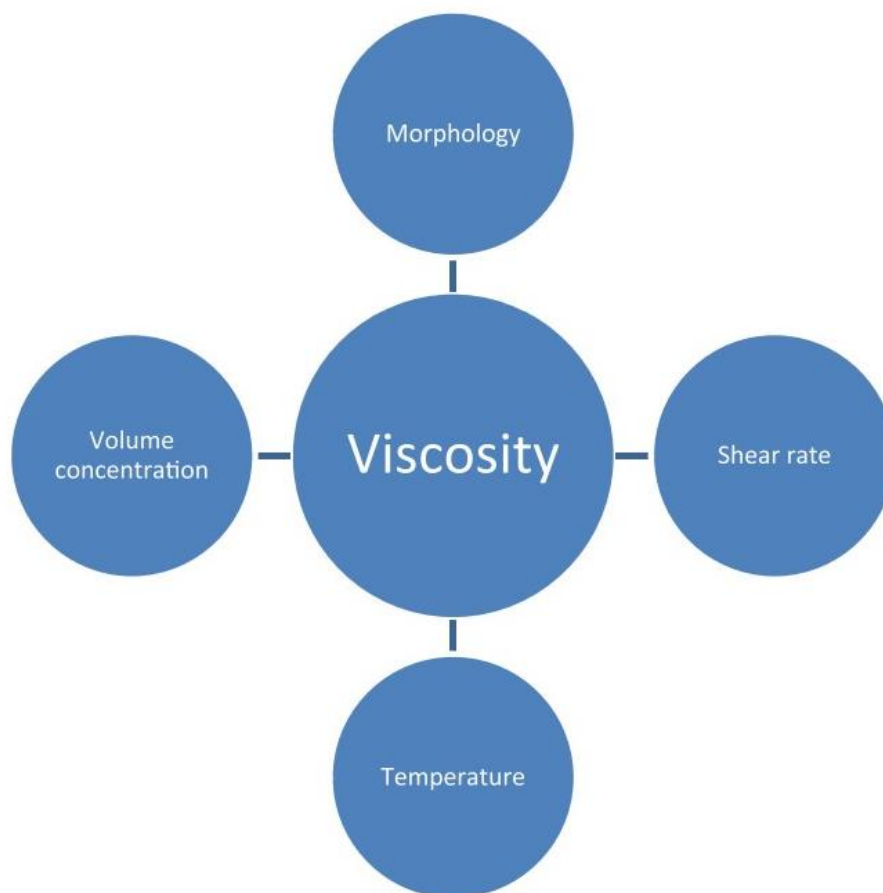


Figure 2.29. Illustration of the factors affecting the viscosity of nanofluids (Gupta et al. 2017)

2.3.7.5. Specific Heat

The thermal performance of any material is determined by its specific heat, which is one of the important parameters of the physical properties of nanofluids, and plays an important role in influencing the heat transfer rate of nanofluids. Specific heat is defined as the amount of heat required to raise the temperature of one gram of nanofluid by one degree Celsius.

Some laboratory results showed that the specific heat has a constant value for a certain temperature and that the size, particle concentration and temperature have an effect on the specific heat capacity of particles and nanofluids (Gupta et al. 2017).

And in a study by Buck and Zhao on the effect of the volume fraction of Al_2O_3 on specific heat. It was found that there is a decrease of 1.10 - 2.27% in the specific heat when the size fraction is 1.34 - 2.78% for the size of the 13 nm nanoparticle.

Finally, most of the laboratory results showed that for most nanoparticles in basic fluids, the specific heat decreases with increasing fraction size. But there is also disagreement in the ongoing research and studies to know the specific heat of nanofluids. Where some experimental observations on some nanofluids show an increase in specific heat capacity with volume fraction or concentration ratio, while other experimental observations show the opposite. Therefore, more study and research is needed to reach a stable state (Verma and Tiwari 2015).

2.3.7.6. Density

The density of nanoparticles is an important physical property that affects the evaluation and performance of heat transfer in nanofluids. It has a direct effect on the coefficient of friction, pressure drop, and the value of both Reynolds and Nusselt numbers. And that the density of nanofluids depends on the concentration of nanoparticles in the nanofluid. In an experimental study by Singh of aqueous/ CuO nanofluid, the density of the nanofluid was decreasing with temperature (Gupta et al. 2017).

2.3.7.7. Convection Heat Transfer

Convection heat transfer is the heat transferred by nanofluids mixed with nanoparticles, so some factors go into an increase or decrease in convection such as particle size fraction, friction, particle type, shape, size, liquid type and operating conditions such as temperature, flow type and flow path.

Some laboratory results showed that the heat transfer coefficient of nanofluids improves by increasing the volume fraction and its concentration compared to the base liquid (Verma and Tiwari 2015).

Ding et.al also mentioned that heat transfer can be enhanced by changing the flow state and liquid concentration (Nagarajan et al. 2014).

2.3.8. Silver

The history of the discovery of silver goes back to the Stone Age, when it was used by the Greeks for the purpose of cooking and to preserve safe water. After that, the human brain evolved to be used for the first time in the medical field in 1965. The thinking of the human mind remained on the use of silver as a metal until the progress of science and technology to enter into the uses of nanotechnology and to be produced at nano scales instead of other measures.

The importance of using silver in various fields and applications is due to the importance of its physical, chemical and other properties such as good thermal conductivity, chemical stability, catalytic activity, anti-bacterial, anti-fungal, anti-viral, anti-inflammatory and in the treatment of cancer as nanoparticles in the medical field (Vaidyanathan et al. 2009).

2.3.8.1. Preparation of Silver Nanoparticles

Among most, metallic NPs, silver (Ag) NPs exhibit a great potential in the scientific community owing to their wide range of applications (Islam et al. 2021). In fact, there are three main methods for synthesizing nanomaterials, namely physical, chemical, and

biological methods (Tulinski and Jurczyk 2017; Xie et al. 2016). The physical methods required highly sophisticated instruments, high pressure, and high temperature (Rao and Biswas 2009)

While the chemical methods have a hazardous impact on the producers and users due to the utilizing precarious chemical materials as reducing capping and stabilizing agents (Modan and Plăiașu 2020). Thus, it causes many difficulties for humans and the environment at the same time. Accordingly, in recent times, researchers have focused on the biological or green method for synthesizing nanomaterials (Amin et al. 2021). In addition, the fabrication of nanomaterials using biological methods is gaining more advantage due to its simplicity, eco-friendly, low cost and avoiding the toxic chemicals. Green synthesis of NPs includes using natural materials, such as plants and microorganisms such as bacteria, fungi, algae and yeasts (Saratale et al. 2018).

However, the existing phytochemicals in plant extracts possess an exceedingly high ability for reducing metal ions within a short time as compared with bacteria, fungi, algae and yeasts, which necessitate a longer incubation period (Saravanan et al. 2021; Ovais et al. 2018). As a result, plant extracts are observed as an outstanding source for synthesizing metallic NPs. In addition, the plant-mediated synthesis procedure, for synthesizing NPs, is a leading process over the microorganism process due to its simplicity, rapidity and avoidance of culture maintenance (Vijayaraghavan and Ashokkumar 2017). Furthermore, plant supplies such as flowers, leaves, seeds, stems, fruits, and peels, have been used as reducing and capping agents in NPs fabrication process (Shamaila et al. 2016).

Silver nanoparticles are generally prepared by conventional, biological and chemical methods, including by spark discharge, solution irradiation, cold chemical synthesis, or by electrochemical reduction.

Conventional versus green synthesis of silver nanoparticles:

In general, environmentally friendly plant extracts have a prominent position because they contain a large number of phytochemicals and enzymes that act as reducing, capping and stabilizing agents (El-Seedi et al. 2019). Functional groups such as $-C = C-$

and $-C = O$ present in phytochemicals can contribute to the production of nanoparticles of different sizes and shapes as well (Keshavamurthy et al. 2018; Zarei et al. 2020; Koduru et al. 2018).

In this method, silver nanoparticles are dispersed colloiddally in the liquid, whether the liquid is water or any other liquid or even organic solvents through chemical reduction. The reduction results in positive silver ions ($+Ag$) in the aqueous colloidal solution with different nanoparticle diameters. When the reduced nanocomplexes are reduced by the method of positive silver ions ($+Ag$), silver atoms (Ag^0) are formed, followed by agglomerations of small particles. Thus, colloidal silver particles are formed. Ag nanoparticles are extracted from all these aggregates. After a strong chemical reduction process to produce small silver Ag particles, the amplification process is followed by further reduction using a weaker reducing agent.

The reduction process is usually in the presence of stabilizers to prevent agglomeration in the fluid. And studies indicate that the process of enlarging the particles in the second step was about (20-45) nanometers to about (120-170) nanometers.

Due to the cost-effectiveness of the energy condensation process and the reduction of environmental damage and side hazards such as hydrazine, experiments have proven that the biological method of nanoparticle synthesis is the best chemical method. In addition, the expectation of agglomerations and accumulations during the production of nanocrystalline silver colloids in aqueous chemical processes limits the process Storage due to the size factor.

There are three main steps for green synthesis of silver nanoparticles that must be evaluated based on green chemistry perspectives, including (1) selection of solvent medium, (2) selection of an environmentally benign reducing agent, and (3) selection of non-toxic AgNPs for stability.

Biological synthesis of silver nanoparticles:

To analyze silver nanoparticles, several methods are used, including TEM or UV-visible spectroscopy and X-ray diffraction. The absorption spectrum of the sample is recorded on an ultraviolet visible spectrophotometer. Based on absorption spectroscopy, AgNPs exhibit a unique peak and are measured in the range from 400-460 nm.

X-ray diffraction was performed to confirm the crystalline nature of the particles. Comparison of the obtained XRD spectrum with that of the standard confirmed that the silver particles formed were in the form of nanocrystals, as indicated by the peaks at 2θ values at 39.01° , 46.48° , 64.69° and 77.62° , corresponding to 111, 200, 220 and 311 planes running for silver(Vaidyanathan et al. 2009).

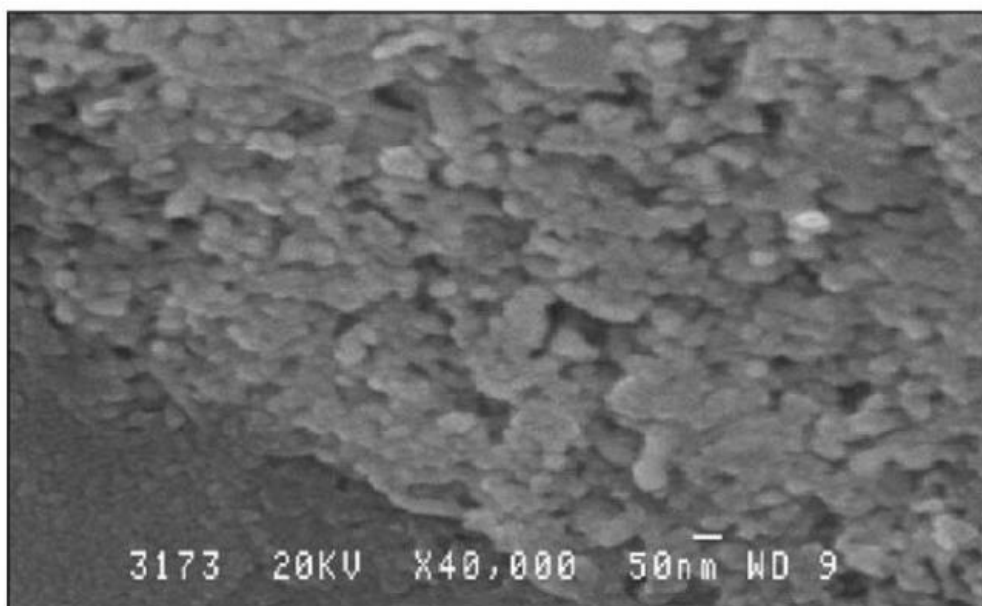


Figure 2.30. SEM micrograph of silver nanoparticles formed after the reaction of the culture supernatant with 1×10^{-3} M AgNO_3 for 24 h. The particles at a higher resolution are indicated by a scale bar of 50 nm(Vaidyanathan et al. 2009)

2.3.8.2. Identification of the Problem Involved in Calculating Concentrations of Silver Nanoparticles

Depending on the shape, size, composition and surface sealing used to form monolayers around the nanoparticles, the optical properties of silver nanoparticles change.

2.3.8.3. Silver Nanoparticle Size and Absorption Spectra Characteristics

Particle size is strongly influenced by the spectra of silver nanoparticles. The extinction coefficient of light is the net effect of scattering and absorption and describes the effect of the interaction between radiation and the material it collides with. To calculate the extinction coefficient, the diameter of the nanoparticles must be known, so the larger nanoparticles contribute more to the value of the extinction coefficient or spectra.

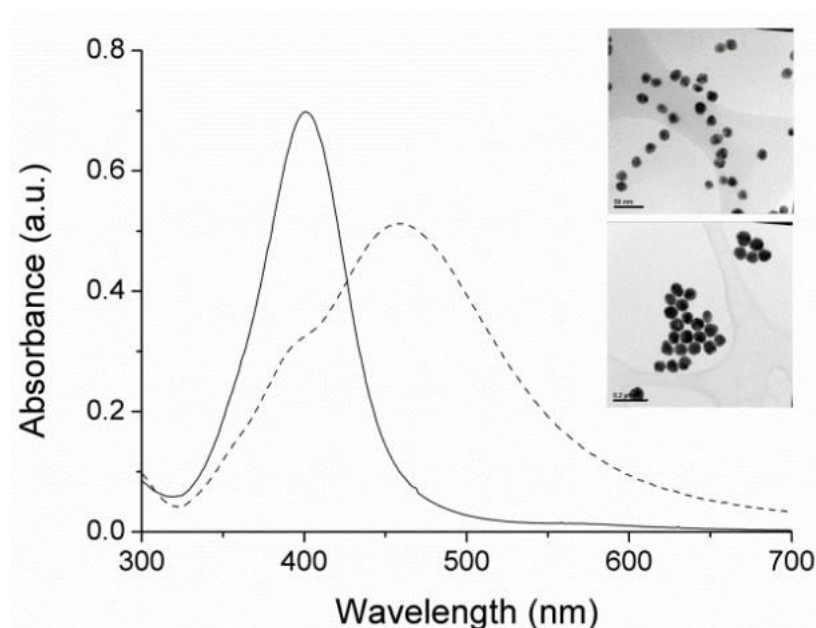


Figure 2.31. UV-visible spectra and HR-TEM example images of 19.0 nm (solid line and top image) and 74.8 nm (dashed line and bottom image) citrate-coated silver nanoparticles. Larger-sized HR-TEM images and histogram data are shown in Figs S5b and S5j format(Paramelle et al. 2014)

As the size has a role in the extinction coefficient, the dispersion in the extinction coefficient is for larger silver nanoparticles,. It is known that the light absorption of silver nanoparticles specified by Beer-Lambert Law is very accurate in dilute samples, where the effect of multiple light scattering is negligible. At 52 nm, the scattering and absorption effects have similar contributions.

To determine the concentrations of silver nanoparticles, a series of absorption spectra measurements must be carried out at different dilutions of silver nanoparticles. Therefore, larger nanoparticles have a more pronounced scattering effect(Paramelle et al. 2014).

2.3.9. Performance and Efficiency of The Solar Collector Using Nanofluids

The performance and efficiency of solar thermal collectors is affected by several factors, including the amount of radiation falling on the collector, the ambient temperature, the temperature of the inlet fluid, and the timing of sunrise and sunset.

To calculate the energy gained by the solar collector, we use the following equation:

$$Q_u = \dot{m}C_p(T_o - T_i)$$

$$Q_u = A_c F_R [G_T(\tau\alpha) - U_L(T_i - T_a)] \quad (4.3) \quad (4.4)$$

Where Q_u is the energy gained, $\dot{m}$ is the fluid flow rate, T_a and T_i are the inlet and outlet temperatures of the solar collector respectively. C_p is the heat capacity at a constant temperature.

The relationship between the efficiency of the complex and the energy gained is (Verma and Tiwari 2015):

$$\eta_i = Q_u / A_c G_T = \dot{m}C_p(T_o - T_i) / G_T$$

$$\eta_i = F_R(\tau\alpha) - F_R U_L(T_i - T_a) / G_T \quad (4.5) \quad (4.6)$$

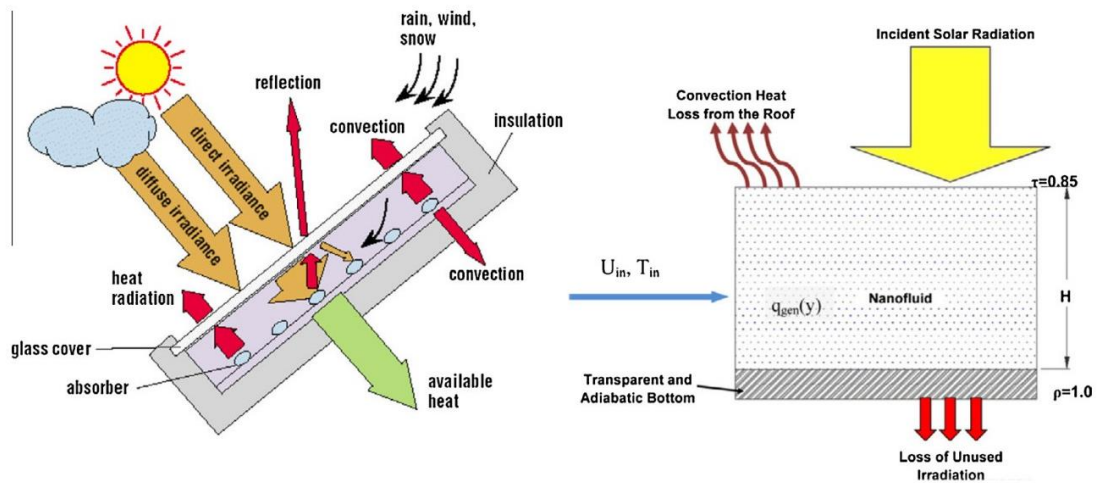


Figure 2.32. Conventional (left) and volumetric (right) solar collectors (Verma and Tiwari 2015)

Some studies have been carried out on the use of nanofluids composed of water and aluminum particles to know the effect of various factors on the efficiency and performance of the solar collector, as shown in the schematic diagram below in Figure 2.33.

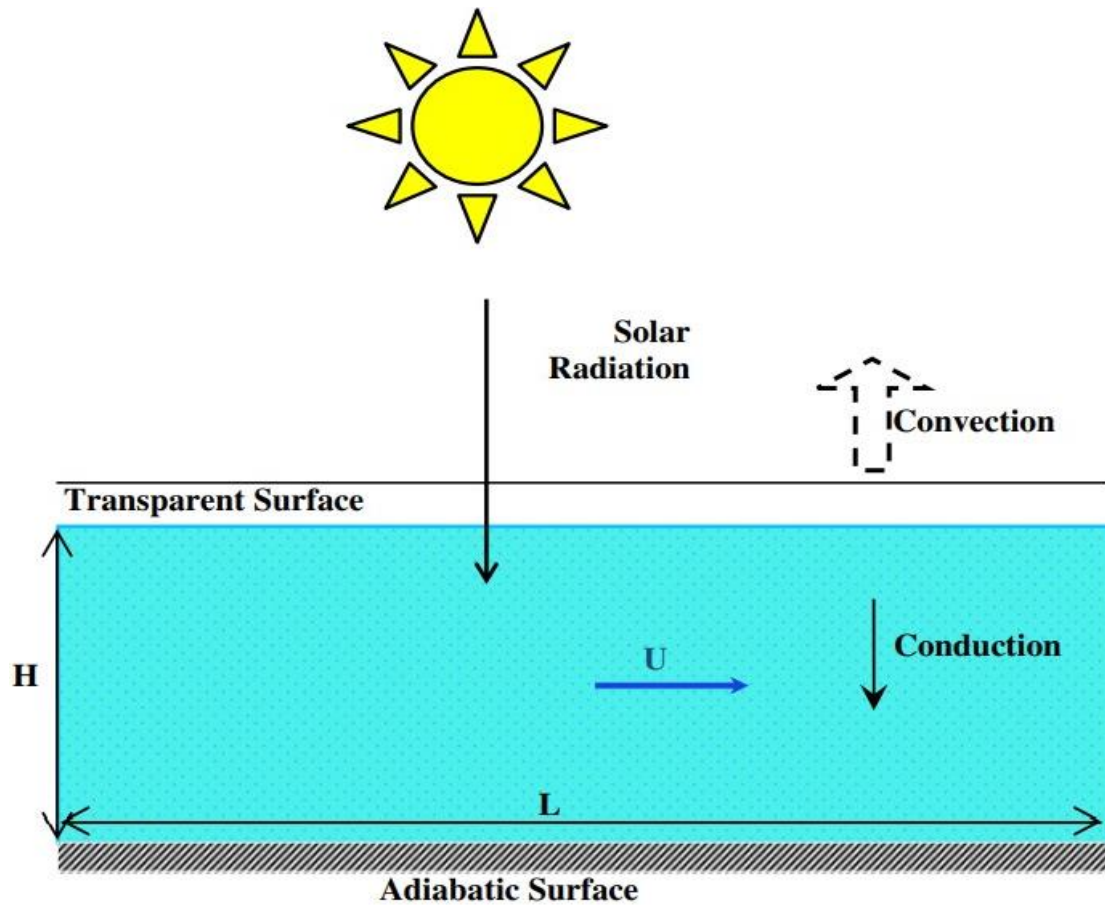


Figure 2.33. Schematic diagram of a nanofluid based direct solar absorption collector

Some hypothetical data were given for the volume fractions of nanoparticles in the liquid as shown in Figure 2.34. The results showed that when the volumetric concentration of nanoparticles in the liquid was increased, the efficiency increased significantly. But at some point the efficiency stabilizes and then the efficiency value increases, but slightly, as shown in Figure 2.35. This means that the increase in the volumetric concentration of nanoparticles in the liquid does not constantly raise the efficiency of the collector.

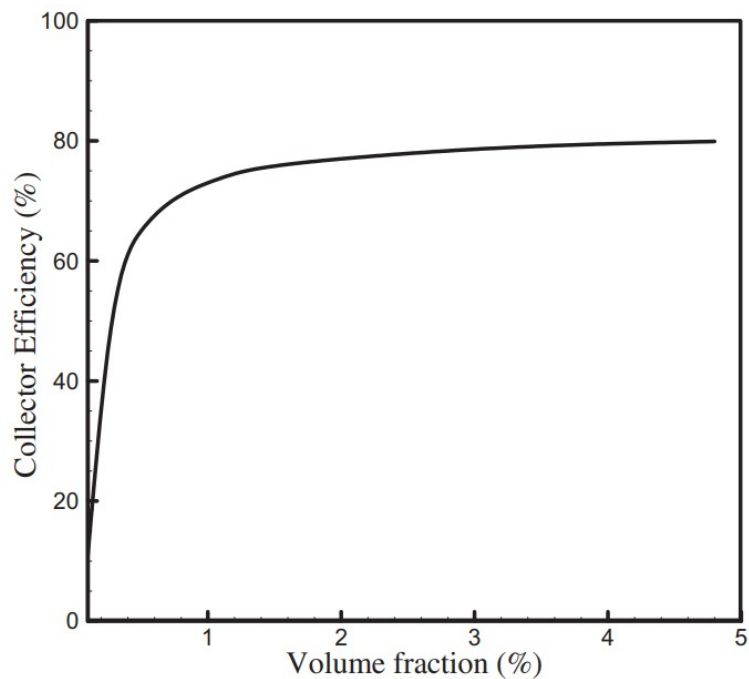


Figure 2.34. Effect of particle size fraction on collector efficiency

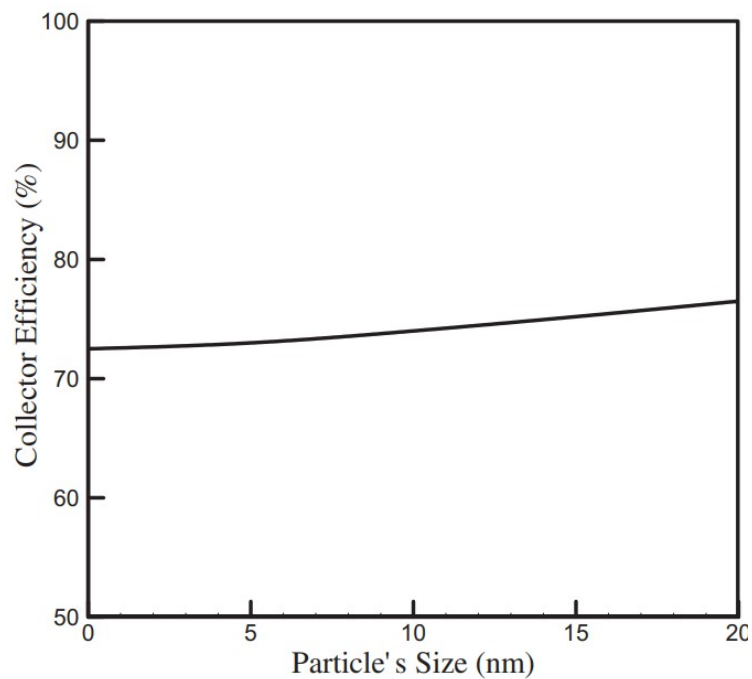


Figure 2.35. Effect of nanoparticle size on collector efficiency

However, when comparing the thermal performance of Taylor et al. in a nanofluid-based solar thermal system with a conventional system. The results show that using a nanofluid in the future can improve efficiency by 10%.

Comparing the effects of volumetric concentration of three different nanofluids, Al₂O₃/Water, ZnO/Water, and MgO/Water on the performance of a tubular solar collector in Li et al. Their results showed that ZnO–H₂O nanofluid with 0.2% volume concentration is the best choice.

2.3.10. Nanofluids in Solar Energy Applications

Nanofluids offer attractive thermal properties compared to conventional heat transfer fluids in solar energy systems.

The goal of using nanoparticles is to enhance the thermal conductivity of basic fluids. Therefore, researchers' efforts are focused on enhancing heat transfer in such systems, by replacing traditional low-efficiency fluids such as water with more suitable nanofluids and efficient working fluids for use in untracked solar collectors due to their lower efficiency.

And the traditional solar collector technology with limited thermal performance with emerging nanofluidic techniques prepared by liquid nanoparticle suspensions, is one of the most effective methods for harvesting solar thermal energy (Cuce et al. 2020; Nagarajan et al. 2014; Gupta et al. 2017).

Also, the optical and radioactive properties of nanofluids that improve the performance and efficiency of the collector have taken a wide field of interest to researchers. The improvement of the thermophysical properties of the base fluid requires only adding a very small portion of nanoparticles to the base fluid.

The ionic radiative properties of liquids result from the amount of energy absorbed by the surface of the particles and their ability to transfer heat to the liquid.

In some laboratory experiments, the technique of combining conventional copper water-based nanofluids with the mass of nanoparticles in the working fluid showed an increase in the efficiency of the solar collector by 23.83%.

And experiments also showed that the thermal losses are much lower than those found in traditional techniques.

In order to obtain the highest efficiency and thermal performance with a reduction in the area and size of the solar collectors, some experiments were carried out by Faizal et al in the selection of water-based nanofluids with nanoparticles such as CuO, TiO₂, Al₂O₃, and SiO₂. The use of nanoparticles with smaller specific sizes and low specific heat improved the thermal conductivity. It was also reached that CuO particles give maximum efficiency. The area of the collectors has decreased by 25.6%, 22.1%, 21.6% and 21.5%, respectively, as shown in the graph Figure 2.36. (Ahmadi et al. 2019).

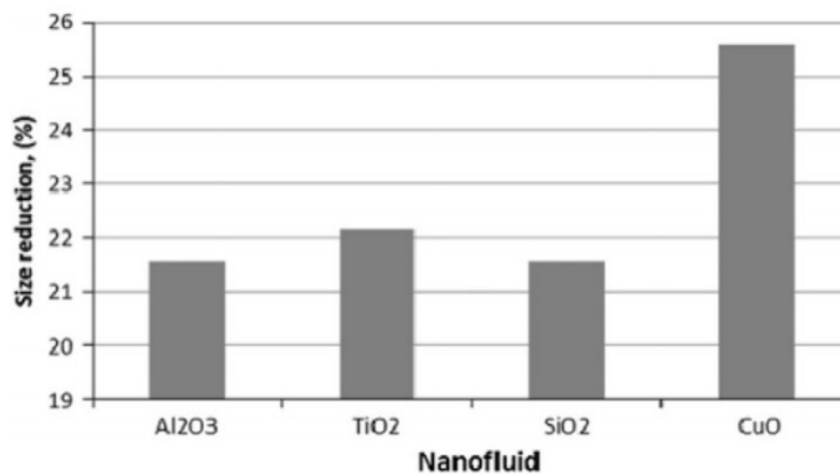


Figure 2.36. Effect of using nanofluids on the size of collectors (Ahmadi et al. 2019)

2.3.11. Challenges in Nanofluids Applications

Many researchers still face many challenges in their studies and tests on the physical and thermal properties of nanoparticles in conventional and nanofluids, including:

- 1- The high costs of producing nanofluids are one of the main obstacles to the use of nanofluids in applications of thermal engineering systems.
- 2- Agglomeration and instability are described as the second problem and challenge of using nanofluids in solar thermal system applications, especially in natural cycle (thermal siphon) systems where there is no pump to circulate the fluid, which flexibly impedes

fluid flow in the transmission pipes. The cause of agglomeration is gradients in temperature.

3-The third challenge is the viscosity factor, where the increase in the degree of viscosity of fluids resulting from an increase in the fraction of nanoparticles in nanofluids leads to a decrease in pressure, which causes a greater energy consumption in pumping fluids.

4-Rust and corrosion of components is the fourth challenge in that the presence of nanoparticles in nanofluids in thermal systems applications used for long periods may lead to rust and corrosion of thermal devices.

5-There is another challenge called the toxicity of some nanofluids resulting from chemical reactions that occur during or after a period of time between nanoparticles and some base liquids, which seriously threatens human health. Like TiO₂ nanoparticles placed in human lung tissue may interact with proteins and DNA (Cuce et al. 2020; Mahian et al. 2013).

2.3.12. Benefits and Advantages of Nanofluids

Despite the challenges mentioned above, nanofluids provide outstanding thermal performance with high efficiency for solar thermal systems compared to other conventional liquids. In Table 2.7. a comprehensive qualitative evaluation of conventional, hybrid and nanofluids in terms of thermal conductivity, viscosity, cost, efficiency and other environmental aspects (Cuce et al. 2020).

Table 2.7. Performance evaluation of nanofluids compared to other liquids (Cuce et al. 2020)

Aspect	Water	Oil	Nanofluid
Viscosity	Low	High	Medium
Thermal conductivity	Low	Medium	High
Cost	Low	Medium	High
Eco-friendly	High	Low	Medium
Efficiency	Low	Medium	High

2.4. Biosynthesis of Silver Nanoparticles and Their Applications in Harvesting Sunlight for Solar Thermal Generation

2.4.1. Biosynthesis of Silver Nanoparticles

Silver (Ag) nanoparticles (NPs) have been synthesized from the effortless, inexpensive, and eco-friendly method. *Petroselinum crispum*, parsley, leaf extract was utilized as a reducing, capping and stabilizing agent, without using hazardous chemical materials, for producing Ag NPs. The biosynthesized Ag NPs were characterized using different characterization techniques, namely UV-Vis, FT-IR spectroscopy, X-ray diffraction (XRD), dynamic light scattering (DLS), zeta potential, differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), transmission electron microscope (TEM), field emission scanning electron microscopy (FESEM), and energy-dispersive X-ray (EDX) analysis to investigate the optical, thermal, structural, morphological, and chemical properties of the plant extract and the biosynthesized Ag NPs.

After that, the biosynthesized Ag NPs have been utilized in harvesting sunlight for solar thermal generation. Surface plasmon resonance (SPR) for the green synthesized Ag NPs with dark colour were adjusted nearly at 450 nm. Once the Ag NPs are excited at the SPR, a large amount of heat is released, which causes a change in the local refractive index surrounding the Ag NPs. The released heat from the Ag NPs under the solar irradiation at the precise wavelength of plasmon resonance significantly increased the temperature of the aqueous medium. Different percentages of Ag NPs were dispersed in water and then exposed to the sunlight, to monitor the temperature of the suspension. It was found that the temperature of the aqueous medium reaches its highest point when 3 wt. % of Ag NPs has been utilized. This investigation is rare and unique and it shows that utilizing a small amount of the biosynthesized Ag NPs, can increase the temperature of the aqueous medium dramatically.

This investigation, focusing on Ag NPs, due to the importance of Ag NPs whose optical properties depend on their size and shape. This dependency, most likely, arises from the surface plasmon resonance (SPR) and free electrons of the nanomaterials (Sharma et al. 2020). In fact, the plasmonic effect describes the interactions of light with metallic

nanoparticles (Castellanos et al. 2019). Also, SPR is the resonant oscillation of the free electrons at the metal surface layer which are excited by incident light sources.

Resonant frequencies for noble metals, such as Ag, are located in the middle of the optical spectrum, thus SPR for such metals interact strongly with light and depend on the size and shape of the NPs (Zada et al. 2020; Xia and Halas 2005). Plasmonic is part of nanotechnology since nanostructures are used as an active component to focus, guide, control and manipulate light. Even though the interaction of light and metallic NPs has long concerned the interest of scientists, plasmonic signifies a rather new level of control and study including both nanostructures and light (Schuller et al. 2010). Moreover, the plasmonic effect in metallic NPs is a multidisciplinary and important area of research owing to its potential applications in optoelectronic devices (Liang et al. 2014), thermodynamic (Magnozzi et al. 2019), sensors (Tong et al. 2014), and medical diagnosis (Islam et al. 2021).

In continuation of our recent works (Azeeza and Barzinjya 2020; Barzinjy and Azeez 2020; Barzinjy et al. 2020a; Barzinjy et al 2020b; Barzinjy et al 2020c; Barzinjy et al 2020d; Nasrollahzadeh et al. 2018; Sajadi et al. 2018) regarding green synthesis nanomaterials, here in this study, an active and easy process of one-pot green synthesis of Ag NPs is proposed. The novelty of this research is that Ag NPs can be formed from a one-pot reaction deprived of employing any exterior stabilizing and reducing agent which is not conceivable by means of the existing processes. Ag NPs were synthesized using *Petroselinum crispum* extract commonly known as parsley.

Parsley is to the Apiaceae carrot family, and its chemical structure contains belonging flavonoids, polyphenols, carotenoids, lipid, polysaccharides, tannins, and essential oils which are considered as bio-reducing and stabilizing agents, flavonoids are the dominant compounds in the parsley extract (Sarwar et al. 2019; Farzaei et al. 2013). Both parsley extract and Ag NPs have been characterized using different characterization techniques. Later, the biosynthesized Ag NPs from parsley extract has been dissolved in water, then its ability to perform the conversion of solar energy to thermal energy, based on the plasmonic effect, for boiling water application, have been investigated.

3. MATERIALS AND METHODS

3.1. Preparation of The Parsley Extract

Parsley was collected from Rashken (Latitude 36°11'58.0"N and Longitude 43°56'54.7"E) in Erbil city, Iraqi Kurdistan Region in the spring season (March 2021). 5 grams of fresh parsley was soaked in a flask contained 100 mL double distilled water (DD water). The solution was heated at 80 °C for 40 min. The extract was allowed to cool down to room temperature, then filtered by using filter paper to remove unwanted organic materials. Later the pure filtrate extract was stored in the refrigerator for further experimental work.

3.2. Synthesis of Silver Nanoparticles

Silver nitrate, Ag NO₃, molecular weight 169.87 g/mol and purity > 99%, were purchased from Sigma Aldrich company and used as received with unpolluted specialized status. 2 mg of silver nitrite, was dissolved in 50 mL double distil water and kept stirring for 20 min at 80 °C. Then 50 mL of parsley extract solution was drop wise added to the dissolved silver nitrite. The final mixture put on the hotplate, heated and stirred at 70 °C for 30 min, until the color of the mixture changed to the brownish color. The new color appearance of the mixture indicated the synthesized of Ag NPs. The obtained precipitates was separated from the mixture by centrifugation at 7.000 rpm for 25 min and afterward heated at 500 °C for 40 min by using oven to remove all of the impurities and organic materials around Ag NPs.

The mechanism of biosynthesizing Ag NPs can be explained through the following steps. First, the activation step involves the reduction of the available metal ions into metal atoms. Second, nucleation and growth step, which includes the combination of the

available atoms to form NPs of a conclusive size and shape. Third, stabilization step, in which the phytochemicals cap the NPs, therefore preventing them from agglomeration. Finally, calcination of NPs should be done to acquire pure NPs. Figure 3.1. represents the schematic diagram and the mechanism of Ag NPs formation by parsley extract. The agglomeration occurred due to the sturdier binding energy between two metal atoms, the agglomeration of NPs is prevented to some extent by the secondary metabolites of plants which act as a capping and stabilizing agent.



Figure 3.1. Proposed mechanism of the biosynthesizing Ag NPs from parsley extract

3.3. Characterization of Ag NPs

X-ray diffraction (XRD) measurements were carried out using a PAN analytical X'Pert PRO (Cu K α = 1.5406 Å[°]). The scanning rate was 10°/min in the 2 θ range from 20 to 80°. XRD can be used for the determination of crystal structure, purity and crystallite size of the nanoparticles. Also, UV-Vis spectroscopy analysis was conducted using a double-beam spectrophotometer (Super Aquarius spectrophotometer-1000) to confirm the formation of Ag NPs. Additionally, the morphology and particle dispersion were investigated by field emission scanning electron microscopy (FE-SEM) (Quanta 450). The chemical composition of the prepared nanostructures was studied using energy-dispersive X-ray spectroscopy (EDX) performed in the FE-SEM instrument. The shape

and size of the Ag NPs were characterized by a high-resolution transmission electron microscope (HRTEM) utilizing a Philips (USA) EM208 microscope functioning at an accelerating voltage of 90 kV. Fourier transforms infrared (FTIR) spectroscopy with a resolution of 4 cm⁻¹ was used to investigate the functional groups in the leaf extract and the NPs independently. The actual size of the biosynthesized Ag NPs was computed by dynamic light scattering (DLS). The particle size was computed utilizing a Malvern Zetasizer 3000HSA (Malvern, Worcs., UK) equipped with a 10-mW He-Ne laser (633 nm) and functioning at an angle of 90° and a temperature of 20 °C. T. Differential scanning calorimetry (DSC) type (TA Instruments USA, DSC Q10) in the range 50–1000 °C was utilized for the DSC curve. Thermogravimetric analysis (TGA) was performed using the Perkin-Elmer-Pyris1 analyzer (USA).

3.4. Rising Temperature During Irradiation of The System

After synthesizing and characterization of the Ag NPs from the green method using parsley extract, the NPs has been used to increase the temperature of the water. A representation diagram of the present study is shown in Figure 3.2. The system contains four equalized beakers fill with 50 mL of distilling water. Different concentrations of Ag NPs, have been used in each beaker and their temperature has been recorded from their own fine thermometer (laboratory thermometer, USA). Then the system was placed in front of the sunlight source to investigate the amount of the released heat by the utilized nanoparticles into the water medium. The temperature of each beaker under the sunlight radiation was monitored sensibly, so there would be no temperature lag and the values of temperature were registered every 2 minutes. The detail of Ag concentration and ambient temperatures are summarized in Table 3.1.

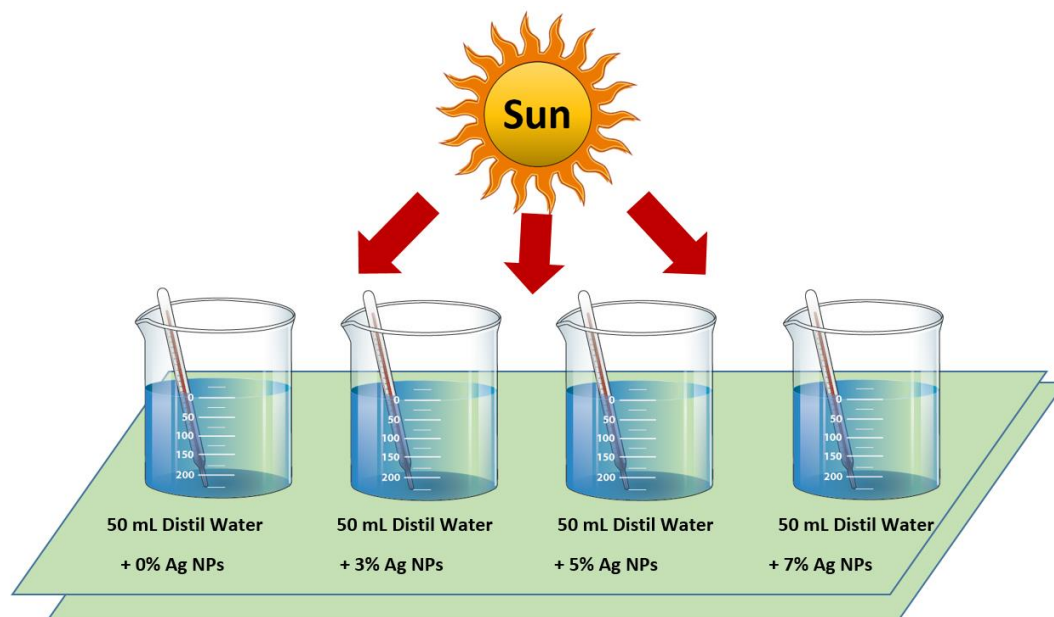


Figure 3.2. Representation diagram of rising temperature during sunlight irradiation using different concentration of Ag NPs

Table 3.1. Temperature measurements profile of water using different concentrations of Ag NPs

Water mL	Ag NPs Concentration	Temp. (2 min) °C	Temp. (4 min) °C	Temp. (6 min) °C	Temp. (8 min) °C
50	0%	14	14.3	14.5	14.8
50	3%	14.8	16.7	16.5	17.4
50	5%	14	14.4	15.6	16.3
50	7%	14.5	17	17.1	17.2

4. RESULTS AND DISCUSSION

4.1. Characterization of Parsley Leaf Extract

The available phytochemicals in parsley extract reduce the available metal ion in the silver nitrate salt to metal zero nanoparticles. Therefore, plant extract, at the same time, acts as a reducing and stabilizing agent. Makarov et al. 2014 suggested that metal atoms will be compressed as organic casing in three steps for their degree of steadiness after reduction by plant extracts. Metal ion reduction and nucleation of a reduced metal atom will be in the activation phase, the NPs steadiness improved through the growth phase, and the shape of the NPs formed during the end phase. UV-Vis spectroscopy observes this reaction growth. Spectra of UV-Vis spectroscopy revealed a peak absorption associated with the surface plasmon resonance, SPR, and gathers conduction band electrons oscillations in responding with electromagnetic waves, demonstrating metal ion reduction and NPs construction (Barzinjy and Azeez 2020). Parsley leaf extract comprises flavonoid, polyphenols, carotenoid, lipid, polysaccharides, tannin, free organic acids, and essential oils (Figure 4.1.) which are deliberated as an essential bioreducing and stabilizing agents, through possessing -OH groups, for NPs formation (Sarmanovna 2019; Mencherini et al. 2007). Flavonoids are predominant compounds of Parsley (Pápay et al. 2012). These phytochemicals, being antioxidant and free from toxic chemicals, are tremendously able to reduce metal ions and stabilizing them in nanoscale length. These phytochemicals, also, are directly affecting the shape and size of the biosynthesized NPs (Ovais et al 2016).

Figure 4.1. displays the UV-Vis spectrum of Parsley leaf extract. We believed that the dominant peaks, at 264 nm and 325 nm, is more likely related to the phenolic components and flavonoid available in Parsley leaf extract. The functional organic-molecules for instance Apiin, phenol, ascorbic acid exists in the Parsley leaf extract

(Sameh et al. 2011). Liu et al. identified that these peaks associated with Apiin, C₂₆H₂₈O₁₄, a natural flavonoid exist in Parsley leaf extract (Liu et al. 2017). Makarov et al. 2014 states that flavonoids, as a general rule, over their -OH groups converted from the enol-mold to the keto-mold, contributing an approachable hydrogen atom which reduces the metallic ion into NPs. Amongst those functional organic-molecules the phenolic groupings present in the extract more possibly had abundant impact on the metals (Rasheed et al. 2019), that reduced Ag⁺ to Ag⁰ (Khalafi et al. 2019).

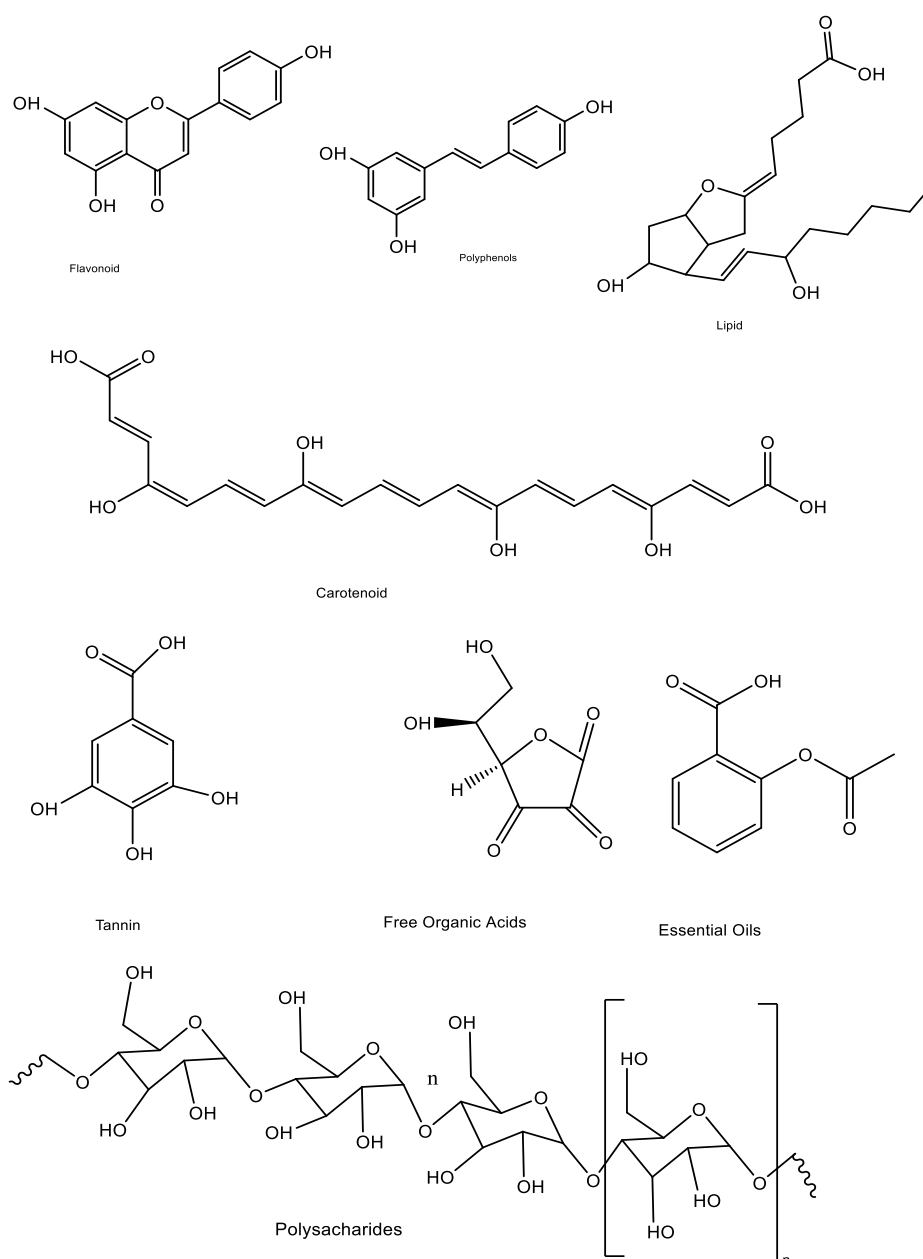


Figure 4.1. Available phytochemicals in Parsley leaf extract

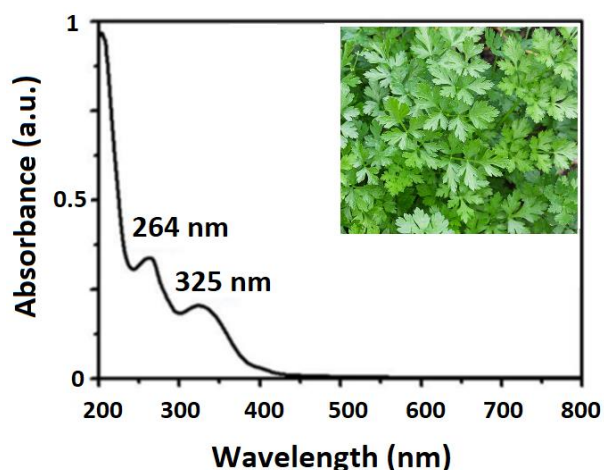


Figure 4.2. UV-Vis spectra of Parsley leaf extract

Fourier transform infrared (FTIR) of parsley leaf extract (Figure 4.3.) has several distinct peaks, and also contains two regions, the functional group region (1800-4000 cm^{-1}) with the fingerprint region (0-1500 cm^{-1}). The bands at 1645 cm^{-1} and 3383 cm^{-1} indicate a C = O expansion of the tertiary amides and an O-H expansion of the phenol group (Isaac et al. 2013). The band at 1079 cm^{-1} indicates the CN stretching vibration of amines while the distinct band at 1562 cm^{-1} defines the bending of the C-H bonds present in (Sathyavathi et al. 2010) hydrocarbons that follow the surface during the production of Ag NPs. The perceived ranges at 1422 cm^{-1} and 667 cm^{-1} may be related to the bending of the C-H alkanes and the corona-alkanes stretching vibrations respectively (Niraimathi et al. 2013).

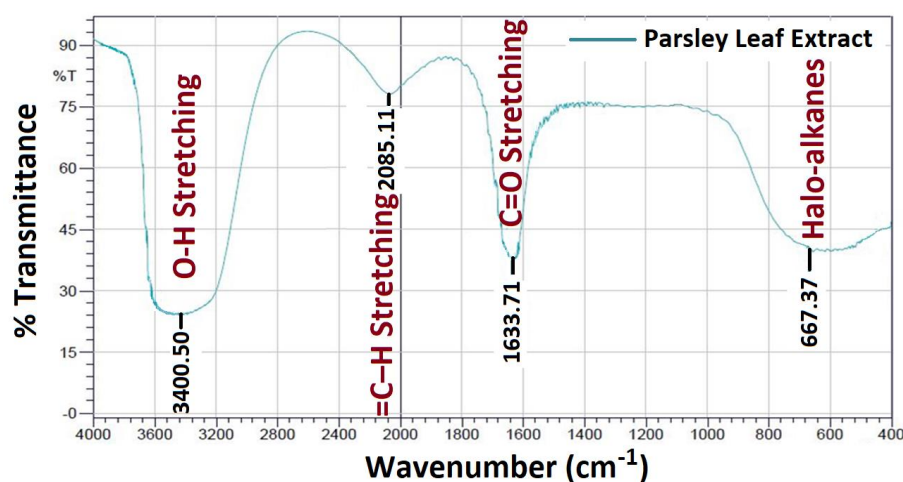


Figure 4.3. Histogram of FTIR spectra of parsley leaf extract

4.2. Silver Nanoparticle Specification Techniques

To characterize silver nanoparticles, we use a range of techniques to show the structure and morphology and properties of stability, heat and light.

4.2.1. UV Vis Spectrophotometry Technology for Biosynthetic Silver Nanoparticles

Once the frequency of the electromagnetic field turns out to be resonant with the coherent electron motion, a robust absorption created, which is the starting point of the observed color whose absorption extremely relying upon the particle size, dielectric medium, and the environments (Umadevi et al. 2012). The UV-Vis absorption spectrum (Figure 4.4. (a) indicator of the creation of silver nanoparticles at the visible range of 440 nm. While if we take the UV-Vis absorption spectra of silver nitrate, Ag (NO₃), solutions the absorption peaks will appear around 310 nm, due to the existence of nitrate ions in the solution (Nakamura et al. 2011). While, in the Ag NPs state both the conduction and valence bands would have lie down very nearby to each other allowing the free flow of electrons that might have consequently given rise to the surface plasmon resonance (SPR) absorption band as demonstrated by Yallappa et al. 2013, Ashraf et al. 2016, and Devaraj et al. 2013. Moreover, the long tail, precisely at the long wavelengths, is a good indicator for having a tiny extent of aggregated particles as reported by Hamed et al. 2012 and demonstrated in the investigation that the solution comprising NPs persisted unchanging for more than one month, with no indicator of aggregation or precipitation displaying the SPR peak at the equivalent wavelength (Mouxing et al. 2006). The purity of silver nanoparticles is due to the absence of any extra peak in the visible and ultraviolet spectrum. The results of this investigation are in agreement with previous studies, which show that the SPR peak of spherical Ag NPs usually appears between 410 and 480 nm (Nakamura et al. 2011; Rahman et al. 2019; Kuntty et al. 2019; Krutyakov et al. 2008, Sharifi-Rad et al. 2021).

Moreover, it can be seen, from Figure 4.4. (a), that the sharp peak is a clear indicator of monomeric dispersion in biocombined Ag NPs (Dar et al. 2013). As for the measured value it appears to be less than the large Ag particles, >100 nm, by 520 nm (Mukherji et al. 2018).

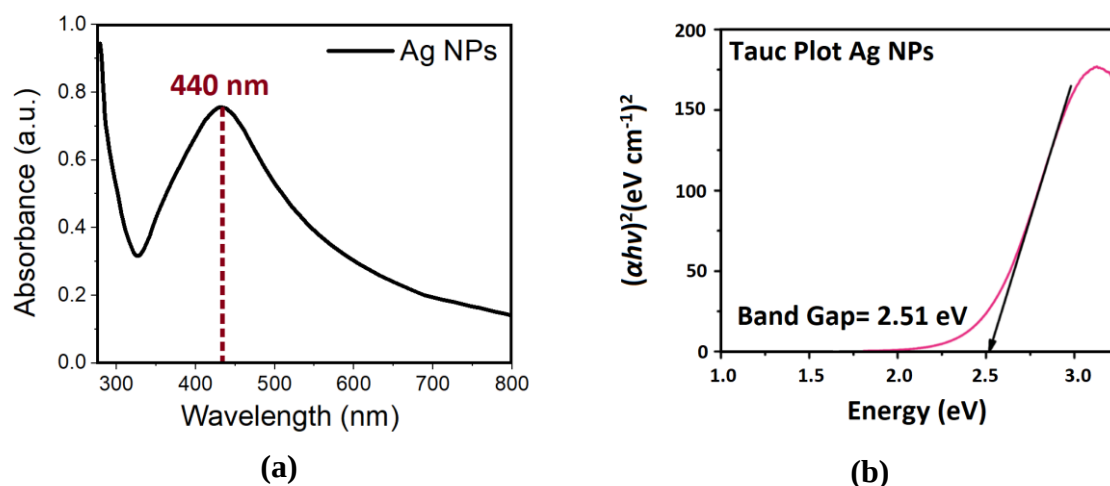


Figure 4.4. (a) UV-Vis spectrum of biosynthesized Ag NPs using parsley extract (b) corresponding Tauc plot for energy gap calculation

The energy band gap of the biosynthesized Ag NPs was computed from Tauc's plot by deducing the linear portion of the UV-Vis curve. Figure 4.2. (b) displays that the biosynthesized Ag NPs from parsley extract possess a value of energy band gap 2.51 eV. These NPs with the, relatively, large value of band gap energy can be supplementary utilized in improved optoelectronic devices, thermal applications, batteries and sensors as a semiconductor material. The corresponding band gap result pretty much similar to the previously reported studies and this value might be as a result of quantum confinement effect (Aziz et al. 2018; Das et al. 2016; Mistry et al. 2021).

4.2.2. FTIR Spectrum Analysis for Ag NPs

The FTIR spectrum of the biosynthesized Ag NPs is displayed in Figure 4.5. which demonstrates absorption peaks positioned between the region around 4000 cm^{-1} and 500 cm^{-1} . The FTIR spectra displayed absorption bands at 3441 cm^{-1} , 2923 cm^{-1} , 1596 cm^{-1} , 1383 cm^{-1} , 1251 cm^{-1} and 1076 cm^{-1} representing the existence of reducing, capping and stabilizing biomolecules with the Ag NPs. The band at 3441 cm^{-1} in the spectra corresponds to the O-H stretching vibration indicating the presence of alcohol and phenol (Rastogi and Arunachalam 2011). The band at 2923 cm^{-1} was related to the C-H stretching vibrations of the primary and secondary amines, respectively (Hamouda et al. 2019). Also, the band at 1596 cm^{-1} is more likely related to C-C/C-N stretching vibrations of Alkene or amines (Prakasham et al. 2012). While, the band at 1383 cm^{-1} is

related to the N=O symmetry stretching typical of the nitro compound (Jemal et al. 2017). Additionally, the bands at 1251 cm^{-1} and 1076 cm^{-1} corresponds to C-N and C-C stretching indicating the presence of proteins amines (Gharibshahi et al. 2017). Normally, the binding of protein with the Ag NPs maintaining considerably the stability of Ag NPs, through acting as capping and stabilizing agents and consequently protecting them from agglomeration (Iravani et al. 2014). Finally, the band at 536 cm^{-1} region is most likely credited to C-Br stretching, which is typical of alkyl halides (Jyoti et al. 2016). Other investigations reported that peaks at minor field in range 400–700 cm^{-1} reflected the metallic nature of any examined sample, Ag NPs in our case (Eltarahony et al. 2021). As stated before, these functional groups, in general, have role in stability/capping of Ag NPs as reported in many studies (Alsharif et al. 2020; Salem et al. 2020; Aref and Salem 2020; Bakhtiari-Sardari et al. 2020).

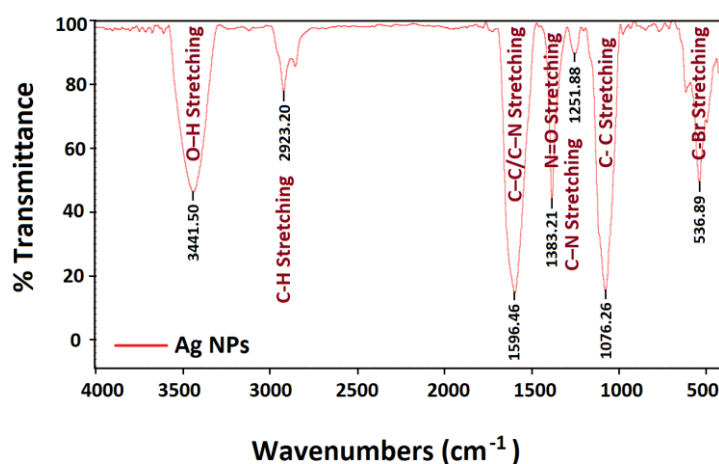


Figure 4.5. FTIR spectrum of biosynthesized Ag NPs

4.2.3. X-ray Diffraction (XRD) Pattern of Ag NPs

Figure 4.6. shows the X-ray diffraction (XRD) pattern of the biosynthesized Ag NPs. This pattern confirmed the crystallinity of the Ag NPs. The peaks at 38.01°, 44.34°, 65.52°, and 77.30° equivalent to (hkl) planes of (111), (200), (220) and (311) planes, respectively. These peaks can be accredited to face-centered-cubic structure of silver nanocrystals and they are in outstanding agreement with the previous studies (Alahmad et al. 2021; Mollick et al. 2012). It can be seen, from the Figure 4.6, that the diffraction pattern was matched with JCPDS card No. 65-2901 and that each wave unit and peak

were classified into pure cubic silver phase. The absence of extra peaks in the XRD patterns is a clear reason for the high purity of Ag NPs that were synthesized by parsley extract. This is a good indication that plant extracts, in contrary to other synthesizing methods, produces pure, high quality and stable NPs (Salem and Fouda 2021). Also, the purity of the sample has been proven by SEM and EDX analysis in the coming sections. The crystallite size and quality can be studied by investigating the full width at half maximum (FWHM) values from the XRD spectrum. Therefore, from the XRD spectrum, one can compute the average crystallite size using Debye–Scherrer equation (Holzwarth and Gibson 2011):

$$D = \frac{0.95\lambda}{\beta \cos\theta} \quad (5.1)$$

Where D is the average crystallite size, λ is wave length of the incident X-ray (0.154 nm), θ is the Bragg's angle and β is the full width at half maximum (FWHM). As a rule of thumb, the narrow FWHM, ~ 0.2475 , is always a cue for having high quality structure of Ag NPs. The calculated average crystallite size of the Ag NPs around 30 nm. Comparable results have been found by other researchers (Raza et al. 2016; Ahani and Khatibzadeh 2017). The crystalline size is relatively smaller than the grain size which can be obtained by SEM images. Thus, in order to calculate the actual nanoparticle size, TEM or DLS should be utilized (Barzinjy and Azeez 2020).

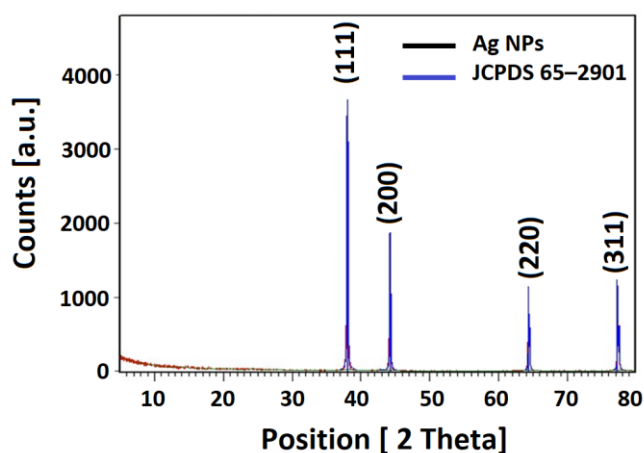


Figure 4.6. X-ray diffraction patterns of the biosynthesized Ag NPs

4.2.4. SEM and EDX Analysis of Ag NPs

The morphology, shape and size of the biosynthesized Ag NPs was investigated using field emission scanning electron microscope (FE-SEM). It can be seen, from Figure 4.7., that the synthesized Ag NPs possess uniformly dispersed spherical NPs, with grain size in the range of 40 nm to 80 nm, the real size of NPs can only be observed by dynamic light scattering (DLS) and transmission electron microscope (TEM) (Tomaszewska et al. 2013). Since XRD provide the crystallite size, relatively smaller than the NPs size, and FE-SEM provide the grain size, comparatively bigger than the NPs size (Barzinjy and Azeez 2020). Figure 4.7., also, shows the agglomeration state of the biosynthesized Ag NPs. Despite of having C-N and C-C stretching bond, as stated before in the FT-IR spectrum, which are signifying the presence of proteins amines around the Ag NPs, they can protect the NPs from agglomeration, there are still agglomerated clusters (Iravani et al. 2014). According to our best knowledge, as stated in the UV-Vis analysis, since there are poly-dispersed Ag NPs this leads to a non-uniform nucleation process and thus forming the agglomerated clusters. On the other hand, agglomeration is usually, owing to the high surface energy per unit volume ratio which is the case in most of the biosynthesized NPs (Khan et al. 2019). Our XRD results were in a good agreement with those of preceding investigations (Raza et al. 2016; Ahani and Khatibzadeh 2017).

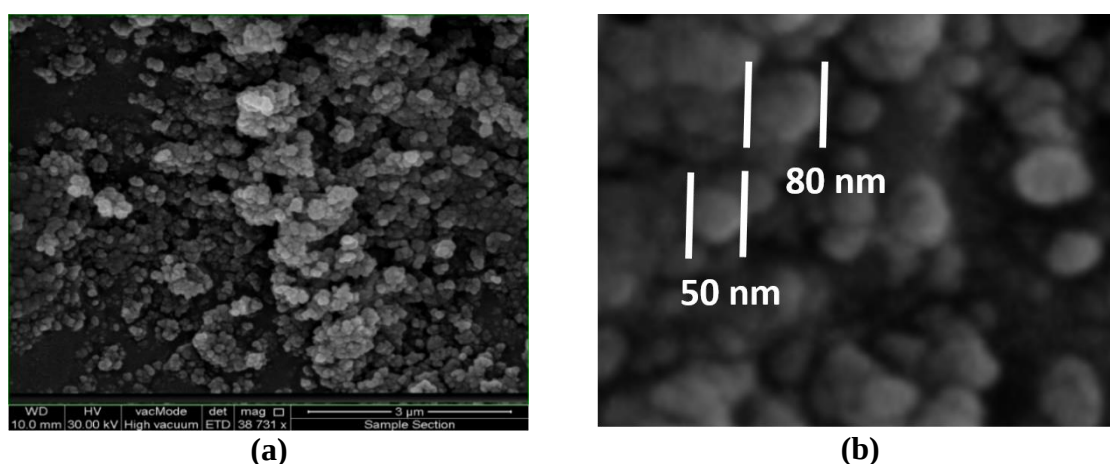


Figure 4.7. (a) Top view and (b) Higher magnification FE-SEM images of biosynthesized Ag NPs

Elemental analysis of the biosynthesized Ag NPs (Figure 4.8.) was investigated by Energy Dispersive X-ray (EDX) analysis. EDX spectra shows a strong signal in the silver

region, i.e. 3 keV, and confirm the formation of nanosilver and its elemental nature. This signal was shaped due to the excitation of surface plasmon resonance of Ag NPs. Some of the weak signals from Au were detected. To improve the clarity and clarity of the signal formation image, Ag NPs were coated with a small layer of gold. Figure 4.8. shows the purity of the biosynthesized Ag NPs which contains only Ag element with no impurity from the other elements. Comparable analysis has been found by previous investigations (Ahani and Khatibzadeh 2017).

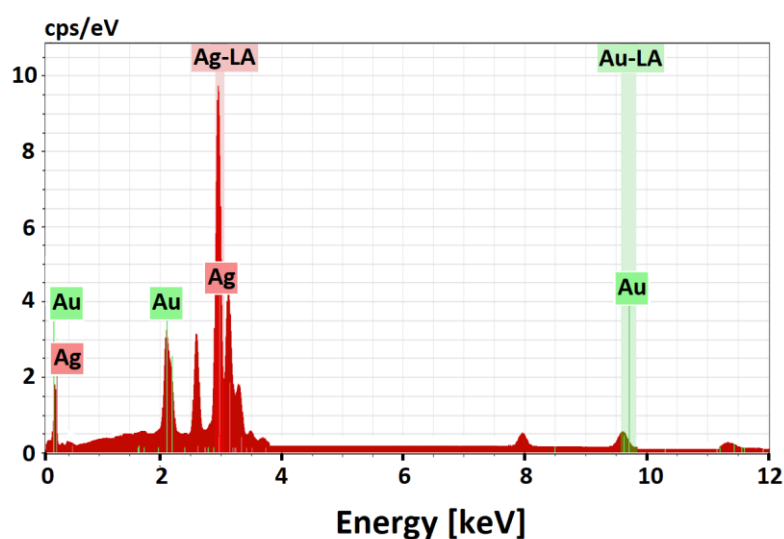


Figure 4.8. EDX analysis of the biosynthesized Ag NPs

4.2.5. Transmission Electron Microscopy Analysis of Ag NPs

To understand the impacts of the biosynthesis circumstances on the shape and size of Ag NPs, the morphology was investigated using transmission electron microscopy (TEM). Figure 4.9. displays the existence of spherical Ag NPs. TEM image shows a NPs size range from 40-60 nm. High resolution TEM (HRTEM) study was utilized to find the structure of the biosynthesized Ag NPs. HRTEM displays the crystalline structure of single Ag NP, with noticeable lattice fringes. For consistency with the SPR range in the UV-Vis and XRD spectra, a grid spacing of 2.3, corresponding to the Miller index level (111) of a face-centered Ag cube (FCC) was calculated. TEM images, similarly, revealed that Ag NPs are highly dispersed and crystalline polys.

It can be seen, from Figure 4.9., that, especially under close observation, the biosynthesized Ag NPs are surrounded by a shaded layers of foreign matter, which most likely represent the capping agent from the parsley leaf extract. Also, the Ag NPs are separated from each other by a uniform inter particle distance. The results of HR-TEM are in an excellent agreement with earlier investigation by Alahmad et al. 2021.

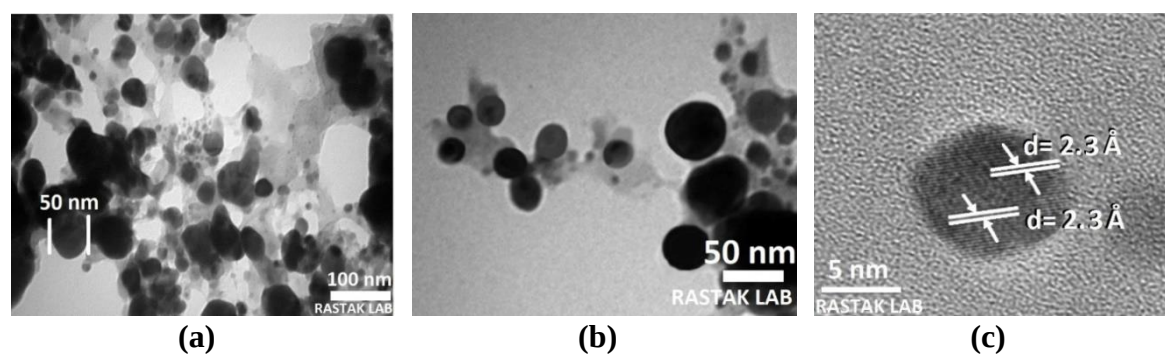


Figure 4.9. (a) HR-TEM (b) closer observation HR-TEM and (c) HR- TEM image f individual Ag NPs

4.2.6. TGA-DSC Analysis

It is well-known that, in many applications, such as the current applications in this study, the thermal properties of nanoscale materials, are extremely important. The impact of temperature in nanoscale materials has been studied widely, such as crystallization, melting and decomposition points (Ghaemi et al. 2018). The purity and thermal stability of the biosynthesized Ag NPs was investigated using thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC) analysis (Figure 4.10.). It can be noticed, from Figure 4.10. (a), that the loss in mass of about 27% demonstrated that the metallic core, Ag NPs, is enclosed by biomolecules. These outcomes agree in a high manner with the HR-TEM results, it has been shown that the shaded layers are representing the capping agents surrounded around the Ah NPs. At the same time, this results solve the dilemma of stability of the available phytochemical inside the plant extract which are stable until high temperature (Arabshahi-D et al. 2007). In addition, TGA analysis (Figure 4.10. (a)) proposed that the weight loss in the temperature range of 0°C - 100°C is due to the moisture absorption by the Ag NPs. This, in turn, proves that the biosynthesized Ag NPs are a good candidate for absorbing moisture in many areas of applications (Traiwatcharanon et al. 2017). From Figure 4.10. (b), a sharp exothermic

peak at 200 °C could be observed together with two small endothermic peaks, one at 450 °C and the other one at 964 °C (Figure 4.10.b) analogous to the melting point of the metallic silver which specifies the purity of the NPs. Deprivation pattern of organic compounds was lasting until 750°C. In other words, there was no deprivation above 750°C which is related to the weight of Ag NPs. Analogous consequences have been found elsewhere by other researchers (Manam 2020; David and Moldovan 2020).

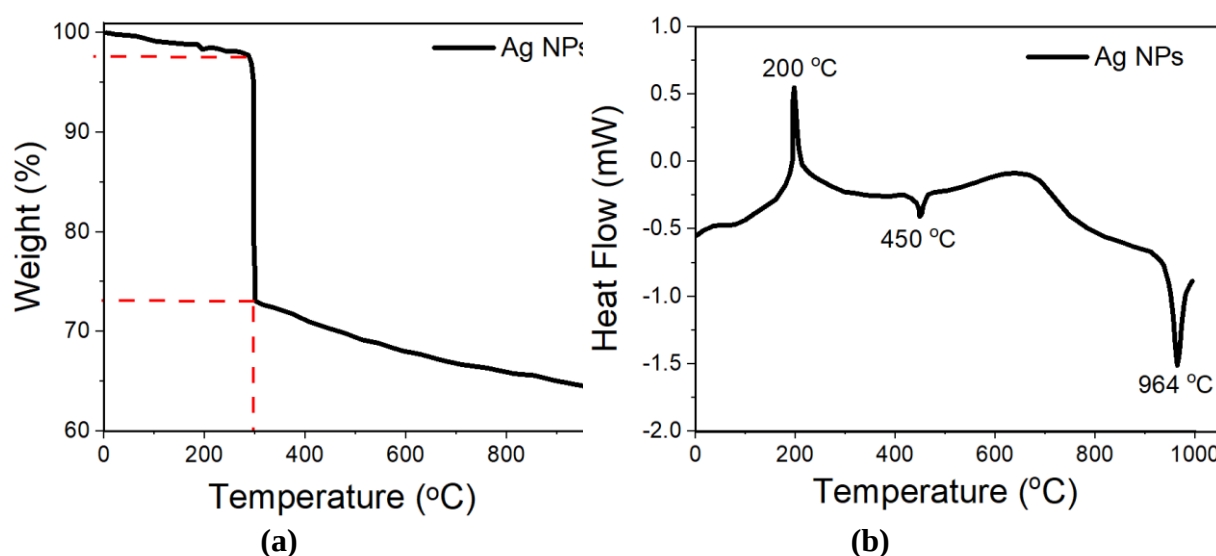


Figure 4.10. (a) TGA and (b) DSC curve of the biosynthesized Ag NPs

4.2.7. Particle Size Distribution and Zeta Potential Measurement

The dynamic light scattering (DLS) is utilized to compute the diameter of the Ag NPs dispersed in liquid. The size dissemination profile of the biosynthesized silver nanoparticles measured by the DLS method is shown in Figure 4.11. The sharp signal confirms the equi-size particle distribution, an indicator for monodispersity, which agrees well with the UV–Vis spectrum. Size distribution profiles reveal one population of NPs with the average size around of 55 nm. Zeta potential, in turn, is a degree of the actual electric charge around the surface of the NPs. Once a nanoparticle possesses a total surface charge, the charge is measured through the ion concentration within an opposite charge near the surface of the NPs (Singh et al. 2014). The zeta potential value was shown to be -50 mV, which is corresponding to the high stability of the biosynthesized Ag NPs. These outcomes are in a good agreement with Netala et al. results (Netala et al.

2016). The DLS results coinciding with the range obtained from the HR-TEM analyses. Consequently, the DLS and TEM analyses provided analogous results for the size range of the NPs. Parsley leaf extract mediated biosynthesized Ag NPs possess high negative zeta potential values and thus they are stable under a wide pH range (Dubey et al. 2010).

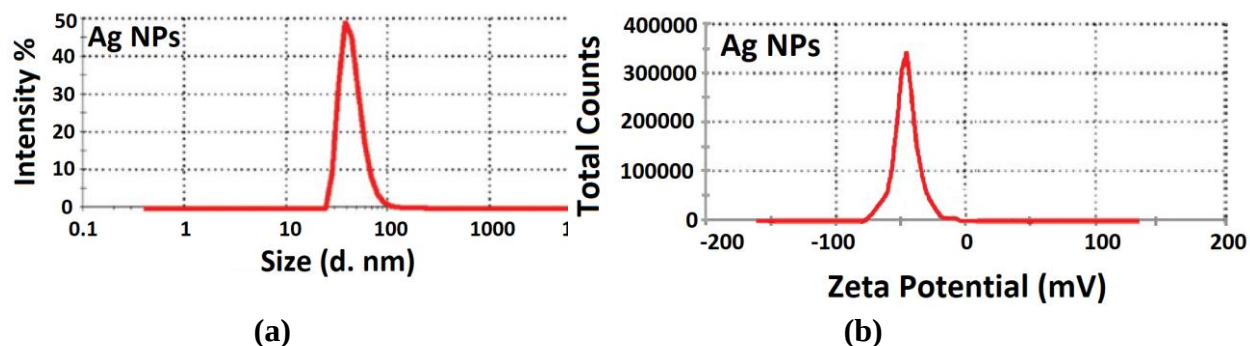


Figure 4.11. DLS analysis of the biosynthesized Ag NPs (a) size distribution (b) Zeta potential

4.3. Solar Energy Harvesting Using Ag NPs

Nanomaterials, in general, own better thermal, electrical, optical, magnetic, and mechanical, properties, which have made them appropriate for countless applications (Baig et al. 2021). For instance, in solar energy absorbers, nanostructured metallic materials are able, due to the high surface area per unit volume, to absorb the maximum incoming light flux through the vicinity of plasmonic structures (Panoiu et al. 2018). In surface plasmonic modes, the energy of the absorbed photons is given directly to the free electrons, and the produced hot electrons can be used in thermoelectric, photovoltaic, and photocatalytic platforms (Boriskina et al. 2013). In other words, metallic nanomaterials can enhance the absorption and emission of light, and then provide a local heating.

The plasmonic photo-thermal characteristics of metallic NPs are of massive attention in biomedical areas since of their robust optical reaction and the aptitude to operate the photo-thermal consequence through the exterior light sources (Kim et al. 2019). In addition, the most important role of plasmonic effects in hot electron production lies in their aptitude to harvest near-infrared and infrared regions of the solar spectrum, which cannot be obtained in conventional photocatalytic devices (Kumar et al. 2019). Among the metallic nanostructured materials, NPs have played, exclusively, an important role in

the development of the photo-thermal generation devices. Nanoparticles such as gold and silver can effectively release heat under the light source (de Aberasturi et al. 2015). The heat generation is due to the plasmonic electric field driving the electrons forcefully inside the nanocrystals, while the energy received by the carrier is converted into heat. Formerly, the heat spreads from the nanocrystal increasing the temperature of the ambient medium (Wole-Osho et al. 2020). Thus, the solar energy can be converted into thermal energy through the interaction between light and the mobile charge carriers in metallic nanoparticles and increase the temperature of the surrounding medium as shown in Figure 4.12.

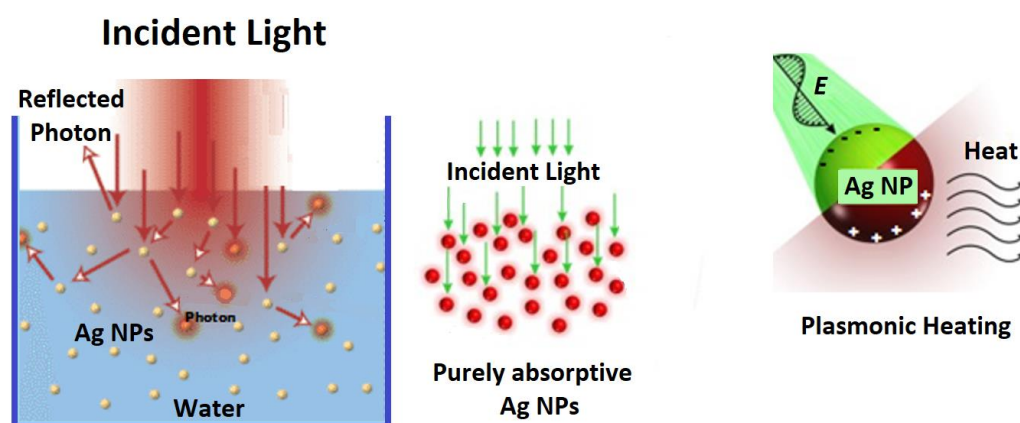


Figure 4.12. Schematic representation of heat generation from the Ag NPs in water when exposed to the sunlight

The reason behind selecting Ag NPs for this purpose is Ag NPs after Au NPs is the best candidate for plasmonic heating generation process (Kim et al. 2019). Meanwhile, in semiconductor NPs, the heat release rate is much weaker since heat is produced over the interband absorption procedure with the formation of a mobile electron and a hole (Zhang et al. 2015).

As shown previously, the utilized biosynthesized method in this study producing spherical Ag NPs. Thus, the movement of electrons in an electric field results in the polarization of the sphere, therefore there is a linear restoring force, which reaches the extreme point at the SPR. Accordingly, in contrast to the bulk material, a free electron in the spherical particles is a vibrational system (Xiong et al. 2020; Tlili et al. 2019).

Figure 4.13. shows temperature profiles of Ag NPs in water medium by heat generation due to SPR of free electrons when exposed to the sunlight. It can be noticed that, the heat released by the Ag nanofluid under sunlight irradiation at the plasmonic-resonant wavelength increased the temperature of the water medium as the irradiation time increases (Lin et al. 2019). In order to achieve an optimal plasmonic heating generation, the wavelength of the light source should be close to the plasmonic resonance wavelength of Ag NPs (Liang et al. 2019).

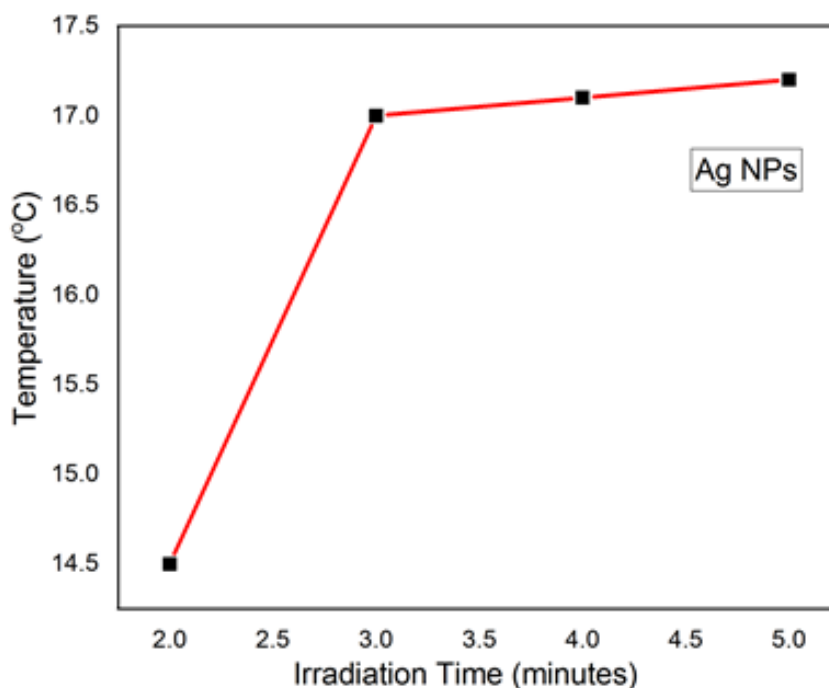


Figure 4.13. Temperature profiles of Ag NPs in water medium under the sunlight

It can be seen from Figure 4.14., the released heat by the Ag nanofluid under sunlight irradiation at the plasmonic-resonant wavelength increased the temperature of the water medium as the concentration of the Ag NPs increased. At low concentration of Ag NPs (3%) the temperature of the water rises up to 17.4 oC after 8 minutes. While, the temperature profiles of containing 5% and 7% of Ag NPs were reached to the 16.3 and 17.2 oC respectively. As a result of the absorption, trapping, and scattering of the incident light by the Ag NPs over a board spectrum, following the generation of heat through non-radiative damping after sunlight absorption as explained in the Figure 4.14. (Lin et al. 2019).

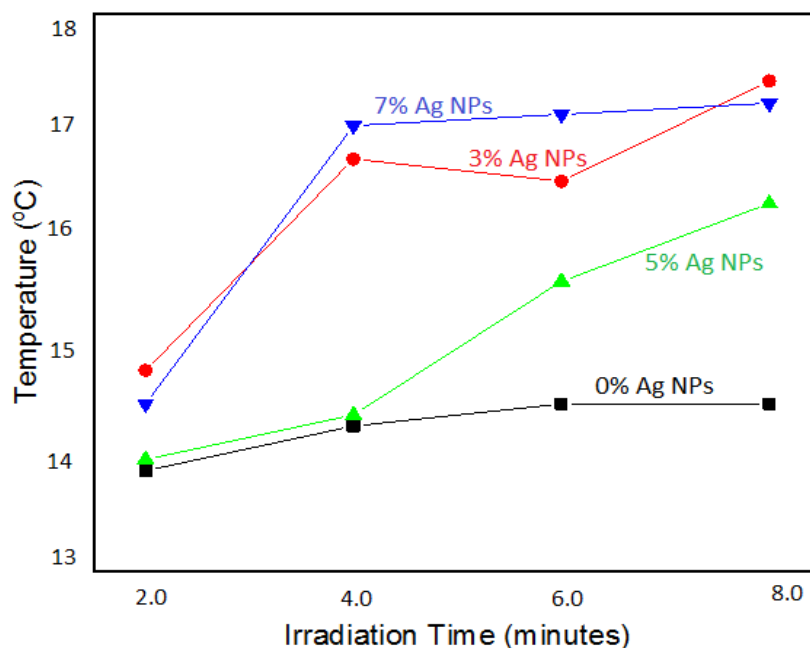


Figure 4.14. Temperature profile of water under irradiation of sunlight containing different percentage of Ag NPs

Beicker et al. studied the photothermal conversion behavior of gold/water and also multi-walled carbon nanotube (MWCNT)/water nanofluids at specific volumetric concentrations (0.0001–0.004% and 0.0001–0.03%, individually (Beicker et al. 2018). They showed that the optimal nanoparticle volumetric concentration was 0.002% for the gold nanofluids and 0.001% for the MWCNT. These results indicate that by optimization, the solar spectrum could be absorbed to its maximum level. However, He et al. used Cu nanofluid as solar absorber nanoparticles and they showed the efficiency of solar collector in the water medium was improved to 23.83% for (25 nm, 0.1 wt%) Cu NPs (He et al. 2013). Moreover, they also showed that, the optical absorption of metallic NPs could be improved more by merging with graphene. Recently, different research groups were synthesized nanofluids based on spherical silver, gold, and copper NPs, covered by graphene oxides (GO) structures and studied their thermal absorption behavior under the sunlight (Campos et al. 2019). These results demonstrated that, the new nanostructured materials could convert the solar energy to the thermal energy under low and high solar irradiation. As stated by Campos et al. (2019) the nanofluids was increased their temperature and reaching the boiling point after 10 minutes. In fact, this is already expected by nanomaterials due to their extraordinary physical properties, such as large surface area per volume. In addition, when the scale of the nanoparticles is

comparable to the free electrons De-Broglie wavelength, the periodic boundary conditions would be change due the size shrinking. Thus, light absorption, magnetic effect, thermal conductivity, chemical reactivity, and melting point can be converting strongly. For instance, the properties of plasmonic resonance frequency change with different particle size, therefore, the NPs size can be tuned to control photothermal conversion with broadband sunlight absorption (Zhang et al. 2019).

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

1- Petroleum energy is the primary source of energy and economy in Iraq since the discovery of oil there. As a result, research and studies on alternative and renewable energies such as solar energy have been delayed for several decades.

2- Switching from the use of electric heaters to solar energy reduces the energy drain, estimated at one third of the total energy generated in electric generating stations.

3- The lack of use of solar-powered heaters for hot water in Erbil Governorate / Iraq is due to its high cost and the traditional engineering designs of houses and buildings.

4- Not to exploit solar energy in all applications and fields, except by 0.01% of the energy reaching the earth, which is 15.000 times what is needed by all the inhabitants of the earth.

5- The rate of solar radiation falling on the site of Hamza Kur in the city of Erbil for different seasons ranges between (1125-1150) watts per square meter, which is a promising quantity if it is used appropriately.

6- The greatest received solar energy is usually at noon on the equator on a clear day.

7- The material of the plate, the purity of the transparent cover, the insulation, the storage, the design engineering and the angle of solar rays capture all affect the improvement and increase the efficiency and performance of the flat solar collector, which reaches about 70%

8- -Heat is transferred from the solar collectors to the tank either automatically (siphon), where the hot water rises from the collector to the tank under constant atmospheric pressure due to its light weight, or through pumps to regulate the movement of the thermal fluid between the solar collectors and the tank, or in the case of using nanofluids that require pressure to raise Fluid as a result of the sedimentation phenomenon in nanoparticles.

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- 9- Nanomaterials generally have better thermal, electrical, optical, magnetic and mechanical properties, which have made them suitable for countless applications
- 10- The majority of laboratory experiments conducted by researchers and laboratory work on silver nanoparticles proved that the thermophysical properties of nanofluids are higher performance and efficiency than conventional liquids.
- 11- Research and laboratory work proved that the thermal performance of nanofluids improves with increasing concentration of nanoparticles masses in liquids within certain limits.
- 12- The size, shape and type of nanoparticles affect the thermodynamics and performance of solar energy systems, as the efficiency increases with the decrease in the size of the particles, and the cylindrical shape is better than the spherical shape, and each type of nanoparticles has different thermal properties.
- 13- Improving the thermophysical properties (conductivity, specific heat, viscosity, etc.) of nanofluids leads to improved performance and efficiency of heating systems.
- 14- Production costs, agglomeration, instability, wear and corrosion of heat transfer equipment are major obstacles to nanofluids in their limited use, as well as the toxicity of some nanoparticles.
- 15- Hybrid nanofluids have better thermophysical properties than single type particle concentration nanofluids.
- 16- Studies have shown that the use of nanofluids in applications reduces toxic carbon dioxide emissions.
- 17- The heat storage properties of nanofluids are better than that of conventional liquids.
- 18- In vitro work, highly purified, thermally stable, spherical Ag NPs were synthesized from simple, rapid, safe, single-pot green methods using parsley leaf extract.
- 19- The biocomposited Ag NPs was used to investigate the plasmonic effect of different concentrations, namely 0%, 3%, 5% and 7% of Ag NPs and to monitor the heat emitted by the nanoparticles in the water medium by irradiation under sunlight. It was found that the ambient water temperature would reach 17.4 °C when 3% Ag NPs was used within 8 minutes of irradiation.
- 20- The study showed that the heat emitted by the biosynthetic Ag NPs from irradiation of about 450 nm would lead to the thermal decomposition of the localized surface resonance of flour.

21- The result of this investigation is promising and confirms that Ag NPs can be used as a source for converting solar energy into thermal energy and then increasing the temperature of the water medium under optimal conditions. The laboratory work has been published in a solid international scientific journal, explained below, for its development in the near future by researchers

5.2. Recommendations

- 1- Intensifying studies and research on the benefits of solar energy and its applications, as it is a promising, sustainable, low-cost and environmentally friendly source.
- 2- Reducing the costs of the traditional solar heater parts (absorbent plate, cover, tubes, insulation and storage) and improving its design, performance and efficiency are important factors in increasing its widespread use.
- 3- Continuing to conduct laboratory work on various nanoparticles to select the best nanoparticles that have good thermal properties at the lowest cost and try to make some applications in thermal systems.
- 4- Continuous pursuit and continuation of laboratory work to improve the thermal, electrical, optical, magnetic and mechanical properties of nanofluids to reach stable results that contribute to using it as an alternative to conventional liquids in thermal solar collectors.
- 5- Focusing on the technology of manufacturing high-purity, thermally stable and spherical Ag NPs from green methods as it is simple, safe and environmentally friendly using parsley leaf extract.
- 6- Continuing the laboratory work on improving the nanosilver particles in terms of shape and size, and mixing it with liquids bearing homogeneity in the concentration of the stable chemical properties with nanosilver to prevent the phenomenon of particle agglomeration.
- 7- The laboratory work proved that the use of nanosilver is promising in raising the temperature resulting from converting solar energy to thermal energy, which affects the performance and efficiency of solar thermal systems, so it is important to continue to reveal the rest of the other important characteristics of nanosilver to complete the investigation and stability in its use in applications process until we reach the production stage at the lowest cost.

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