Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2017, 4(7):93-102

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Dust effect on PV outcomes at five different sites around Baghdad

Raid S Jawad[1], Khaleel I Abass[2]*, Ali A Al-Wailie[3], Dina S M Al-Zubaidi[4]

[1]Energy and Renewable Energies Technology Centre, University of Technology, Baghdad, Iraq
[2]Mechanical Engineering Dept., University of Technology, Baghdad, Iraq
[3]Ibn-Rusher College, University of Baghdad, Baghdad, Iraq
[4]Mechatronics Eng. Dept., Al-Khwarizmi Collage of Engineering, Baghdad University, Iraq

Abstract The excessive use has peaked and consumed most of the oil reserves, and impending climate change is driving the adoption of photovoltaic (PV) decisively as a sustainable, renewable and environmentally friendly alternative. Research is under way to find a breakthrough to increase the efficiency of conversion of commercial PV units significantly. The installation of photovoltaic power systems to achieve the highest conversion efficiency is primarily dictated by the geographical location (latitude and solar exposure available) and the design of the structures (inclination, direction, and elevation) to maximize exposure to solar energy. However, addressing these parameters appropriately does not mean that there are no other factors that affect the performance and efficiency of the system. Dust significantly affects the performance of plants in Pf which is a major factor in areas that are constantly exposed to dust. This paper provides an assessment of the use of photovoltaic panels in five different locations around Baghdad City on the performance of the cell. Complex systems in agricultural areas such as Al-Zafrania, and Al-Rashidia can be considered less affected by dust, while compounded sectors such as Al-Aameria, Al-Sader city, and Al-Sinaa are more affected by this pollutant.

Keywords dust, location effect, PV outcome, current, Iraq

Introduction

During this century, the world faces several challenges, the most serious of which is famine and war, and at least as much, climate change and environmental pollution [1-2]. Iraq is a country that has suffered from an unjust siege for fourteen years and a severe drought for more than 20 years, causing muchenvironmental damage [3]. Perhaps the most important manifestations of this devastation that has been inflicted on Iraq are a decrease in the area of arable land to less than half, as well as the high percentage of salinity of rivers and groundwater [4]. The multiple wars Iraq has waged over the last 30 years have caused a major disaster in terms of lack of services and extensive destruction of the country's infrastructure [5]. The low power supply caused citizens to use gasoline and diesel generators, causing large quantities of exhaust pollutants, and an unthinkable increase in the number of personal vehicles and trucks, making Iraqi cities suffer from high air pollution [6-7]. The shift to the use of renewable, environmentally friendly energies is imperative if the country is to survive [8]. The talk about renewable energies means talking about the energies available in Iraq such as solar energy, water and groundwater energy [9]. To date, successive Iraqi governments have not taken any action to use renewable energies, especially solar energy, to rely entirely on the country's oil reserves [10]. Research is still under way in Iraq to check the validity of solar energy use [11].

Photovoltaic is the direct conversion of light into electricity at the atomic level [12]. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured electric current results, which can be used as electricity [13]. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module [14]. Modules are designed to supply electricity at a certain voltage, such as a common 12 volts system. The current produced is directly dependent on how much light strikes the module [15]. Research and development in photovoltaic (PV) systems has usually been concentrated in studies on radiation availability,

efficient operating strategies, design and sizing of these systems [16-18]. On the other hand, the influence of dust on the performance of PV systems has not been given much attention [19-20].
Dust is one of the natural elements available in the environment. The variation in dust particles' sizes and compositions depends on the location [21]. In some regions, dusty weather conditions tend to be more severe than in others. It causes deterioration in visibility during dusty days [22]. Also, dust tends to settle down creating a fine layer of accumulated dust on any exposed surface. It has been reported that different parameters support the accumulation of dust such as gravitational forces, wind speed, wind direction, electrostatic charges and the wetness of the surface [23-24]. Out of those parameters, the most dominating effects are the gravitational effect, particle size and wind direction. Slow wind will increase the deposition of dust, while fast wind speed will help remove dust if wind is incident in an appropriate direction [25]. The random accumulation of dust on the PV module surface area can produce spots with varying concentration of dust particles [26]. These spots vary in shape, location and concentration density. The variation in dust accumulation in any place can lead to different transmittance of light into the module, thus leading to small random areas on the PV module with partial shading from the solar radiation [27].
It has been reported that falling dust has a direct effect of reducing the performance of solar PV modules [28]. Accumulated and airborne dust reduces the amount of solar radiation incident on the surface of a PV module. A relation is provided between airborne dust, accumulated dust and the reduction in PV cell short circuit current. Others have reported a relation between dust particle size, particle distribution, tilt angle and the reduction in transmittance of solar radiation [29].
The losses associated with dirt accumulated on the surface of the modules are one of the loss factors that have influence in the system performance ratio [30]. This dirt can be due to the dust accumulated on the modules surface, usually uniformly distributed. This fact implies that the photovoltaic cells receive less irradiance. In other cases there may be non-uniformly distributed dirt that frequently is due to bird droppings; this dirt produces important partial shading on the cells [31]. Obviously, if maintenance tasks include periodic cleaning of modules these losses can be avoided. However, these tasks are costly in time and depending on the type of system (fixed, sun-tracking) moreover they are expensive in many cases, especially because of water scarcity in these areas [32].
In this work we will investigate the effect of dust on the PV performance by collecting dust samples from different places in Baghdad Governorate-Iraq. The output of the PV system will be analyzed. In addition, different amount of dust will be utilized to allow further investigation of the effect of the quantity of dust. The electrical performances of Photovoltaic panels are studied experimentally for the effect of deposited dust particles. The experimental data are used for the calculation of the energy efficiency and power output of the PV systems. This work is a part of the Energy and Renewable Energies Technology Center in the University of Technology to wide spread the culture of using renewable energies instead of fossil fuels. The center's researchers conducted several research papers in hydrogen energy and its applications [33-47]. Also, the center conducted many investigation papers in the fields of solar ponds [48-49], solar towers [50-51], concentrated solar power [52-53], heating water and air [54-56]. Besides, many technical works were conducted on the use of Trombe walls in Iraq [57-59]. The use of phase change materials (PCM) in solar thermal applications takes a part of the center efforts [60-62]. Finally, solar distillation and improved solar distillation production have been extensively studied for its importance in the foreseeable future [63-65], as well as using nano materials in energy applications [66-68].

Experimental Setup
The selected location

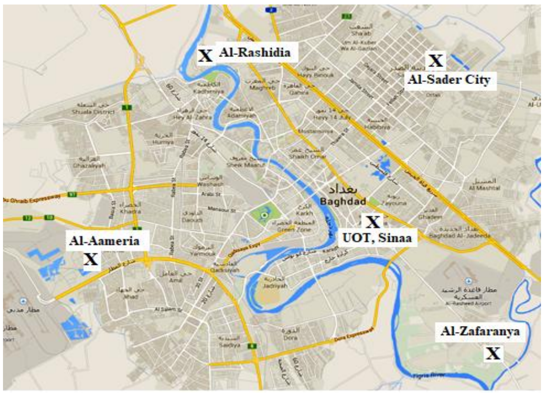

Figure 1: The Baghdad Governorate map and the study selected location are marked by X

Five variable locations in Baghdad Governorate were selected to conduct this study. Fig. 1 represents the Governorate map and the selected locations.
The five locations were selected to represent the four directions of Baghdad city (North-Al-Rashidia, South-Al-Zafrania, East- Al-Sader city, and West- Al-Aameria) and the center of the city is the University of Technology Campus in Al-Siaa.

Apparatus

Three PV panels were used in the present study (its specifications are listed in the Table 2); Fig. 2 shows a photo of the used PV group. The three panels were fixed on the Energy and Renewable Energy Technology Center roof facing south.
A controller was used to measure the short circuit current and open circuit voltage as well as the current and voltage during the tests periods. A weight balance type (AND-EJ6I0) was used to measure the weight of the dust added to the panels in each interval. A rocking machine was used to vibrate the panels and distribute the dust eventually before test.

Table 2: The used PV specifications

Solar module type	APM-P 110-12
Peak power	110 W
Max. Power voltage	17.2 V
Max. Power current	6.40 A
Open-circuit voltage	21.6 V
Short-circuit current	7.0 A
Weight	11.4 kg
Dimensions	1450x 720x35
Operating temperature	-40^{o}C to 90^{o}C
Wind resistance	2400 Pa

Figure 2: the used PV cells group

Test Procedure

Five PV panels were used to collect dust from air. These panels were placed horizontally and in a shaded area that prevents rainwater from reaching them but is open to ambient air. The accumulated dust on the PV panels is weighted using a weight balance. When the dust accumulated on the panel reached 100 grams, it was taken to the laboratory where it was tested in an indoor solar simulator and then returned to its location to gather more dust. When the accumulated dust weight 200 gram the second test was conducted on it.The gathering period extended from for the period from September-2016 to May-2017. All the measured values were compared the values obtained from a clean PV panel.

Results and Discussion

Table 2 illustrates the results obtained current when the panels were polluted by 100 gram of dust brought from the tested sites compared with the clean panel current:

Table 2: The resulted current for the tested sites panels

Location	Quantity (g)	PV (A)	Gathering time (days)
Clean panel	0	5.7	0
UOT campus	100	3.40	53
Al-Rashidia	100	3.48	81
Al-Zafrania	100	3.5	76
Al-Sader City	100	3.42	55
Al-Aameria	100	3.44	61

Table 2 indicates a high reduction in PV current in the urban areas of Baghdad while the lower reduction was in agricultural areas. The gathering period of dust was shorter in urban areas. High traffic causes high dust in the air in addition to the wind movement, and therefore in urban areas, the dust accumulates quicker. The type of the accumulated dust has an influence on the resulted output. As the table shows, the same quantity of dust caused variable current reductions. Fig. 3 declares the variation in the resulted current with each tested site. The results obtained clearly shows the obvious influence of the PV performance. Generally, the output gained kept decreasing in all cases. The maximum difference between the "no dust" output and the output gained was noticed at “UOT Campus” which was (2.3A), with a reduction percentage of 40 %. While the minimum difference was detected when using “Al-Zafarania” dust which was (2.2) A, thus the percentage of reduction was 38%. All other cities' dust was similarly affected by the quantity of dust.

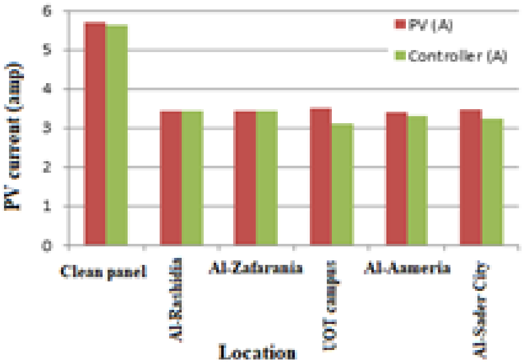

Figure 2: The effect of 100 grams of dust accumulation on the PV current for the tested sites

Table 3 listed the results of the impact of 200 grams of dust accumulation of the PV panel. The results indicate high reduction in the current especially for the UOT campus compared to clean panel. This result illustrates the importance of cleaning the panel at intervals and after every dust storm. Fig. 4 shows these differences graphically. The differences in the resulting current are caused by the location from which the dust came and its physical and chemical properties. Table 3 shows that urban areas cause a greater spread of dust in the atmosphere and thus a faster accumulation of photovoltaic cells. The traffic of the cars causes the dust to rise, in addition to the heavy building processes. The reconstruction movement is heavy in cities causing building materials to rise in the air. Therefore, the pollutants in the urban areas are more closely related and widespread on the solar panel. As the tabulated results and the graph clearly indicates that the output decreased gradually at a higher amount. The percentage of losses increased significantly. Specifically, the smallest reduction was in "Al-Rashidia" with a percentage of 40%. While the largest percentage was in “UOT Campus " by 49%.

Table 3: The resulted current for the tested sites panels'

Location	Quantity (g)	PV (A)	Gathering time (days)
Clean panel	0	5.7	0
UOT campus	200	2.9	85
Al-Rashidia	200	3.38	99
Al-Zafrania	200	3.36	111
Al-Sader City	200	3. 0	83
Al-Aameria	200	3.1	92

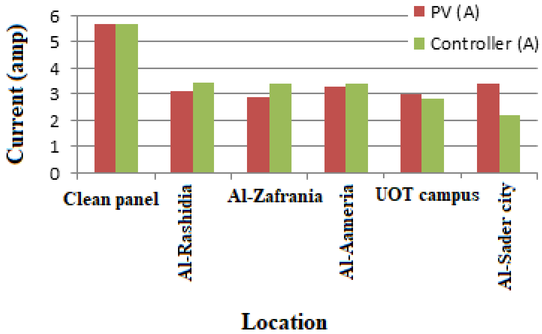

Figure 3: The effect of 200 grams of dust accumulation on the PV current for the tested sites

Table 4 represent the reduction in the PV panel outcomes when the dust accumulated on it compared with clean panel. The results reveal increasing rate with the increase in the dust accumulation quantity. This result confirms what we concluded previously about the need for cleaning the PV panels on periods to avoid the high dust accumulation on it causing high reduction in the panels' output. Fig. 4 shows these differences graphically.

Table 4: A comparison between the outputs gained versus the percentages of reduction from the “no dust” output

Location	100 (gm)	200 (gm)
	% of reduction	% of reduction
UOT campus	40	49
Al-Rashidia	38	42
Al-Zafrania	38	40
Al-Sader City	39	45
Al-Aameria	40	47

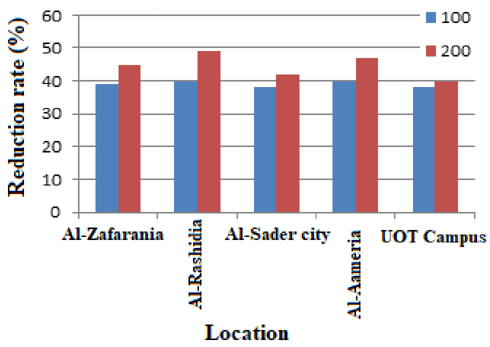

Figure 4: The reduction rate differences with accumulated dust

Conclusion

The effect of dust on the performance of PV system was investigated. The dusts of five cities were selected to study the behavior of the gained output. The obtained and discussed results showed clearly that the efficiency of the PV system decreased when dust was spread over the PV.

The difference among the output of each city, suggest that the geographic considerations must be taken into account. Thus, when installing PV system, the nature and the geographical structure of the area must be investigated as this could affect the performance of PV systems. To overcome this problem, it is recommended to use the scheduled cleaning of the solar panels that could provide efficient enhancement for the PV system outcomes. Finally, Iraq is located in an area that is one of the most places of the world where the solar energy could be utilized to provide renewable electricity. Thus, it is vital to encourage the usage of it and to study and solve the different factors that could prevent from using this renewable energy.

References

[1]. Al-Maamary, H. M. S., Kazem, H. A., Chaichan, M. T. (2016).Changing the Energy Profile of the GCC States: A Review. International Journal of Applied Engineering Research (IJAER), 11(3): 1980-1988, 2016.

[2]. Al-Maamary, H. M. S., Kazem, H. A., Chaichan, M. T. (2017). Renewable Energy and GCC States Energy Challenges in the 21st Century: A Review. International Journal of Computation and Applied Sciences IJOCAAS, 2(1):11-18.

[3]. Al-Maamary, H. M. S., Kazem, H. A., Chaichan, M. T. (2017). Climate Change: The Game Changer in the GCC Region. Renewable and Sustainable Energy Reviews, 76: 555-576. http://dx.doi.org/10.1016/j.rser.2017.03.048.

[4]. Yaseen, B. R., Al Asaady, K. A., Kazem, A. A., Chaichan, M. T. (2016). Environmental Impacts of Salt Tide in Shatt al-Arab-Basra/Iraq. IOSR Journal of Environmental Science, Toxicology and Food Technology, 10(1-2): 35-43.

[5]. Chaichan, M. T. & Kazem, H. A. (2012). Status and Future Prospects of Renewable Energy in Iraq. Renewable and Sustainable Energy Reviews, 16(1): 6007–6012.

[6]. Al-Waeely, A. A., Salman, S. D., Abdol-Reza, W. K., Chaichan, M. T., Kazem, H. A., Al-Jibori, H. S. S. (2014).Evaluation of the Spatial Distribution of Shared Electrical Generators and their Environmental Effects at Al-Sader City-Baghdad-Iraq. International Journal of Engineering & Technology IJET-IJENS, 14(2): 16-23.

[7]. Chaichan, M. T., Kazem, H. A., Abid, T. A. (2016). The Environmental Impact of Transportation in Baghdad, Iraq, Environment, Development and Sustainability, DOI: 10.1007/s10668-016-9900-x.

[8]. Chaichan, M. T. (2013).Experimental Evaluation of the Effect of Some Engine Variables on Emitted PM and Pb for Single Cylinder SIE. Association of Arab Universities Journal of Engineering Science, 2(20): 1-13.

[9]. Chaichan, M. T., Abaas, K. I.,Salih, H. M. (2014). Practical Investigation for Water Solar Thermal Storage System Enhancement Using Sensible and Latent Heats in Baghdad-Iraq Weathers. Journal of Al-Rafidain University Collage for Science, 33: 158-182.
[10]. Chaichan, M. T. (2014).Combustion of Dual Fuel Type Natural Gas/Liquid Diesel Fuel in Compression Ignition Engine. Journal of Mechanical and Civil Engineering (IOSR JMCE), 11(6): 48-58.
[11]. Chaichan, M. T.,Faris, S. S. (2015). Practical Investigation of the Environmental Hazards of Idle Time and Speed of Compression Ignition Engine Fueled with Iraqi Diesel Fuel. International J for Mechanical and Civil Eng., 12(1): 29-34.
[12]. Kazem, H. A.,Chaichan, M. T. (2015).Effect of Humidity on Photovoltaic Performance Based on Experimental Study. International Journal of Applied Engineering Research (IJAER), 10(23): 43572-43577.
[13]. Kazem, H. A., Al-Waeli, A. H. A., Al-Mamari, A. S. A., Al-Kabi, A. H. K., Chaichan, M. T. (2015). A Photovoltaic Application in Car Parking Lights with Recycled Batteries: A Techno-Economic Study. Australian Journal of Basic and Applied Science, 9(36): 43-49.
[14]. Kazem, H. A., Al-Waeli, A. H., Chaichan, M. T., Al-Mamari, A. S., Al-Kabi, A. H. (2016).Design, Measurement and Evaluation of Photovoltaic Pumping System for Rural Areas in Oman, Environ Dev Sustain, DOI 10.1007/s10668-016-9773-z.
[15]. Chaichan, M. T., Kazem, H. A., Mahdy, A. M. J., Al-Waeely, A. A. (2016).Optimal Sizing of a Hybrid System of Renewable Energy for Lighting Street in Salalah-Oman using Homer Software. International Journal of Scientific Engineering and Applied Science (IJSEAS), 2(5): 157-164.
[16]. Chaichan, M. T., Kazem, H. A., Mahdy, A. M. J., Al-Waeely, A. A. (2016). Optimization of Hybrid Solar PV/ Diesel System for Powering Telecommunication Tower, IJESET, 8(6): 1-10.
[17]. Kazem, H. A., Chaichan, M. T., Alwaeli, A. H., Mani K. (2015). Effect of Shadow on the Performance of Solar Photovoltaic, WREN/WREC World Renewable Energy Congress, Rome, Italy.
[18]. Kazem, H. A., Chaichan, M. T. (2016). The Impact of using Solar Colored Filters to Cover the PV Panel on its Outcomes. Bulletin Journal, 2(7): 464-469, 2016. DOI: 10.21276/sb.2016.2.7.5.
[19]. Al-Waeli, A. H., Kazem, H. A., Chaichan, M. T. (2016). Review and Design of a Standalone PV System Performance. International Journal of Computation and Applied Sciences IJOCAAS, 1(1): 1-6.
[20]. Kazem, H. A.,Chaichan, M. T. (2016). Design and Analysis of Standalone Solar Cells in the Desert of Oman. Journal of Scientific and Engineering Research, 3(4): 62-72.
[21]. Darwish, Z. A., Kazem, H. A., Sopian, K., Alghoul, M. A. and Chaichan, M. T. (2013). Impact of Some Environmental Variables with Dust on Solar Photovoltaic (PV) Performance: Review and Research Status, International J of Energy and Environment, 7(4): 152-159, 2013.
[22]. Kazem, H. A., Chaichan, M. T.,Kazem, H. A. (2014). Effect of Dust on Photovoltaic Utilization in Iraq: Review Article. Renewable and Sustainable Energy Reviews, 37: 734-749.
[23]. Chaichan, M. T., Mohammed, B. A.,Kazem, H. A. (2015). Effect of Pollution and Cleaning on Photovoltaic Performance Based on Experimental Study. International Journal of Scientific and Engineering Research, 6(4): 594-601.
[24]. Chaichan, M. T., Kazem, H. A., Kazem, A. A., Abaas, K. I., Al-Asadi, K. A. H. (2015).The Effect of Environmental Conditions on Concentrated Solar System in Desertec Weathers. International Journal of Scientific and Engineering Research, 6(5): 850-856.
[25]. Kazem, H. A., Chaichan, M. T., Saif, S. A., Dawood, A. A., Salim, S. A., Rashid, A. A., Alwaeli, A. A. (2015).Experimental Investigation of Dust Type Effect on Photovoltaic Systems in North Region, Oman. International Journal of Scientific & Engineering Research, 6(7): 293-298.
[26]. Al-Waeli, A. H. A., Al-Mamari, A. S. A., Al-Kabi, A. H. K., Chaichan, M. T., Kazem, H. A. (2016).Evaluation of the Economic and Environmental Aspects of using Photovoltaic Water Pumping System.9th International Conference on Robotic, Vision, Signal Processing & Power Applications, Malaysia.

[27]. Kazem, H. A.,Chaichan, M. T. (2016). Experimental Effect of Dust Physical Properties on Photovoltaic Module in Northern Oman, Solar Energy, 139: 68–80.
[28]. Kazem, H. A., Yousif, J. H., Chaichan, M. T. (2016).Modeling of Daily Solar Energy System Prediction using Support Vector Machine for Oman. International Journal of Applied Engineering Research, 11(20): 10166-10172.
[29]. Chaichan, M. T., Kazem, H. A. (2017). Effect of Sand, Ash and Soil on Photovoltaic Performance: An Experimental Study. International Journal of Scientific Engineering and Science, 1(2): 27-32.
[30]. Kazem, H. A., Albadi, M. H., Al-Waeli, A. H. A., Al-Busaidi, A. H. and Chaichan, M. T. (2017). Techno-Economic Feasibility Analysis of 1 MW Photovoltaic Grid Connected System in Oman, Case Study of Thermal Engineering, 10: 131-141.
[31]. Al-Waeli, A. H. A., Kazem, H. A., Sopian, K.,Chaichan, M. T. (2017).Techno-Economical Assessment of Grid Connected PV/T Using Nanoparticles and Water as Base-Fluid Systems in Malaysia. International Journal of Sustainable Energy, 2017. DOI: 10.1080/14786451.2017.1323900
[32]. Al-Waeli, A. H. A., Sopian, K., Kazem, H. A., Chaichan, M. T. (2017). Photovoltaic Thermal PV/T Systems: A Review. International Journal of Computation and Applied Sciences IJOCAAS, 2(2): 62-67.
[33]. Chaichan, M. T. (2016). Spark Ignition Engine Performance Fueled with Hydrogen Enriched Liquefied Petroleum Gas (LPG). Scholars Bulletin Journal, 2(9): 537-546.
[34]. [34] Chaichan, M. T. (2016).EGR Effects on Hydrogen Engines Performance and Emissions. International Journal of Scientific & Engineering Research, 7(3): 80-90.
[35]. Chaichan, M. T., The Effects of Hydrogen Addition to Diesel Fuel on the Emitted Particulate Matters, International Journal of Scientific & Engineering Research, Volume 6, Issue 6, pp: 1081-1087, June-2015.
[36]. Chaichan, M. T. (2013). The Measurement of Laminar Burning Velocities and Markstein Numbers for Hydrogen Enriched Natural Gas. International Journal of Mechanical Engineering & Technology (IJMET), 4(6): 110-121.
[37]. Chaichan, M. T. (2013).Measurements of Laminar Burning Velocities and Markstein Length for LPG–Hydrogen–Air Mixtures. International Journal of Engineering Research and Development, 9(3):1-9.
[38]. Chaichan, M. T. (2012).Characterization of Lean Misfire Limits of Alternative Gaseous Fuels Used for Spark Ignition Engines.Tikrit Journal of Engineering Sciences, 19(1): 50-61.
[39]. Chaichan, M. T.,Abaas, K. I. (2010). Experimental Comparison of CO Emissions Emitted From Single Cylinder S I Engine Fueled with Different Kinds of Hydrocarbon Fuels and Hydrogen. Iraqi Journal for Mechanical and Material Eng., 10(3): 397-405.
[40]. Chaichan, M. T.,Saleh, A. M. (2010). Practical Investigation of Single Cylinder SI Engine Performance Operated with Various Hydrocarbon Fuels and Hydrogen. Al Mostaseria Journal for engineering and development, 14(2): 183-197.
[41]. Chaichan, M. T. (2010). Practical Measurements of Laminar Burning Velocities for Hydrogen-Air Mixtures using Thermocouples. Association of Arab Universities Journal of Engineering Science, 17(2): 20-31.
[42]. Chaichan, M. T.,Abaas, Q. A. (2010). Study of NOx Emissions of SI Engine Fueled with Different Kinds of Hydrocarbon Fuels and Hydrogen. Al Khwarizmi Eng. Journal, 6(2): 11-20.
[43]. Chaichan, M. T. (2010). Study of NOx and CO Emissions for SIE Fueled with Supplementary Hydrogen to Gasoline. Baghdad Engineering Collage Journal, 16(1): 4606-4617.
[44]. Chaichan, M. T. (2009). Study of Performance of SIE Fueled with Supplementary Hydrogen to LPG. Association of Arab Universities Journal of Engineering Science, 16(1): 125-145.
[45]. Chaichan, M. T. (2006). Study of Performance of SIE Fueled with Supplementary Hydrogen to Gasoline.Baghdad Engineering Collage Journal, 12(4): 983-996.
[46]. Salim, A. A.,Chaichan, M. T. (2004). Study of SIE Performance Fueled With Hydrogen, Sabha University Journal, 6(3):32-57.

[47]. Chaichan, M. T., Ali, N. M. (2016). Experimental Investigation of the Effect of Exhausts Gas Recirculation (EGR) On NOx-Smoke Trade-off for SIE Fueled With Blends of Gasoline/Bioethanol. Al-Rafidain Collage Journal, 39: 388-404.
[48]. Chaichan, M. T.,Abaas, K. I. (2012). Productivity Amelioration of Solar Water Distillator Linked With Salt Gradient Pond.Tikrit Journal of Engineering Sciences, 19(4): 24-34.
[49]. Chaichan, M. T., Abaas, K. I., Hatem, F. F. (2009). Experimental Study Of Water Heating Salt Gradient Solar Pond Performance in Iraq. Industrial Applications of Energy Systems (IAES09), Sohar University, Oman, 2009.
[50]. Chaichan, M. T. 92011).Practical Study of Basement Kind Effect on Solar Chimney Air Temperature in Baghdad-Iraq Weather. Al Khwarizmi Eng. Journal, 7(1): 30-38.
[51]. Ahmed, S. T., Chaichan, M. T. (2011).A Study of Free Convection in a Solar Chimney Sample. Engineering and Technology J, 29(14): 2986-2997.
[52]. Chaichan, M. T.&Abaas, K. I. (2012). Practical Investigation For Improving Concentrating Solar Power Stations Efficiency In Iraqi Weathers. Anbar J for Engineering Science, 5(1): 76-87.
[53]. Chaichan, M. T., Kazem, H. A., Kazem, A. A., Abaas, K. I., Al-Asadi, K. A. H. (2015) The Effect of Environmental Conditions on Concentrated Solar System in Desertec Weathers. International Journal of Scientific and Engineering Research, 6(5): 850-856.
[54]. Chaichan, M. T., Abass, K. I., Al-Zubaidi, D. S. M., Kazem, H. A. (2016). Practical Investigation Of Effectiveness of Direct Solar-Powered Air Heater. International Journal of Advanced Engineering, Management and Science (IJAEMS), 2(7):1047-1053.
[55]. Chaichan, M. T., Kazem, H. A. (2016).Energy Conservation and Management for Houses and Building in Oman-Case study. Saudi Journal of Engineering and Technology, 1(3): 69-76.
[56]. Chaichan, M. T., Abaas, K. I., Rasheed, M. A., Kazem, H. A. (2013).Using Paraffin Wax as a Thermal Storage Material in a Solar Air Heater.International Conference for Renewable Energies, UOT, Baghdad, Iraq, 2013.
[57]. Chaichan, M. T., Abass, K. I., Jawad, R. S., Mahdy, A. M. J. (2017). Thermal Performance Enhancement of Simple Trombe Wall. International Journal of Computation and Applied Sciences IJOCAAS, 2(1): 33-40.
[58]. Chaichan, M. T., Abaas, K. I., Al-Zubaidi, D. S. M. (2016).A Study of a Hybrid Solar Heat Storage Wall (Trombe Wall) Utilizing Paraffin Wax and Water. Journal of Research in Mechanical Engineering, 2(11): 1-7.
[59]. Faris, S. S., Chaichan, M. T., Sachit, M. F., Jaleel, J. M. (2014). Simulation and Numerical Investigation of Effect Air Gap Thickness on Trombe Wall System. International Journal of Application or Innovation in Engineering & Management (IJAIEM), 3(11): 159-168.
[60]. Chaichan, M. T., Abaas, K.I. (2015).Performance Amelioration of a Trombe Wall by using Phase Change Material (PCM). International Advanced Research Journal in Science, Engineering and Technology, 2(4): 1-6.
[61]. Chaichan, M. T., Kamel, S. H., Al-Ajeely, A. N. M. (2015). Thermal Conductivity Enhancement by using Nano-Material in Phase Change Material for Latent Heat Thermal Energy Storage Systems, SAUSSUREA, 5(6): 48-55.
[62]. Chaichan, M. T., Al-Hamdani, A. H., Kasem, A. M. (2016). Enhancing a Trombe Wall Charging and Discharging Processes by Adding Nano-Al2O3 to Phase Change Materials. International Journal of Scientific & Engineering Research, 7(3): 736-741.
[63]. Chaichan, M. T.,Kazem, H. A. (2015). Water Solar Distiller Productivity Enhancement Using Concentrating Solar Water Heater and Phase Change Material (PCM). Case Studies in Thermal Engineering, Elsevier, 5: 151-159, 2015.
[64]. Chaichan, M. T., Abaas, K. I., Kazem, H. A. (2016).Design and Assessment of Solar Concentrator Distillating System using Phase Change Materials (PCM) Suitable for Desertec Weathers. Desalination and Water Treatment, 57(32): 14897-14907. DOI: 10.1080/19443994.2015.1069221

[65]. Chaichan, M. T., Kazem, H. A., Abaas, K. I., Al- Waeli, A. A. (2016). Homemade Solar Desalination System for Omani families. International Journal of Scientific & Engineering Research, 7(5):1499-1504.

[66]. Gawaad, R. S., Sharma, S. K., Sambi, S. S. (2011). Comparative study of Nano and RO membrane for Sodium Sulphate Recovery from Industrial Waste Water. ARPN Journal of engineering and applied Sciences, 6: 114-119.

[67]. Jawad, R. S., Abduljabar, S. N. (2016). Nanofiltration Means (Reduced in Pollution, Water Consumption, and Win Money. International Journal of Computation and Applied Sciences IJOCAAS, 1(3): 21-25.

[68]. Jawad, R. S., Chaichan, M. T., Kadhum, J. A. (2016). Nanoparticles (Nps) Leverage in Lithium-Ion Batteries Performance. International Journal of Pharmacy & Technology, 8(3): 18995-19004.