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Naturel Punica granatum L and Beta vulgaris Dyes in Luminescent Solar Cells

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ABSTRACT
The illuminated solar concentrator (LSC) was fabricated consisting of a cube-shaped trough containing four silicon solar cells, with a total conversion efficiency of (**η** = 0.892) . Dyes extracted from natural plants (Punica granatum L and Beta vulgaris) were used to increasing fluorescence, where an increase (Δη =13.7%) was observed over the previous conversion efficiency, and when mixing these dyes in different proportions (75% dye with 25% ZnO nanoparticles and 50% dye with 50% ZnO nanoparticles), it was found that there is a clear and significant increase in the conversion efficiency, becoming by (Δη =165.3%) for nanomaterials (75%) and by (Δη =171.9%) that for nanomaterials (50%).

INTRODUCTION
One of the main problems facing civilization today is the availability of sustainable energy supplies for an expanding and increasingly productive globe. In order to fulfill this issue, Renewable Energy looks at the practical and financial potential of renewable energy sources. Within the context of their environmental impacts, economics, and future prospects, the underlying physical and technological principles of power generation from direct solar (solar thermal and photovoltaics), indirect solar (biomass, hydro, wind, and wave), and non-solar (tidal and geothermal) energy sources are explained. [1] Since the sun is a pure source of energy, it is frequently used to produce electricity worldwide. The two primary technologies for converting solar energy into electricity through the photo-electric effect are photovoltaics (PV) and solar thermal generators [2]. Figure (1) shows the Luminescent Solar ConcentratorWhich is one way to increase the conversion efficiency of the solar cell .

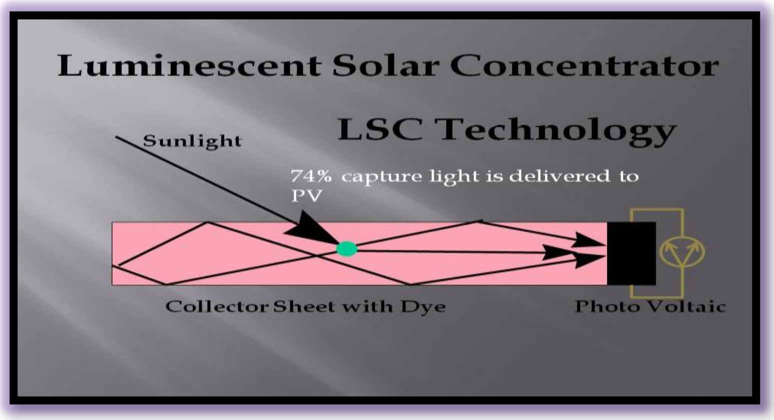

Figure 1:Luminescent Solar Concentrator [3].

The difference in wavelength or frequency units between the positions of the large absorbance and emission spectra of the identical electronic transitions is known as the Stokes shift. The oscillatory relaxation or attenuation in the solvent rearrangement causes the Stokes shift. [4, 5, 6]. Figure (2) shows the shift (Stokes shift) between the absorbance spectrum and the emission spectrum fluorescence. .

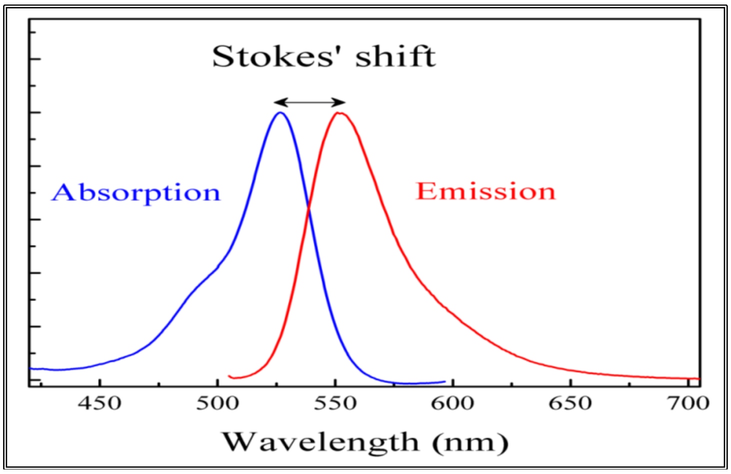

Figure Error! No text of specified style in document.**:**Stokes shift and overlap of the absorbance and fluorescence spectra [7].

The greater the overlap area between the absorption and fluorescence curves, the greater the losses, because the emitted photon will be re-absorbed again and will not reach the solar cell placed at the edges LSC . Therefore, materials with little overlap between the absorption curve and the fluorescence curve are preferred.

Solar Cell Efficiency (η)

The efficiency of a solar cell is defined as its electrical output power at its maximum current-voltage power divided by its input power [8].

$$\eta = \frac{V_{max} I_{max}}{P_{in}} = \frac{P_{max}}{P_{in}} = \frac{V_{oc} I_{sc}}{P_{in}} FF$$

Fill Factor (*FF*)

The sharpness of the current-voltage knee in the solar cell is measured by the filling factor. It is known as the curve factor, and it illustrates how successfully the series resistance and connection of the PV cell were built [9,10]

$$FF = \frac{V_{max} I_{max}}{V_{oc} I_{sc}} = \frac{P_{max}}{V_{oc} I_{sc}}$$

Fluorescence

Fluorescence is the phenomenon of an excited electron moving to a high level and then returning to a low level with the emission of photon. Radiative lifetime (τ_{FM}), which is defined as the inverted radiation transition possibility (K_{FM}) in unit (sec^{-1}), is the length of time required for a radiative transition to occur from a lower vibrational level to an excited electronic state, then to a ground vibrational level, and finally back to its initial state. [11]

$$\tau_{FM} = \frac{1}{K_{FM}}$$

Absorbance

The absorbance (A), also known as optical density, its a mathematical concept that describes the connection between the density of particles (concentration) in a sample and its thickness (length of the optical route) [12].

$A = \log(I_o/I)$

I: is the intensity of light transmitted sample (penetrated light intensity).

I_o: is the intensity of the incident light beam [13].

Photovoltaic (PV) Cells

The semiconductor absorbs optical photons with energies greater than the energy gap. Each photon creates an electron hole, and these two quickly combine to convert the energy into heat. With the barrier area, the hole is routed to the other outer conductor in the (p) area while the electron produced by photon absorbance flows to the outer conductor in the (n) area. These electrons build up on both ends and produce voltage, which causes an electric current to flow[14].

Experimental Part

The plants used in this study were ground into powder [15] to make dyes (Punica granatum L and Beta vulgaris), which were then combined with zinc oxide (znO) nanoparticles after dissolving a certain amount in ethanol using a concentration law.

FINDINGS AND DISCUSSION

Results obtained by measuring the fluorescence and absorbance spectrum of the dyes (Punica granatum L and Beta vulgaris) with zinc oxide (ZnO) nanoparticles divided in to two parts:

1-The Absorbance and Fluorescence spectraof the Punica granatum LDye in Ethanol

Three phases were used to study the Punica granatum L dye's absorption and fluorescence spectra: the Punica granatum L dye alone, the Punica granatum L dye mixed with 75% dye and 25% ZnO nanoparticles, and the Punica granatum L dye mixed with 50% ZnO nanoparticles. The absorbance and fluorescence spectrum illustrated in figs (4 – 6).

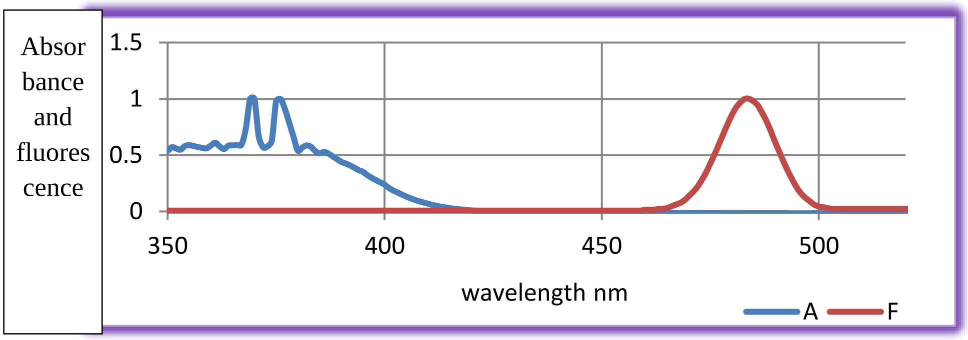

Figure4: Absorbance and fluorescence spectra For Punica granatum Ldye only.

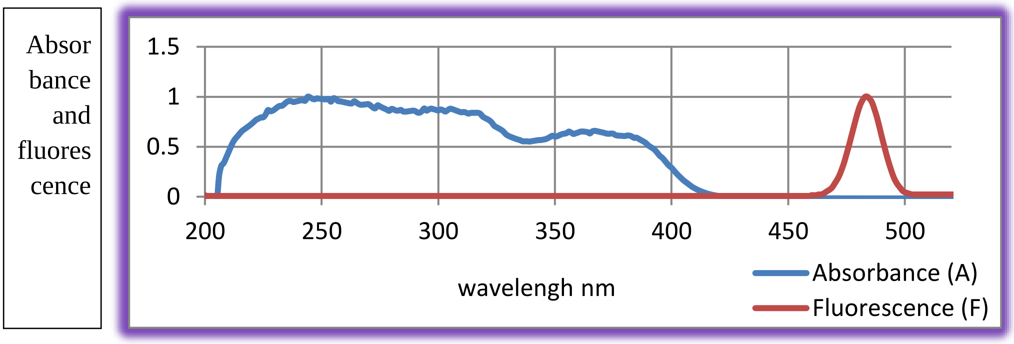

Figure 5: Absorbance and fluorescence spectra For 75% Punica granatum L dye with 25% Zno

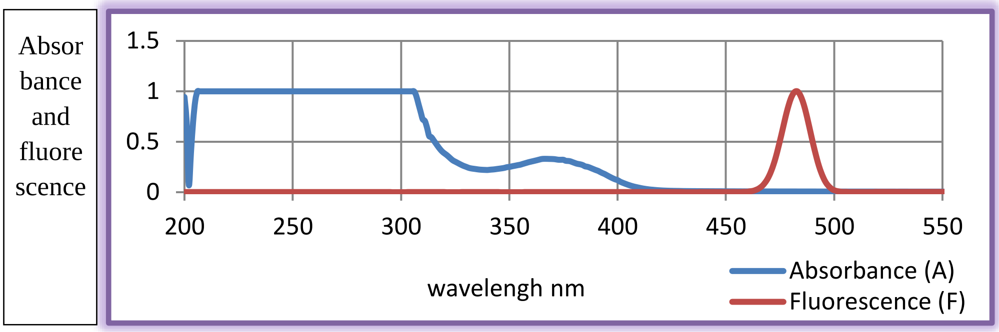

Figure 6: Absorbance and fluorescence spectra For 50% Punica granatum L dye with 50% Zno

Figure (7) shows the analysis of the relationship between wave number (k) and molar absorption coefficient (ε), and they were used to calculate the non-radiative lifetime (τ_{fm}), fluorescence lifetime (τ_f), as well as calculate the area under the curve for three different phases: Punica granatum L dye alone, Punica granatum L 75% dye with 25% ZnO nanoparticles, 50% Punica granatum L dye With 50% ZnO nanoparticles.

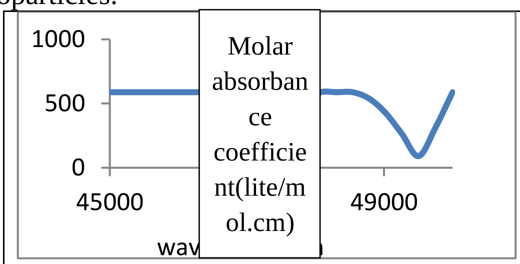

Figure 7 - A : (Punica granatum L dye only)

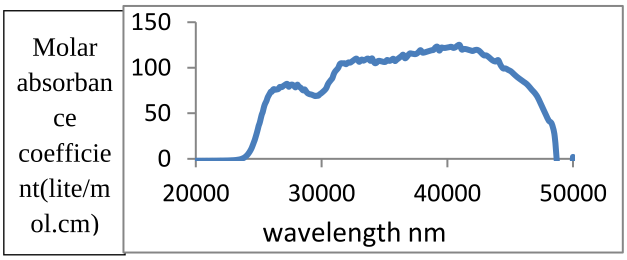

Figure 7- B: (75% Punica granatum L dye with 25% Zno)

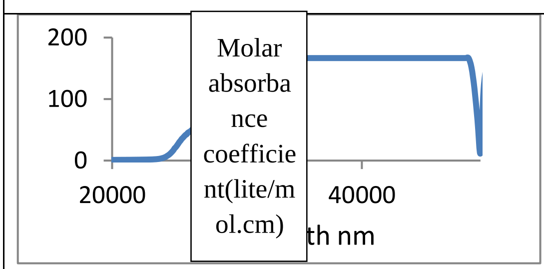

Figure7-C : (50% Punica granatum Ldye with 50% Zno)

Table (1) shows the wavelength of the greatest absorption(λ_{Amax}) and Fluorescence(λ_{Fmax}) , as well as the quantitative effectiveness of the Punica granatum L dye with and without zno nanoparticles.

samples (mol/L)	nax	nax	kes Shift λ_{flo}-λ_{abs}	radiated time n sec	fluorescence time n sec	ntum ciency%
y Dye				74.77	94.57	27
6 dye+25%zno				9.278	7.565	28
6 dye+50%zno				54.17	27.68	27

2-The Absorbance and Fluorescencespectra of theBeta vulgaris Dye in Ethanol

Three phases were used to study the absorption and fluorescence spectra of the Beta vulgaris tincture: the tincture of Beta vulgaris alone, the tincture of Beta vulgaris mixed 75% dye with 25% of ZnO nanoparticles, and the tincture of Beta vulgaris mixed with 50% of zinc nanoparticles with 50% dye in the final stagefig (8-10).show the Absorbance and fluorescence spectra of this three phase .

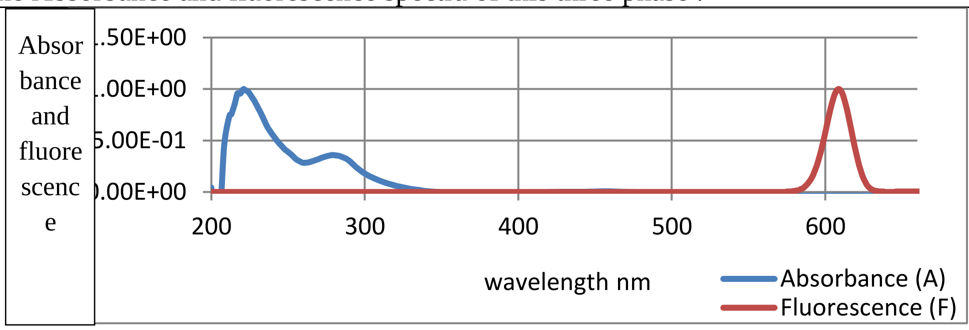

Figure 8: Absorbance and fluorescence spectra For Beta vulgarisdye only.

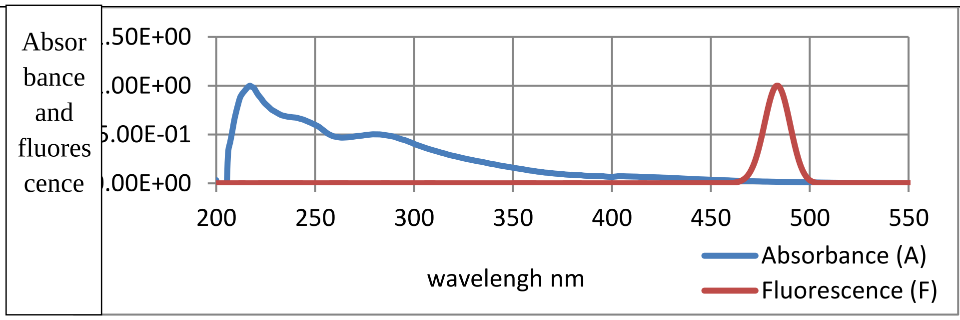

Figure 9: Absorbance and fluorescence spectra For 75% Beta vulgarisdye with 25% Zno

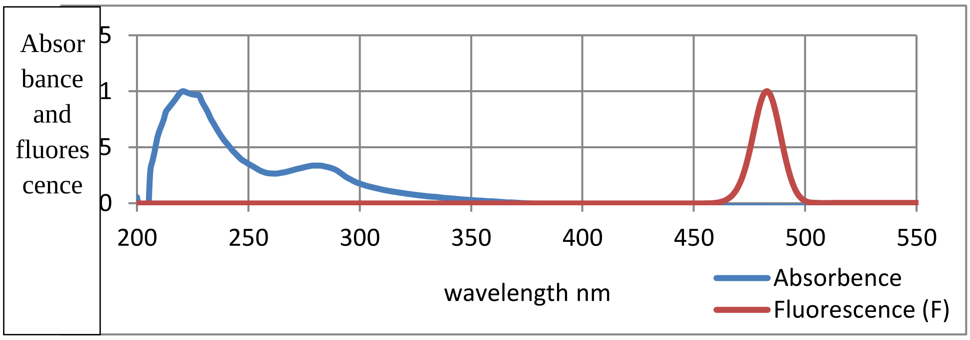

Figure 10: Absorbance and fluorescence spectra For 50% Beta vulgarisdye with 50% Zno

Figure (11) shows the analysis of the relationship between wave number (k) and molar absorption coefficient (ε), and they were used to calculate the non-radiative lifetime (τ_{fm}), fluorescence lifetime (τ_f), as well as calculate the area under the curve for three different phases: Beta vulgaris dye alone, Beta vulgaris 75% dye with 25% ZnO nanoparticles, 50% Beta vulgaris dye With 50% ZnO nanoparticles.

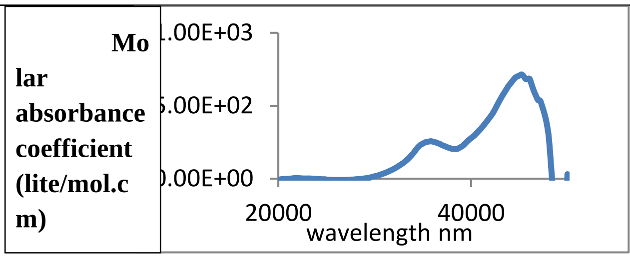

Figure 11 - A : (Beta vulgarisdye only)

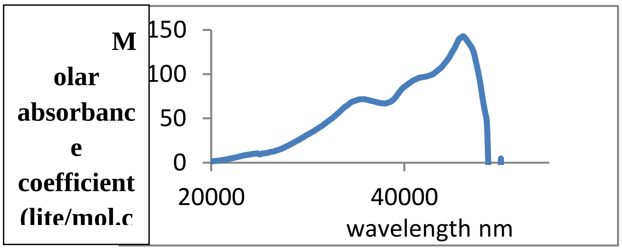

Figure11- B : (75% Beta vulgarisdye with 25% Zno)

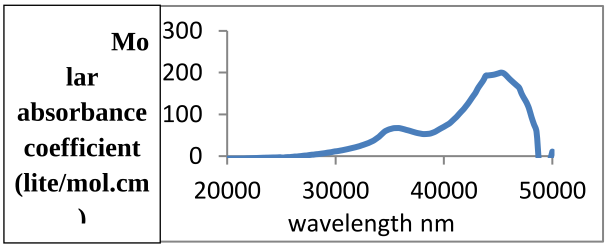

Figure 11- C : (50% Beta vulgarisdye with 50% Zno).

Table (2) shows the wavelength of the greatest absorption(λ_{Amax})andfluorescence(λ_{Fmax}), as well as the quantitative effectiveness of the Beta vulgaris dye with and without zno nanoparticles.

The samples (mol/L)	λ_{Amax} (nm)	F_{max} (nm)	kes Shift $=\lambda_{flo}-\lambda_{abs}$ (nm)	e radiated Life time τ_{fm} n sec	e fluorescence Life time τ_f n sec	The quantum efficiency% Q_{fm}
Only dye	221	609	388	3888.23	3549.177	0.9128
75% dye+25%zno	217	484	267	8747.216	7984.459	0.9128
50% dye+50%zno	221	483	262	13426.13	12255.37	0.9127

Table (3) It shows that the efficiency of the solar cells before applying the material dye solution is (0.892%), which is the efficiency of the pure solar cell, and also shows all the solar cell coefficients (I_{max}, V_{max}, FF, η).

Table 3: Efficiency evaluation of pure solar cells.

The samples (mol/L)	I_{max} (mA)	V_{max} (volt)	FF	%η

Single cell	329.9	0.422	0.764	0.892

Table4: Solar cell efficiency (η) by using (LSC) panels of Punica granatum L dye.

The samples (mol/L)	I_{max} (mA)	V_{max} (volt)	FF	η%	Δη%
Only dye	327.3	0.453	0.793	0.950	6.5
75% dye+25%zno	672.7	0.506	0.693	2.181	139.4
50% dye+50%zno	750.4	0.515	0.824	2.477	171.9

Table 5: Solar cell efficiency (η) by using (LSC) panels of Beta vulgarisdye.

The samples (mol/L)	I_{max} (mA)	V_{max} (volt)	FF	η%	Δη%
Only dye	332.2	0.477	0.717	1.015	13.7
75% dye +25%zno	735.1	0.513	0.708	2.417	165.3
50% dye+50%zno	734.8	0.521	0.845	2.454	169.4

Through Table (5,4), It is evident from the readings confirmed by the table that when mixing the zinc oxide nanoparticles with the dyes, we obtain an increase in the solar cell efficiency (η) compared to the efficiency of the solar cells before addition.The addition of nanoparticles ZnO molecules, which operate to scattering the light beams that incident on the LSC, is the cause of the solar cell's increased efficiency. The latter scattering would be the end consequence, directing the photons of the incident ray to the solar cell that is fixed in all directions of the LSC. In contrast to the situation where no LSC is used, a substantial amount of photons then enter the solar cell.

Conclusions

1. Natural dyes improved the efficiency of the solar cells to varying degrees, but beta vulgaris had the highest efficiency (η = 1.015%).
2. Solar cell efficiency was improved by dyes (Punica granatum L and Beta vulgaris) and zinc oxide nanoparticles upon mixing (75% dye Beta vulgaris with 25% ZnO), but the sample with the highest efficiency was 75% Beta vulgaris with 25% ZnO (η = 2.417%).
3. these dyes mixed with zinc oxide nanoparticles (50% dye with 50% ZnO) enhanced the solar cell efficiency, but the sample containing (50% Punica granatum L with 50% ZnO) was the best (η= 2.477%).
4. The best efficiency of the solar cell was (η = 2.477%) for the mixture (75% Punica granatum L+ 25% ZNO).

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