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Theoretical study of Linke's Turbidity at Some Iraqi Sites Based on Solar Radiation

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ABSTRACT

Turbidity was calculated by solar irradiance (Linke's Turbidity) for sixteen Iraqi sites. These sites were distributed among middle, north and south of Iraq. We have updated these results of turbidity by depending on direct solar radiation, diffuse solar radiation, total solar radiation, and solar constant as inputs for mathematical models in computer programs. The latter calculations taking into account the hours of actual sun shine, hours of theoretical sun shine of the sun, the angle of the sun's rays, and the angle of the sun during the months of the year.

The results showed that turbidity in the Iraqi sites which considered in this research depends mainly on the months of the year regardless of the fact that this site is located in the north, middle or south of Iraq. The amount of turbidity is at its greatest value during the winter season, specifically the month of December, where the average turbidity varied for those sites. In latter month the turbidity was ranged from (4.85 to 5.73), while in January it ranged from (4.75 to 5.72), then it began to decrease until the value of turbidity in most sites reached its lowest level in September, where the average turbidity of the studied sites varied (except for the site of Najaf) in this month (2.82 - 3.10) While the Najaf site was unique in registering the lowest average amount of turbidity in June by (3.25). The results showed that the turbidity in all sites included in this research ranges between (2.82 - 5.73) during the year.

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دراسة نظرية لعكورة لينك لبعض المواقع العراقية اعتمادا على الاشعاع الشمسي

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الــــخُــلاصـــة

حسبت العكورة بوساطة الإشعاع الشمسي (عكورة لينيك) لـ ستة عشر موقعاً عراقياً توزعت هذه المواقع بين الشمال والوسط والجنوب وقد تحصلنا على هذه النتائج بالاعتماد على الإشعاع الشمسي المباشر والإشعاع الشمسي المنتشر والإشعاع الشمسي الكلي و الثابت الشمسي كمدخلات لنماذج رياضية في برامج حاسوبية . أخذين بنظر الاعتبار ساعات السطوع الفعلي وساعات السطوع النظري للشمس وزاوية سقوط أشعة الشمس وزاوية ارتفاع الشمس خلال أشهر السنة.

بينت النتائج ان العكورة في المواقع العراقية التي أجري عليها البحث تعتمد بشكل اساسي على اشهر السنة بغض النظر عن كون هذه الموقع يقع في شمال او وسط او جنوب العراق فمقدار العكورة تكون في قيمته العظمى خلال فصل الشتاء وبالتحديد شهر كانون الاول حيث تراوح متوسط العكورة لتلك المواقع في هذا الشهر (*4.85 – 5.73*) ثم كانون الثاني (*4.75 – 5.72*) و تبدأ بالتناقص الى ان تصل قيمة العكورة في معظم المواقع في ادنى مستوياتها في شهر ايلول حيث تراوح متوسط العكورة للمواقع المدروسة عدا موقع النجف في هذا الشهر (*2.82 – 3.10*) فيما أنفرد موقع النجف بتسجيله لأقل مقدار لمتوسط العكورة في شهر حزيران بمقدار (*3.25*) . وبينت النتائج ان مقدار العكورة في كافة المواقع المشمولة في هذه البحث تتراوح بين (*2.82 - 5.73*) خلال السنة.

الكلمات المفتاحية:

الإشعاع الشمسي
الإشعاع الشمسي المباشر
الإشعاع الشمسي المنتشر
الإشعاع الشمسي الكلي
العكورة
عكورة لينك

1. INTRODUCTION

During the last ten years, I conducted many researches on the subject of turbidity and solar radiation. One of the most prominent of these was:

Sahib. N. Abdul Wahid and Hassan Abbas Judeh [1]: It has relied on the solar radiation as a basic input for mathematical models to find turbidity for 16 Iraqi cities during 30 years, They were found that the amount of turbidity ranges between 4.27 - 4.75, there was a slight difference in the amount of turbidity from one location to another and that its average value varies from north to south.

Sahib Neamh Abdel Wahid and others [2]: In this work they have the use of hours of sun shin and solar radiation in the inputs of different mathematical models for the period from 1961 to 1991 AD and for different regions of Iraq it was found that the maximum values of diffuse radiation are in the summer while the minimum values of dispersed radiation are during December and January.

Rasool.R. Attab[3]: This study included mathematical methods to calculate the amount of total solar radiation falling on the horizontal surface of the unit area of the city of Nasiriyah. It has been proved that the angle of solar radiation fall as well as weather factors that influence the amount of measured radiation.

Walid Asmeer Al-Raghu and Shaimah Hussein Rasool [4]: In this paper, they developed a mathematical model to estimate total solar radiation falling on the horizontal surface as a function of both relative humidity, average temperature and sun shin ratio. The year for 17 Iraqi sites.

Alah Rahim Muhammad Jawad Al-Shimarti [5]: The study showed that the electric energy generated by solar radiation in the cities of Iraq varies according to the geographical location, where the largest amount of energy generated by solar radiation was recorded in the holy city of Najaf and the lowest amount in Mosul.

Ali Mahdi Al-Dujaili and others [6]: In this research a comparison has been made between the amount of electric energy generation by solar radiation across different regions of Iraq and it has been found that there is a variation in the amount of electric energy generated time and place according to the difference in the angles of solar radiation fall and the actual hours of sun shin and the clarity of the air.

Fayad Abdul-Dulaimi and Ghazi Yusef Muhammad [7]: The aim of the study was to find a correlation between solar radiation and temperature with weather conditions and relative humidity. Measurements were made during the days of the year and different hours of the day. It was found that the data change from 4% to 5 % of the minimum and maximum levels due to the different weather conditions for the location in which the study was conducted.

Thaer Hussein Muhammad [8]: In this thesis a hundred dust storms were studied and analyzed in the city of Baghdad from 2008 to 2012. It appeared that these storms affected solar radiation where it was found that the maximum decrease of solar radiation was during the period between April and September. This it is proportional to the frequency of dust storms in this period.

Muhannad Hussein Khidr [9]: This thesis Considered 18 Iraqi sites during 2008 to study the effect of dust phenomena on solar radiation, where the daily rate of solar energy lost due to dust reached 33.39% to 71.25% during the period between April and September.

Nahla Mohamed Jassim Al-Tamimi [10] can predict the values of solar radiation in areas where there are no devices to measure it, depending on either Mathematical model by applying mathematical equations whose inputs are derived from climatic elements or the use of an angstrom equation or Computer model is represented by the Cropwat program which is a computer program for calculating solar radiation through inputs such as temperature, humidity and wind speed ...

Oras Ghani Abdul Hussein Al-Yasiri and Badr Jadoua Ahmed Al-Ma'mouri [11]: In this research it was proved that the atmosphere of Iraq is characterized by a large number of sunny hours during all months of the year, including winter, as well as the ease of installing solar energy systems, which means that the option of solar radiation is the first option for alternative energy in Iraq.

Oras Ghani Abdul Hussein Al-Yasiri [12]: This study came to link dust between storms and total solar radiation that reaches the central and southern regions of Iraq. The results have shown that the values of total solar radiation and dust storms in these regions have increased.

This research aims to verify the relationship between the turbidity of the atmosphere and the amount of solar radiation arriving to Earth in different Iraqi locations geographically and how solar power plant constructors can avoid areas known as seasonal dust storms because of their negative impact on the amount of solar radiation energy reaching stations.

2. The theoretical part:

Renewable energy sources in the world are extremely important because they are non-acceptable and can be produced at the lowest economic cost and are available in most regions and do not cause any health or environmental problems. Solar energy is one of the most important sources of renewable energy and Iraq's atmosphere is an ideal atmosphere for investment the energy in solar radiation is that it has more than 3000 hours of brightness during one year, with an average radiation of 5 Kw.h per m^2.

There are many factors that affect the value of solar radiation reached from the sun to the earth and the turbidity of the atmosphere is one of these factors. It cause a decrease in the transparency of the air due to aerosols. Aerosols are solid particles or moist particles present in the gas atmosphere, since air turbidity is considered as a measure of the value of total aerosols in the air.

The angle of the sun's rays falling (δ) between the plane of the equator and the line connecting the center of the earth to the center of the sun can be calculated as follows:[14]

$$\delta = 23.45 \, \mathrm{Sin}\,(360\,(284 + J) / 365) \quad ... (1)$$

The value of (J) is the order of the day of the year as shown in Table (1) [13].

Table (1). The values of (J)

The month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Day's order of the year	17	47	75	105	135	162	198	228	258	288	318	344

The value of dr, which is the inverse of the distance between the Earth and the sun during the year, and its value is variable according to the change in the value of (J) [16].

$$dr = 1 + 0.033 \text{ Cos } (2\pi / 365 \text{ J}) \quad \ldots (2)$$

To calculate the amount (Cos θ) and then the value (θ)

Where θ is the angle of the solar fall, and it represents the angle between the solar beam falling on the surface of the site and the vertical erected on that surface, which is variable during the day

ⓐThe rotation of the Earth around itself, causing the site to change.
ⓑThe rotation of the earth around the sun, which causes a relative change in the location of the sun, i.e. changes in the days of the year to a specific location.
ⓒThe timing during the day, that is, the time change from sunrise to sunset for a specific location and for a specific day.

So the angle (θ) [17] can be calculated.

$$\text{Cos } \theta = \text{Cos } \Phi \text{ Cos } \delta \text{ Cos } \omega + \text{Sin } \Phi \text{ Sin } \delta \ldots (3)$$

Where Φ is the latitude angle.
δ angle of inclination of sunlight. Defined in equation (1).
ω is the hour angle or time angle [15]

$$\omega = 15 (12 - h) \ldots (4)$$

The time was taken at (12 PM), then the value of ω = 15 (12 - 12) = 0 the value of Cos ω = 1

so that (Cos θ = Cos Φ Cos δ + Sin Φ Sin δ), then the value of the angle (θ) can found by

$$\theta = \text{Cos}^{-1} (\text{Cos } \Phi \text{ Cos } \delta + \text{Sin } \Phi \text{ Sin } \delta)$$

To find the value of this angle in radian degrees, one can use:

Degree = 2π /360 or π /180

To find the air mass (m) which is the length of the solar pathway in the atmosphere of the Earth can be obtained by the following equation [3].

$$m = 1 / \text{Cos } \theta + 0.15 (93.885 - \theta)^{-1.253} \quad \ldots (5)$$

To find the coefficient of clearness Kr, the average of attenuation of solar radiation for all the distance traveled by this effect by the effect of the particles of the medium passing through it [1]

$$Kr = 6.6296 + 1.7513m - 0.1202m^2 + 0.006m^3 - 0.00013m^4 \quad \ldots (6)$$

We find the amount of direct solar radiation, R_d , and it represents the amount of radiation incident on the unit area of a surface that is perpendicular to the radiation coming directly from the sun [16].

$$R_d = (R_G - R_{diffuse}) \times 11.574 \quad \ldots (7)$$

R_G is global solar radiation. It refers to the total solar radiation that reaches a certain point on the surface of the earth. It includes direct solar radiation and diffuse solar radiation.

$R_{diffuse}$ Diffused solar radiation, and represents the amount of solar radiation falling on the unit area of a surface indirectly from the sun. Rather, it is diffused due to molecules and atoms in the atmosphere. Four models have been developed. Mathematical [2].

Finding Linke's Turbidity T_L [2].

$$T_L = \left(\frac{-1}{Kr\ m} \ \ Ln \frac{Rd}{1367\ dr} \right) \qquad \ldots(8)$$

We used several mathematical models and data we obtained from the weather station and were applied to sixteen Iraqi sites, according to Table(2)[1].

Table (2): The values of Latitudes

The sequence	Site	Site code	Latitude
1	Basra	61001	30.51^0
2	Hai	5201	32.13^0
3	Diwaniya	58001	31.95^0
4	Rutbah	31011	33.03^0
5	Sulaimaniya	46001	35.53^0
6	Samaua	66001	31.26^0
7	Amara	62001	31.83^0
8	Mosul	41001	36.31^0
9	Nasiriyah	64001	30.01^0
10	Najaf	54001	31.95^0
11	Baghdad	10001	33.3^0
12	Haditha	31004	34.13^0
13	Khanoqin	32007	34.35^0
14	Zakho	42002	37.13^0
15	Karbala	42002	32.56^0
16	Kirkuk	36001	35.46^0

3. RESULTS

Different values of the direct solar radiation appeared at the same site and at the same time because four different models of diffuse solar radiation were taken. Therefore different values of turbidity appeared and the average values of turbidity were found for each site during the months of the year.

Through the resulting graphs showing the relationship between the turbidity and the months of the year for 16 Iraqi sites, the following results were obtained:

Figure (1) represents turbidity for Basra site (61001). From the figure, it becomes clear that the turbidity is at its highest during the winter season, specifically in the month of December, where the average turbidity in this month was(4.85), while the turbidity is the lowest in September and the average turbidity in this month was(3.07) and the turbidity is starting from the month of March Until October due to similar weather conditions that affect the amount of turbidity during this period.

Figure (2) represents the location of Hai (5201). The largest amount of turbidity in December was (5.03) while during the spring and summer seasons it was low, while the lowest amount of turbidity in September was(3.06).

Figure (3) represents Diwaniya's site (58001). The largest average amount of turbidity in December was(5.07) and gradually begins to decrease until the lowest average size of turbidity in September is(3.08).

Figure (4) location of Rutbah (31011) . Accordingly, the largest amount of turbidity in December was (5.08) while the lowest value was for turbidity in December (3.01). It is indicated through the graph that there is a variation in turbidity models especially in the spring and summer seasons due to the geographical location of the Rutbah located in the western plateau and the changing weather conditions.

Figure (5) represents location of Sulaimaniya (46001) turbidity will be large starting from the month of November (4.9), then December (5.26) and January (5.28), as Sulaimaniya is located in northern Iraq, and this period is mostly cloudy and after that, the turbidity decreases until it reaches its lowest amount in September (2.95).

Figure (6) represents location of Samaua (66001) Because it is located in a desert region, the weather will be unstable, which causes the variation of solar radiation. In one of the computational models, a jump in the amount of turbidity has been recorded, reaching (6.30)in a month. December while the lowest rate of turbidity was recorded in the month of September at(2.83), which is a low value.

Figure (7) represents site of Amara (62001). The highest rate of turbidity was recorded in January was (5.05), while the lowest rate of turbidity was recorded in Iraq during a full year, at (2.285)in September.

Figure (8) represents location of Mosul (41001), the greatest turbidity rate in January was (5.72) and then it started to decrease gradually until it reached (2.92), which is the lowest amount of turbidity on this site during the month of September.

Figure (9) represents site of Nasiriyah (64001), it differs from the rest of the sites recorded for the highest rate of turbidity, where the highest rate of turbidity was recorded in the month of October by (5.00) and this is due to the large number of dust storms during this month, which increases the amount of turbidity, while the month of September recorded the lowest headquarters for the turbidity rate of(3.19).

Figure (10) represents site of Najaf (54001), the highest rate of turbidity was recorded during the month of December(5.04), while this site was unique by recording the lowest rate of turbidity in June of (3.25). This is clearly different from the rest of the sites recorded during the month of September, as Najaf is located in the outskirts of the Plateau .

Figure (11) represents Baghdad site (10001). In which the turbidity in the spring and summer seasons is close to the presence of a green belt that reduces the effects of dust storms that are active in Iraq during these two seasons, while the turbidity is greatest in the winter and the lowest amount of turbidity was recorded in September(3.01).

Figure (12) represents Haditha site (31004). From this latter figure, there is a discrepancy between the mathematical models during the same time period and this is due to the extreme desert geographical location. The highest amount of turbidity was recorded in December (5.24), while the lowest turbidity was (3.02) in September.

Figure (13) represents Khanoqin site (32007). According to this figure, the highest turbidity rate was recorded during the month of December then January and begins to decrease until it reaches the lowest amount of turbidity in September(3.10) .

Figure (14) represents Zakho site (42002). According to this figure, the highest average amount of turbidity in Iraq during the year was recorded on this site in December (5.73), while the lowest average turbidity in this site during September was(2.96).

Figure (15) represents Karbala site (42002). According to this figure, the turbidity is at a certain level during the spring season. Turbidity decreases and is at a lesser level during the summer until the turbidity rate reaches its lowest level in the month of September(3.05), then turbidity begins to increase until the value of its average value reaches the highest amount in (5.09) in December.

Figure (16) represents location of Kirkuk (36001). According to this figure, the lowest value of turbidity in the month of September is (3.00), which starts to increase significantly until the value of the highest turbidity rate in December reaches (5.65) after which it begins to decrease gradually.

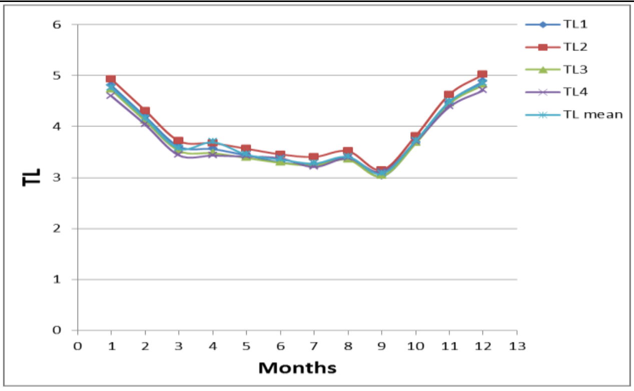

Figure (1): the amount of turbidity during the months of the year for the Basrah site

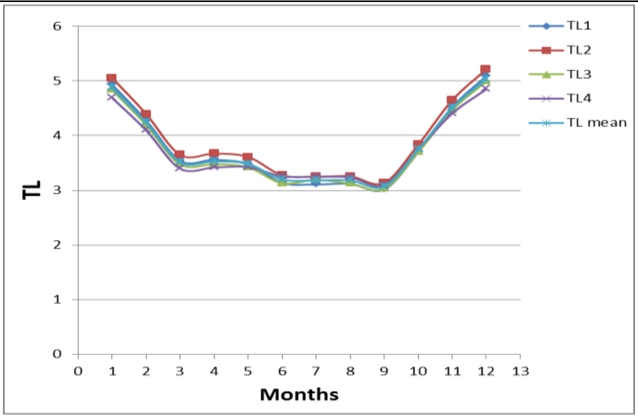

Figure (2): the amount of turbidity during the months of the year for the Hai site

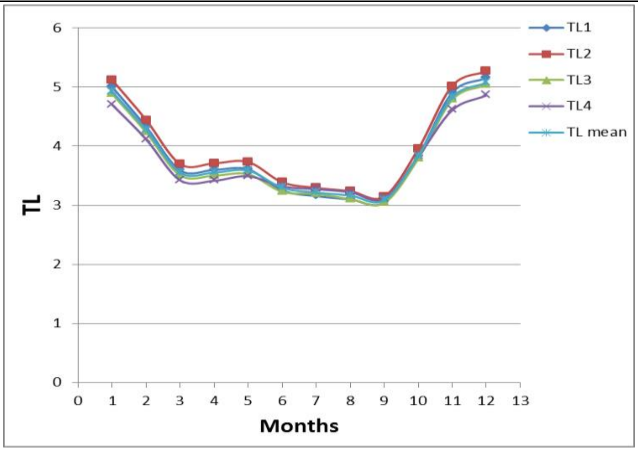

Figure (3): the amount of turbidity during the months of the year for the Diwaniyah site

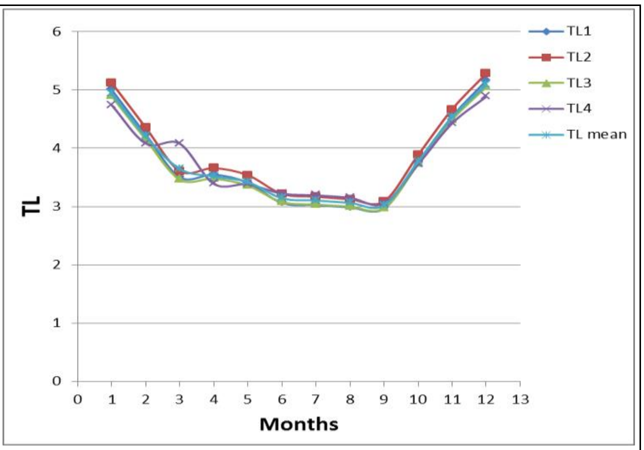

Figure (4): the amount of turbidity during the months of the year for the Rutbah site

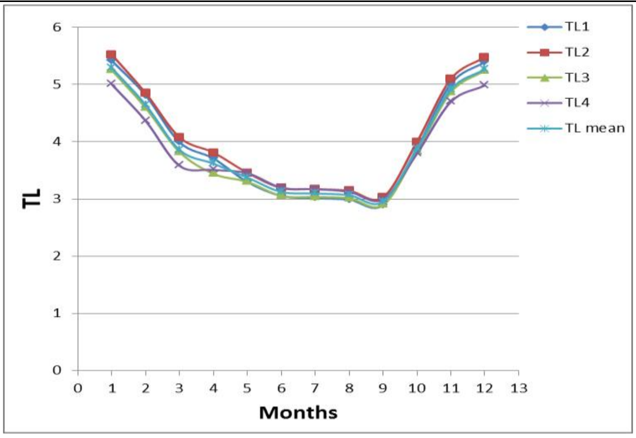

Figure (5): the amount of turbidity during the months of the year for the Sulaimaniya site

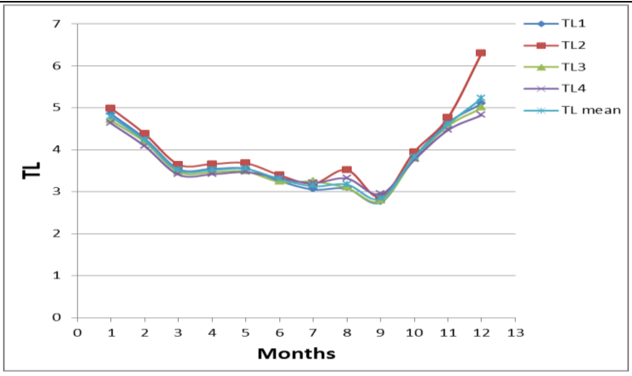

Figure (6): the amount of turbidity during the months of the year for the Samaua site

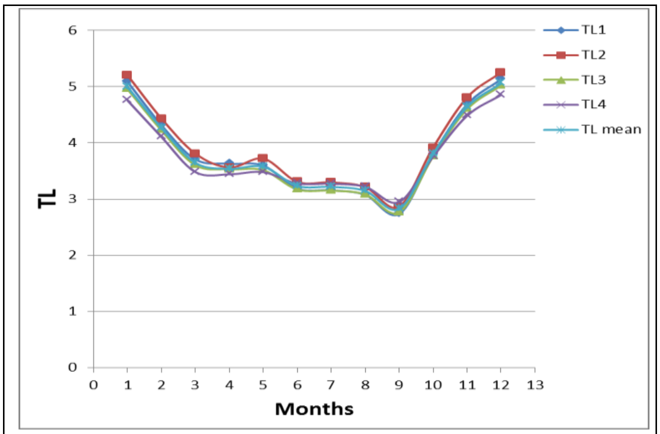

Figure (7): the amount of turbidity during the months of the year for the Amara site

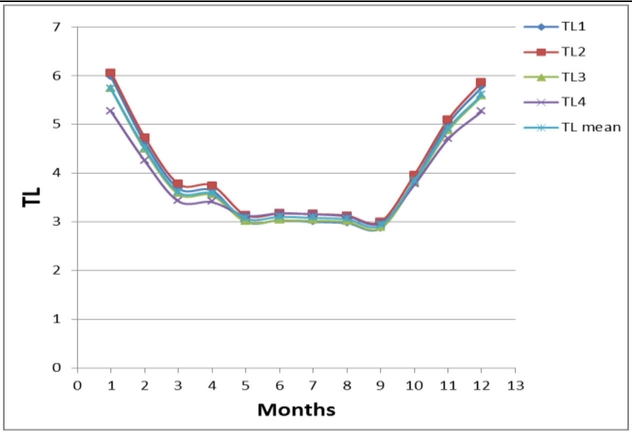

Figure (8): the amount of turbidity during the months of the year for the Mosul site

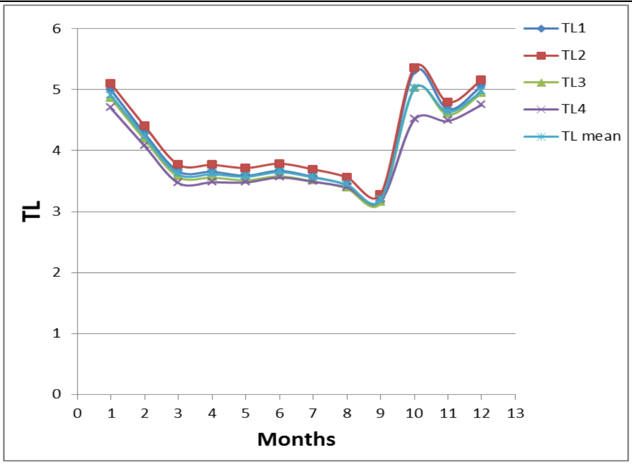

Figure (9): the amount of turbidity during the months of the year for the Nasiriyah site

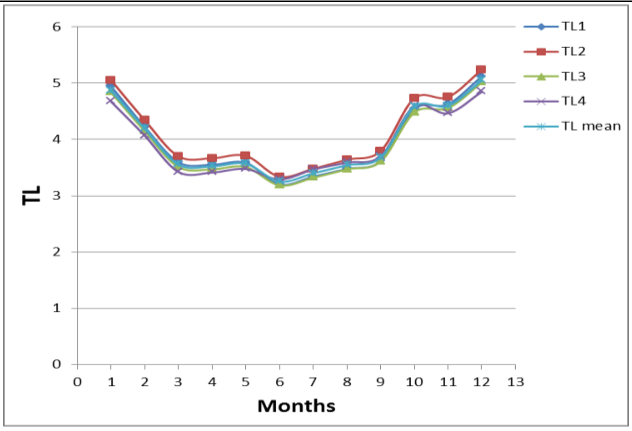

Figure (10): the amount of turbidity during the months of the year for the Najaf site

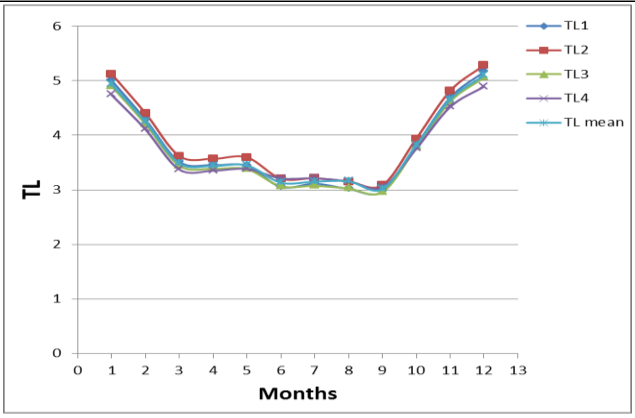

Figure (11): the amount of turbidity during the months of the year for the Baghdad site

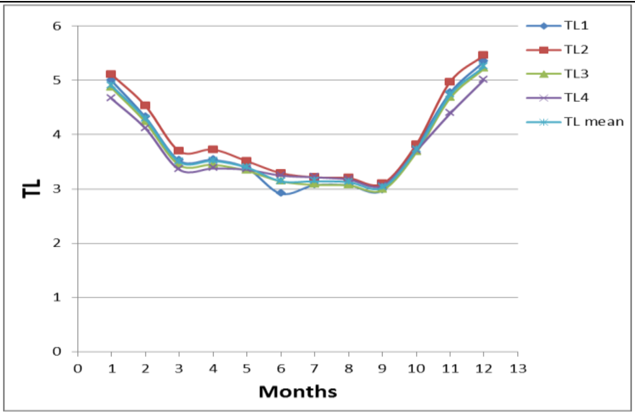

Figure (12): the amount of turbidity during the months of the year for Haditha

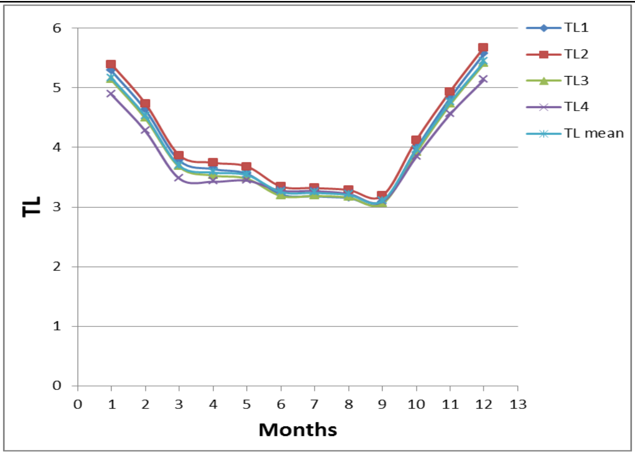

Figure (13): the amount of turbidity during the months of the year for the Khanoqin site

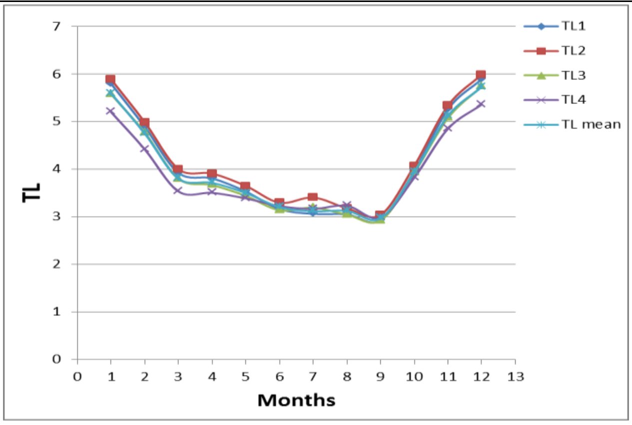

Figure (14): the amount of turbidity during the months of the year for the Zakho site

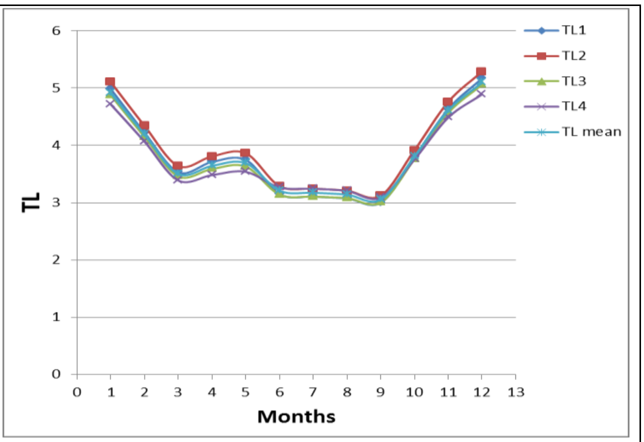

Figure (15): the amount of turbidity during the months of the year for the Karballa site

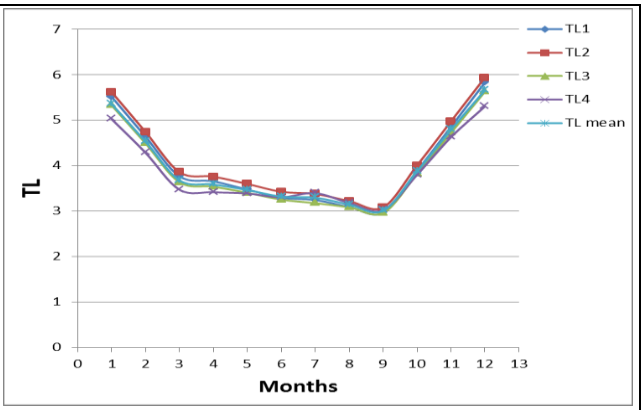

Figure (16): the amount of turbidity during the months of the year for the Kirkuk site

Table (3) shows the sites that recorded the highest and lowest average turbidity during the months of the year where the difference between the highest and lowest average turbidity during the month of November is the greatest possible and reached (1.52) where Zakho scored (5.12) while the Karbala site record (3.60) and the turbidity values the rest of the sites between these two values while the difference between the highest average turbidity and the lowest average turbidity is the lowest possible and reached (0.21) during the month of April where the Karbala site scored (3.64)while the Baghdad site record (3.43) and the turbidity values for the rest of the sites fall between these two values.

Table (3). Comparison shows maximum and minimum average turbidity for sites under study during the months of the year.

The month	Site	The maximum average turbidity	Site	The minimum average turbidity
Jan	Mosul	5.72	Basra	4.75
Feb	Zakho	4.75	Basra	4.16
Mar	Sulaimaniya	3.85	Amara	3.46
Apr	Karbala	3.64	Baghdad	3.43
May	Karbala	3.68	Mosul	3.06
Jun	Nasiriyah	3.64	Mosul	3.01
Jul	Nasiriyah	3.55	Mosul	3.08
Aug	Nasiriyah	3.44	Zakho	3.05
Sep	Khanaoqin	3.10	Amara	2.82
Oct	Nasiriyah	5.00	Hadetha	3.71
Nov	Zakho	5.12	Karbala	3.60
Dec	Zakho	5.73	Basra	4.85

4. CONCLUSIONS

After studying the 16 Iraqi sites that distributed over the majority of the northern, central and southern areas of Iraq, and during all months of the year, the results of the research reached the following conclusions:

1. Variation in the amount of turbidity does not depend on the location factor. If 16 sites are studied in the same time period, then the difference is very small between one site

and another. The smallest amount of this variation is during April where the Karbala site recorded the highest value of turbidity by(3.64) while the Baghdad site recorded the lowest value of turbidity by (3.43) while November witnessed the highest relative variation between these sites so the amount of turbidity in Zakho site at its greatest value by (5.12), while the Karbala site had the lowest value, it recorded (3.60).

2. The difference in the amount of turbidity depends on the time factor, so the values of turbidity were different if a particular site is taken and studied during different months or seasons of the year and this can be observed from all graphs for all the sites that studied.
3. The highest amount of turbidity in the Zakho site was in December and was (5.73), while the lowest amount of turbidity was recorded at the Amara site in September and its value was (2.82).
4. All the locations that were studied were the greatest values of turbidity in December or January, during the winter and in these two months in particular, all regions of Iraq are cloudy, and studies indicate that approximately a quarter of the solar radiation reaching the Earth is reflected by clouds while they are turbidity during the spring and summer seasons is high, but it is less than winter. The reason for turbidity here is the seasonal dust storms that cause absorption and dispersal of solar radiation, while the lowest magnitude of turbidity in most locations during September is due to the clarity of the weather and the lack of clouds.
5. It is possible to control the amount of turbidity for most months of the year except at December and January, because the turbidity is caused by clouds, so the rest of the months can reduce the amount of turbidity because it is caused by dust storms, so you can increase the green areas that, in addition to its beauty, health, economic and environmental benefits, it reduces the value of turbidity and thus the maximum benefit of the solar radiation energy can be generated in generating electric energy depend the solar radiation.

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