D Estimation Wave Energy in the Iraqi Coastal Region

Ethar Ammar Talib Hazim Hamoud Hussain Husam Tariq Majeed
Mustansiriyah University / College of Science, Department of Atmospheric Science.
Baghdad - Iraq
E_mail: ethar.ammar@uomustansiriyah.edu.iq

Abstract

Wave energy is an important renewable energy source in coastal regions due to its high energy density, abundance, good kinetic energy, and many other reasons. The process of estimating wave energy in a specific area is controlled by many factors, including metrological factors such as wind speed, direction, and season, and wave factors such as wave height and water depth. The data taken from Al Faw grand port station for year 2022 which include wind speed and direction and wave height. The wind rose used to determine the frequency of wind direction and wind speed in the study area It was found that the dominated wind direction is northwesterly. The wind speed varies between 0.1-18.1 m/s. The Significant wave height ranges between 0.06-0.4 m. The Relationship between significant wave height and wave power is directly proportional where an increase in significant wave height cause increasing in wave power. The wave power in the Iraqi coastline is un suitable for production electrical energy from wave energy by the present techniques. The aims of this study to estimate the wave power from significant wave height in coastal region of Iraq.

Keywords: Renewable Energy, Wave Energy, Wave Power, Wave Height and Coastal Region.

تقدير طاقة الأمواج في منطقة الساحل العراقي

ايثار عمار طالب حازم حمود حسين حسام طارق مجيد
الجامعة المستنصرية / كلية العلوم / قسم علوم الجو. بغداد - العراق

الخلاصة

تعد طاقة الامواج احد انواع الطاقة المتجددة المهمة. وذلك بسبب كفاءتها العالية ، وفرتها ، طاقتها الحركية جيدة والعديد من المزايا الاخرى. ان عملية تقدير طاقة الامواج تتحكم بها العديد من العوامل منها انوائية مثل سرعة واتجاه الرياح واختلاف المواسم ومنها عوامل متعلقة بالبحر مثل ارتفاع الموجة و عمق المياه. هذه الدراسة تهدف الى تقدير طاقة الامواج في الساحل الشمالي من الخليج العربي. تم اخذ البيانات من محطة بحرية في ميناء الفاو في محافظة البصرة جنوب العراق لعام 2022 وتشمل هذه البيانات سرعة واتجاه الرياح وارتفاع الموجة. تم استخدام وردة الرياح لحساب تكرارات سرعة الرياح مع الاتجاه خلال مدة الدراسة وقد تبين ان الاتجاه السائد لهبوب الرياح هو شمالي غربي. ان سرع الرياح تتراوح بين 0.1-0.18 متر/ثا. ان اعلى ارتفاع موجة كان يتراوح بين 0.06-0.41 متر. ان العلاقة بين ارتفاع الموجة وقدرة الموجة هي علاقه طردية حيث ان اي زيادة في ارتفاع الموجة تتبعها زيادة في قدرة الموجة. ان قدرة الموجة في الساحل العراقي غير مناسبة لإنتاج الطاقة الكهربائية من طاقة الأمواج واسطة التقنيات المتاحة حالياً. ان الهدف من هذه الدراسة هو لتحديد طاقة الموجة بواسطة ارتفاع الموجة في الساحل العراقي للاستفادة منها توليد الطاقة الكهربائية من طاقة الأمواج.

الكلمات المفتاحية: الطاقة المتجددة، طاقة الأمواج، قدرة الموجة، ارتفاع الموجة والمنطقة الساحلية.

Introduction

Reliance on renewable energy sources is significant in our current area because of global warming and the lack of fossil fuel sources worldwide, particularly in Iraq (Kasim, *et al*., 2020). Fossil fuel sources such as oil and gasoline harm the environment as they cause water and air pollution (Kasim, *et al*., 2021). The decision-makers decided to replace the traditional methods of electric power generation with renewable energy to reduce the risks of environmental pollution (Kareem & Hussain, 2021). It is necessary to resort to renewable energy in Iraq to reduce dependence on generated electric power from fossil fuels, which leads to severe environmental damage (Abed, *et al*.,2023). Wave energy generated by wind is one of the most important types of renewable energy and has a high energy density compared to the others as its kinetic energy is much greater than wind energy and it is possible to produce wave energy in low wind conditions. The main factors that affect the wave energy are the significant wave height, wave duration and the distance from the coastline (the depth) (Blackledge, *et al*., 2013). Wave energy produces two types of energy, potential and kinetic. Potential energy is affected by the height of the wave, while kinetic energy depends on the movement of sea waves (Rahuna, *et al*., 2023). Wave energy is considered a modern marine technology, as it exploits ocean energy in special systems that capture energy in different ways. Wave energy conversion (WEC) systems are designed to capture ocean waves in different forms and with different devices (Karduri & Ananth, 2023). WEC devices vary depending on the depth of the water, the working mechanism, the cost, and the amount of electrical energy produced (Burhanudin, *et al*., 2022). There many studies in the field of wave energy (Nezhad, *et al* 2018) Assessment wave energy in the nearshore Iranian coast by using measured wave data for year 2010. The results show that wave power in Qeshm, Chabahar, and Anzali exhibits the most potential, making them the most suitable candidates for further investigation on the installing of Wave Energy Converter device. (Sergent, *et al*., 2020) estimate wave energy in the onshore Atlantic coast of France by using four onshore WEC families. The result show that Annual wave power levels are maximum in Bayonne with 24 kW/m. (Goharnejad, *et al*., 2021) estimate the wave energy and wave height in the Persian Gulf in the Iran's southern coastline for years 1988 to 2017 by using buoy data from six stations (P1—P6). The results indicate that the mean wave height ranges from 0.2 to over 1.75 m and the mean historical wave power ranging from 0.18 to 0.62 kW/m (Average of 0.4 kW/m). The variation in the coastal water is produced by wind wave storms and ocean circulation which leads to several interaction processes such as wave-current interaction and tide surge interaction causing changes in the water levels and wave height (Wang & Elahi, 2023). The present research aims to estimate the wave power in the Iraqi coastal region for the purpose of generating electrical energy using renewable energy devices. Wave energy is used to transform mechanical energy into different forms of energy.

Materials and Methods Study Area

The Iraqi coastal region, represent by Al Faw in Basra governorate near the northern end of Arabian Gulf. As shown in Figure (1), it has a strategically fundamental position in the Arabian Gulf, it is located within latitude 29.5° and longitude 48.4° (Abbas, *et al*., 2020). This region is marked by its possession of the Shatt al-Arab which formed by the confluence of the Tigris and Euphrates rivers, it is exposed to physical alterations due to several factors, such as wind, precipitation, waves, and tides (Khalifa, 2020). Basra characterized by a hot arid and semi-arid climate in summer (Majeed & Qasim, 2021), so its high temperature and higher levels of humidity (Abbood, *et al*., 2024) as a result of its close proximity to the coastline, but the winter of Basra city is characterized by cooling and humidity (Al-Zuhairi, *et al*., 2023). Basra located 3 m above sea level (Rasham & Mahdi, 2018). This location causes high relative humidity and abundant winter rainfall and about the temperature, it is moderate in the winter season, with a mean temperature of 20° C. In this area the dominant wind direction is north-westerly (Hassoon, *et al*., 2021). Because of to the northern winds that come from the Arabian Gulf and move towards this area, carrying out significant energy from the Gulf's waters (Abdulkareem & Nemah, 2021).

Figure (1) Location of Study Area (Yassen, et al., 2024)

Data Source and Method

The data taken from general company for Iraqi port Al-Faw Grand Port station in Iraq. Which represent wind data (wind speed and direction) by wind sensor device at height 6 m above sea level with time interval 10 minute and wave data by ultrasonic device which represent wave hight with time interval 1 hour. The Wind rose was used by the Origin program to compute the wind direction frequency and wind speed for year 2022.

Wave Power Estimation

The wave energy index is the magnitude and temporal variation in energy that is transferred from the atmosphere as wind energy to the ocean as wave energy in a certain period. It gives us important information about the wave, such as wave height and wave duration (Orejarena, *et al*., 2022).

$$\lambda = CT \qquad \text{...... (1)}$$

$$\lambda/T = gT/2\pi = \frac{gT^2}{2\pi} \qquad \text{...... (2)}$$

$$C = gT/2\pi \qquad \text{...... (3)}$$

But in shallow waters the depth has significant impact on the motion of waves in shallow waters, especially coastal areas because shallow waters are closer to the sea bottom so the wave speed will decrease as the depth decreases, the wavelength λ also decrease, just the period remain constant (Organization, 1998).

$$C = \sqrt{gh} \qquad \text{...... (4)}$$

Where h is water depth

The Energy density is calculated according to eq (1) (Kamranzad, *et al*., 2013):

$$E = \frac{1}{16}\rho g H_{m0}^2 \qquad \text{...... (5)}$$

Where H_{m0} is significant wave height, ρ is water density=1025 kgm^{-3}, g is the gravitation acceleration =9.81 ms^{-2}

The wave power density or wave energy potential it is the amount of energy reaching a given location (Guillou, *et al*., 2020). Ti is calculated according to eq (6) (Karmanzad, *et al*., 2013):

$$P = EC_g = EC_n \qquad \text{...... (6)}$$

Where C is the wave speed, n is the ratio of wave group velocity to for shallow water (Clara de Abreu, *et al*., 2019; Organization, 1998).

$$P = \frac{1}{16}\rho g H_{m0}^2 * \sqrt{gh} \qquad \text{...... (7)}$$

Results and Discussion

The wind rose is obtained for frequency of wind speed and direction for year 2022 with time interval 10 minute. As shown by wind rose in Figure (2) it was found that the prevailing wind direction of annual wind data is mostly north-westerly about 32% and 68% blowing in other directions and that is important indicator for estimation wave energy.

The wind rose indicates that the wind speed varies between 0.1-18.1 m/s and the most prevalent wind speed data is between the range of 3.1-6.1 m/s, followed by the range of 6.1-9.1 m/s. The data ranges of 12.1-15.1 and 15.1-18.1 exhibit minimal frequencies over the entire year.

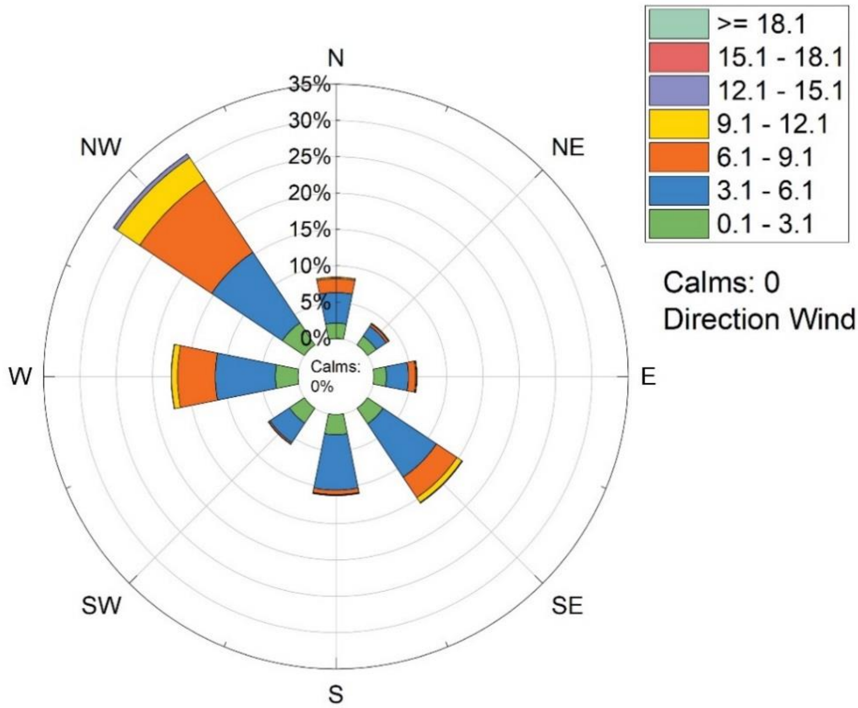
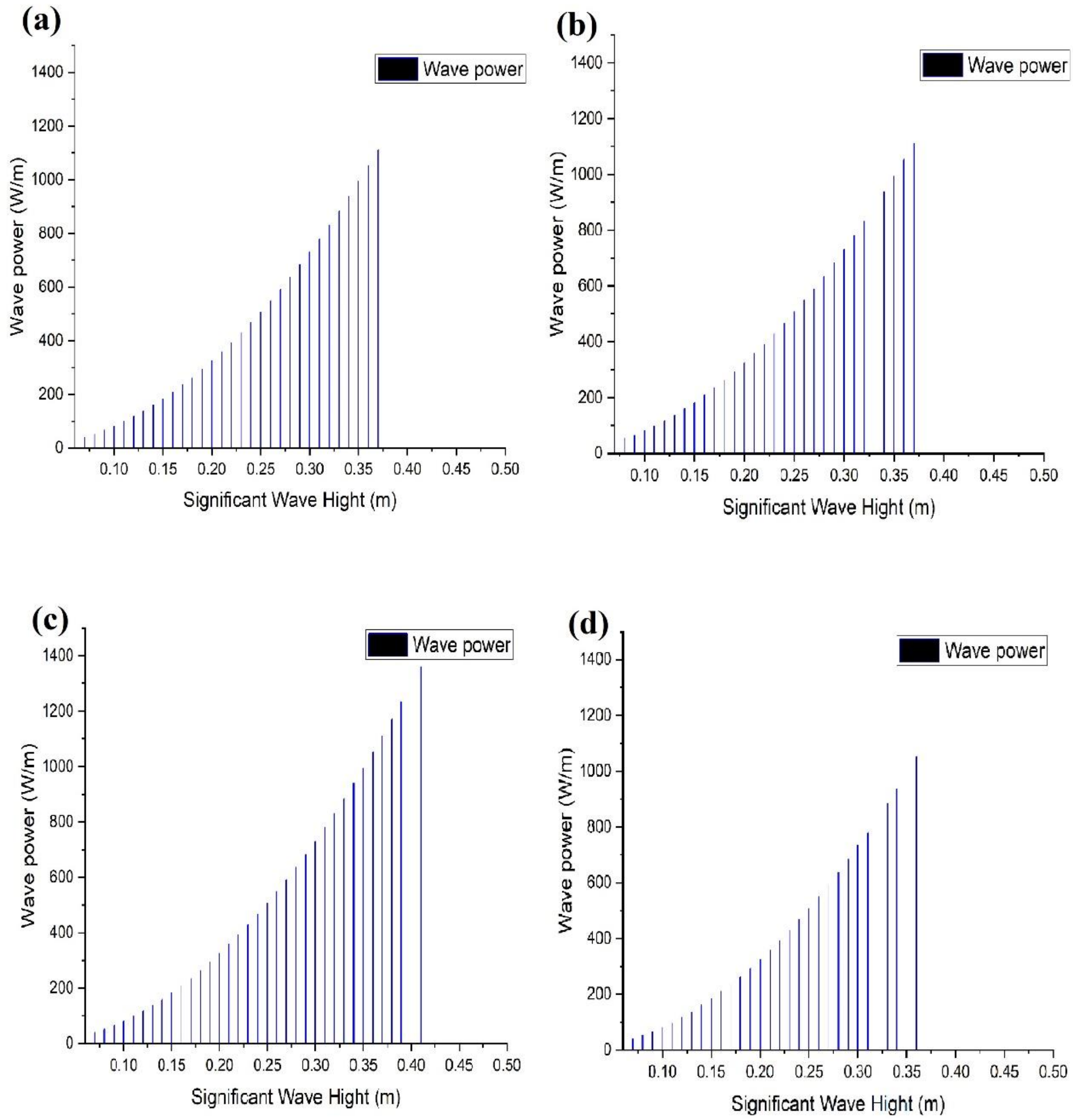
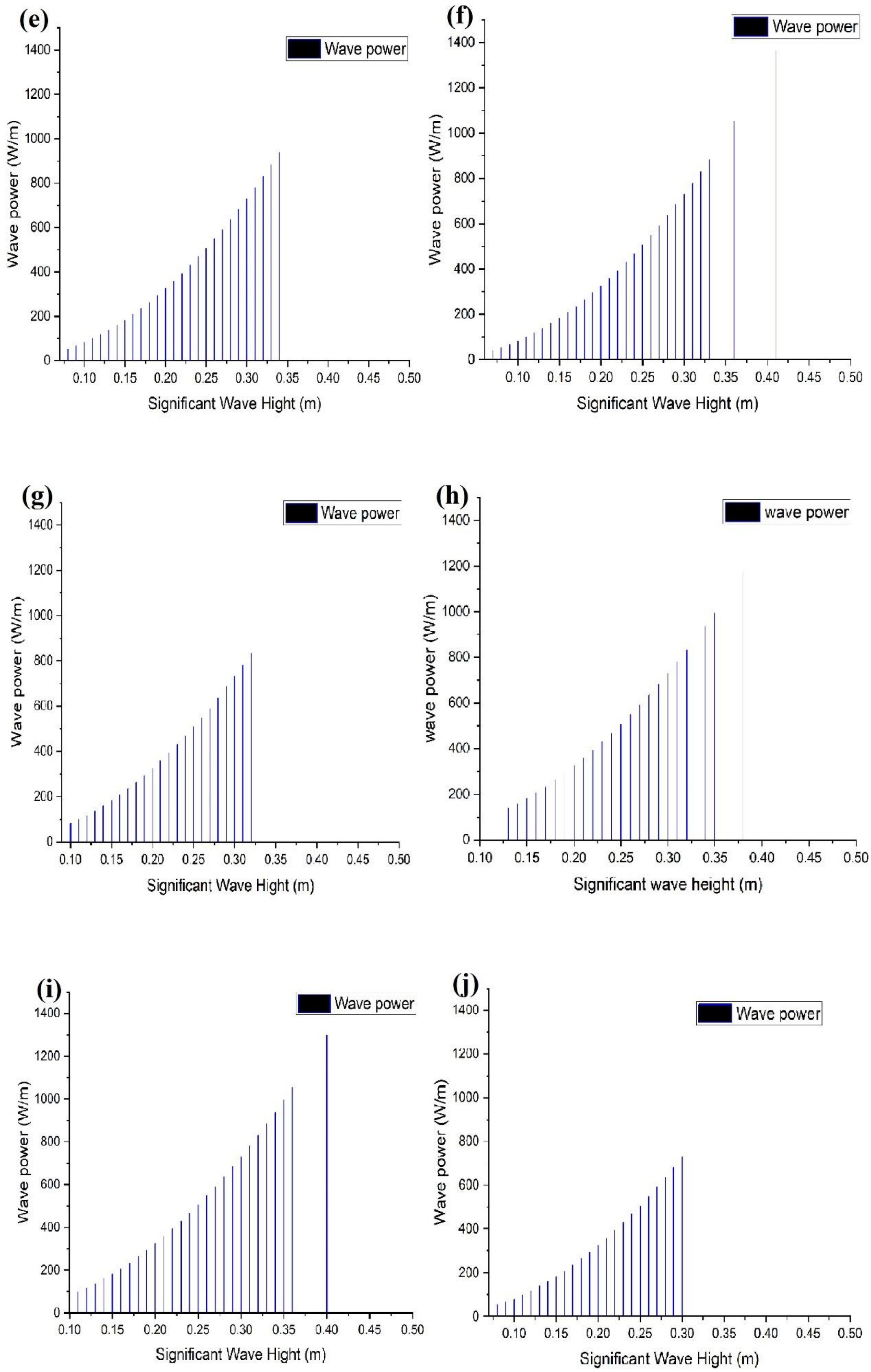


Figure (2) Wind Rose for Year 2022

The figure **(**3) represents the relationship between hourly Significant wave height H_{m0} and wave power P for every month of year 2022. The Significant wave height ranges between 0.06-0.4 m, the maximum Significant wave height and wave power was found in March and June exceeding 1300 W/m at Significant wave height 0.41 m and then September and December reaching approximately 1300 W/m at Significant wave height 0.4 m. The figure (3) indicate that the most wave height values are below 0.35 m, while those over 0.35 m are relatively few; thus, wave power exhibits a similar pattern.



(a)
Wave power
Wave power (W/m)
Significant Wave Hight (m)
(b)
Wave power
Wave power (W/m)
Significant Wave Hight (m)
(c)
Wave power
Wave power (W/m)
Significant Wave Hight (m)
(d)
Wave power
Wave power (W/m)
Significant Wave Hight (m)


(e)
Wave power
Wave power (W/m)
Significant Wave Hight (m)
(f)
Wave power
Wave power (W/m)
Significant Wave Hight (m)
(g)
Wave power
Wave power (W/m)
Significant Wave Hight (m)
(h)
wave power
wave power (W/m)
Significant wave height (m)
(i)
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(j)
Wave power
Wave power (W/m)
Significant Wave Hight (m)

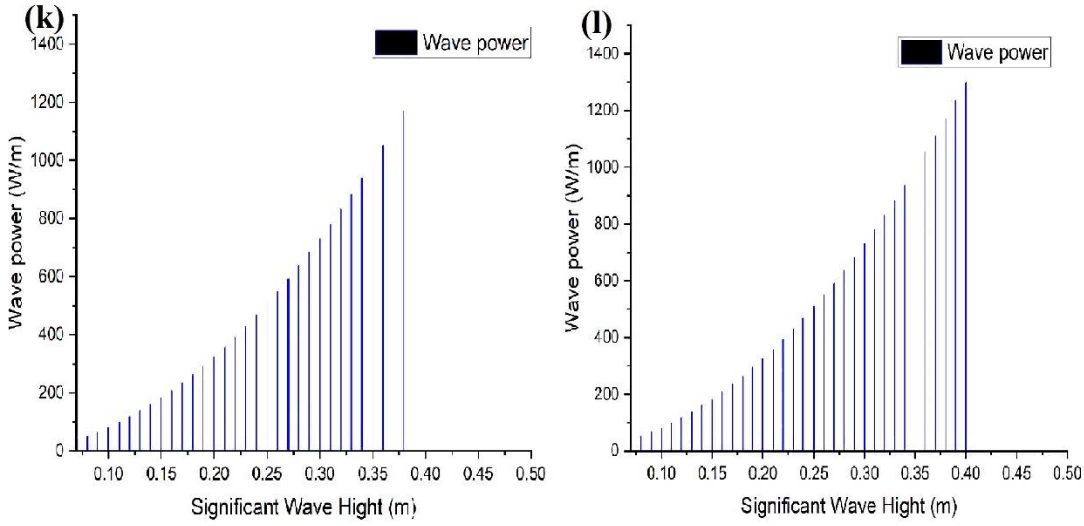

Figure (3) Relationship between Significant Wave Height and Wave Power for Months (a) January b)February c) March d) April(e) May (f) June (g) July (h) August (i) September(j) October (k) November (l) December.

Figure (4) illustrates a directly proportional relationship between wave height and wave power, as wave height is the primary determinant of wave power magnitude. The lowest values were seen between October and April because of low wind speed at these months which effect on the wave height because wind conditions are the primary source for producing wave energy.

About the wave parameters in table (1), the highest monthly average wave height occurs in August and September reaching 0.206 and 0.202 respectively, caused by increased wind speeds during these months, which is an influence to wave height beside sea depth. These months exhibits the highest wave height values, both minimum and maximum, relative to other months, resulting in an elevated overall average for this period. While the minimum average monthly significant wave height was found in October and April reaching 0.161 and 0.166 Respectively. In table (1) the highest wave power was found in August and September reaching 356 and 350 respectively. While the minimum value of wave power was found in October and April reaching 231 and 248 respectively.

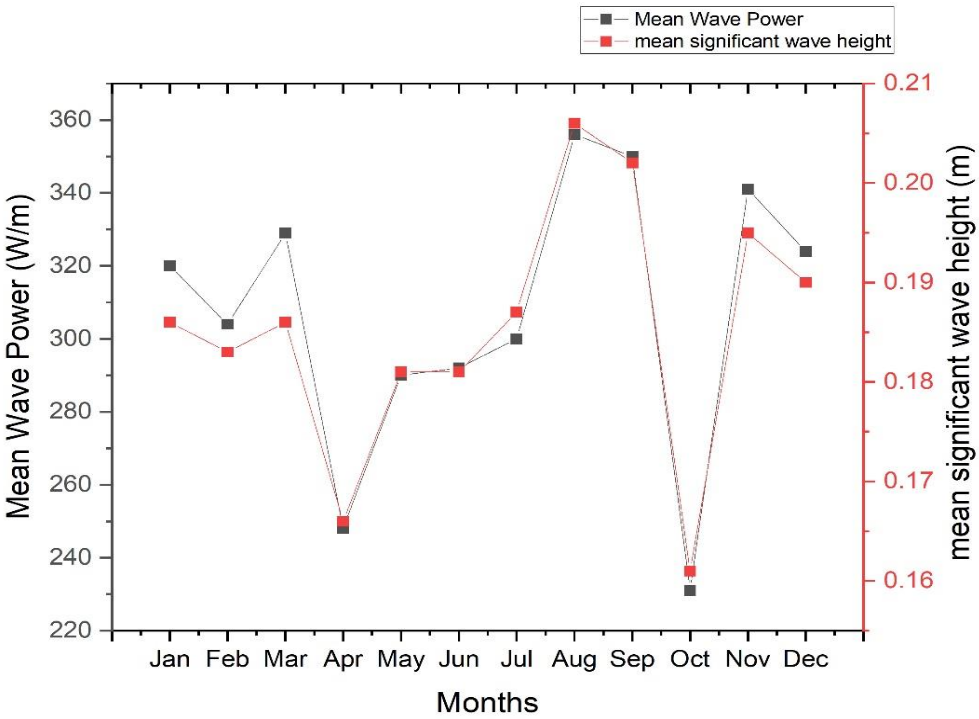

Figure (4) Relationship between Average Monthly Significant Wave Height and Average Monthly Wave Power for Year 2022.

By comparison with other study (Jaswar, *et al*., 2014) in table (2) they use Wave Star device (WEC), which converts wave energy into electrical energy, where this device has a specified limit for significant wave height ranging from 0.5 -3 m and wave period 2-13 s, it is the only device work with low significant wave height in the currently available technologies for wave energy conversion systems. The wave power in the Iraqi shoreline is un suitable for electrical energy generation from Wave energy conversion systems.

Table (1) Wave Parameter in Study Area for Year 2022

Month	H_{m0} (m)	T_p (s)	P W/m
Jan	0.186	4	320
Feb	0.183	4	304
Mar	0.186	4	329
Apr	0.166	4	248
May	0.181	4	290
Jun	0.181	4	292
Jul	0.187	4	300
Aug	0.206	4	356
Sep	0.202	4	350
Oct	0.161	4	231
Nov	0.195	4	341
Dec	0.190	4	324

Table (2) The Working Requirement and Electrical Power for Wave Star Device (WEC)

H_{m0} (m)	T_p (s)	E P KW
0.0-0.5	2-7	0
0.5-1.0	2-7	49-86
1.0-1.5	2-7	54-196
1.5-2.0	2-7	106-322
2.0-2.5	2-7	175-457
2.5-3.0	2-7	262-600

Conclusions

The prevailing wind direction of annual wind data is mostly north-westerly about 32% and 68% blowing in other directions, The presence of a prevailing wind pattern is important in determining wave energy, as increasing wave height requires high wind speeds in one direction. The most prevalent wind speed data is between the range of 3-6 m/s, followed by the range of 6-9 m/s. The data ranges of 12-15 and 15-18 exhibit minimal frequencies over the entire year. This effect on the average of the wind speed through each month and over the entire yea. High wind measurements alone are insufficient; a lot of elevated values are necessary for obtaining a good average wind speed.

The highest values of the mean significant wave height were in the months of August and September, because the minimum value for these months was 0.1 and 0.3 respectively, which affects the general average of the significant wave height in these two months, and it is greater than the rest of the months. For example, in the month of January, the minimum value of the significant wave height was 0.06.

The most wave height values are below 0.35 m, while those over 0.35 m are relatively few; Thus, this effect of the general average of significant wave height in every month and the hole year. The main factor affecting the wave power is the wave height, as the relationship between them was direct, which made the wave power behave in the same manner as the wave height.
The lowest values of significant wave height and wave power were seen between October and April due to reduced wind speed during these months, which influences wave height, as waves are generated by the friction between wind and the sea surface. The wave height in the Iraqi coastline is too small which cause decrease in wave power and because of that the process of production electrical energy from wave energy is unsuitable by the present techniques of wave energy conversion systems.

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