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THE DETERMINATION OF OCEANOGRAPHIC PHYSICAL PROPERTIES AT THE COASTAL AREA OF TEGAL CITY

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Abstrak

Selama proses penelitian berlangsung, kawasan pesisir Tegal belum dilengkapi dengan data geologi dan data oseanografi, khususnya pola sebaran arus laut di sekitar kawasan pesisir Kota Tegal. Sifat pola arus laut di dekat pantai sangat penting untuk diketahui karena kawasan pantai digunakan untuk kegiatan rekreasi dan kegiatan pelayaran dari dan ke pelabuhan. Kecepatan arus laut dan kemana arahnya perlu dijelaskan agar pengguna kawasan pantai dapat memantau dengan baik bahaya atau tidaknya. Pada kajian pola arus di kawasan pesisir Kota Tegal, alat yang digunakan dirancang berdasarkan metode Lagrangian dan metode Helmholtz untuk mendapatkan arah dan besaran kecepatan arus laut. Permasalahan dalam menentukan pola arus adalah bahwa sinyal arus merupakan hasil dari berbagai sinyal yang memiliki frekuensi tertentu yang dihasilkan oleh beberapa gaya yang berbeda. Masalah selanjutnya dalam menentukan ketinggian gelombang, dibutuhkan titik koordinat awal sebagai titik nol. Dari permasalahan tersebut peneliti tertarik dengan pola arus yang terbentuk. Arus laut adalah pergerakan massa air laut dari satu tempat ke tempat lain, baik secara vertikal (gerakan ke atas) maupun horizontal. Tujuan penelitian ini untuk mengetahui energi arus laut dan sifat fisik oseanografi dekat pantai, untuk mendapatkan tingkat bahayanya jika digunakan untuk tempat rekreasi, kegiatan pelayaran, dan kegiatan penelitian.

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***Kata kunci**: Pesisir Tegal, sifat fisik oseanografi pantai, pola arus laut, arus laut.*

***Keywords**: Tegal's coastal area, physical properties of coastal oceanography, ocean currents patterns, ocean currents.*

Abstract

Throughout our observations, the coastal area of Tegal has not been equipped with geological data and oceanographic data, especially the distribution of ocean current patterns around the coastal area of Tegal City. It is very important to know the nature of the pattern of ocean currents near the coast because the coastal area is for recreational activities and shipping activities to and from the port. The speed of ocean currents and where they are heading needs to be described so that the users of the coastal area can monitor well about the danger or not. In the study of the current pattern at the coastal area of Tegal City, the tool used was designed based on the Lagrangian method and the Helmholtz method to obtain the direction and magnitude of the ocean current's velocity. The problem in determining the current pattern is that the current signal is the result of various signals having a certain frequency generated by several different forces. The next problem in determining the height of the waves, the initial coordinate point is needed as the zero point. From this problem, researchers are interested in the current pattern that is formed. Ocean currents are the mass movement of seawater from one place to another, either vertically (upward motion) or horizontally. The purpose of this study finds the *energy of ocean currents and the physical properties of oceanography near the coast, to get the level of danger if used for recreational areas, shipping activities, and research activities.*

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INTRODUCTION

Flow is the process of moving water masses towards an equilibrium which causes horizontal and vertical displacement of water masses. The movement is the result of several forces acting and several factors that influence it. The movement is like the Coriolis force, which is a force that deflects the direction of the current from the earth's rotational force. The deflection will point to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This force causes the gyre to flow clockwise (to the right) in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. The change in the direction of the current from the influence of the wind to the influence of the Coriolis force is known as the Ekman spiral. The Antarctic Circumpolar Current (ACC) is an ocean current flowing clockwise around the Antarctic continent. It is primarily driven by strong westerly winds (blowing from west to east), resulting in an overturning circulation (circulation in the vertical plane) and an eastward flow overall. Changes in the Southern Hemisphere westerly winds can also influence eddy formation in the Southern Ocean. Ocean currents are the mass movement of seawater from one place to another, either vertically (upward motion) or horizontally (sideways movement).

Seawater has a complex current system. Ranging from predictable tidal currents to fickle rip currents, ocean currents may be driven by tides, winds, or differences in density. They profoundly affect the weather, marine transportation, and the cycling of nutrients. Knowledge of ocean currents is essential to the shipping and fishing industries and is helpful for search-and-rescue operations, hazardous material cleanups, and recreational swimming and boating. Using a combination of predicted and real-time measurements of current patterns, boaters can safely dock and undock boats, rescuers can determine where a missing person who may drift, cleanup crews can anticipate where spills might go and surfers can position themselves to catch the perfect wave. This study aims to obtain a model of ocean currents patterns and look for ocean currents' energy and oceanographic physical properties of the research area, for the placement of current turbines around the natural coast of Tegal City.

LITERATURE REVIEW

Characteristic Ocean Flow

Characterized by the distinctive finite-amplitude billows it generates, is an important mechanism in the development of turbulence in the stratified interior of the ocean. Ocean flow, also known as ocean surface current or ocean current, refers to the process of comparatively stable flowing of seawater, which may be affected by its inner changes and various external acting forces. Seas and Oceans are dynamic ecosystems. Oceans are very vast bodies of water. Wind blowing on the surface of the ocean has the greatest effect on the movement of surface water. The vertical or horizontal movement of both surface and deep water masses happens in the world's oceans. They are called Ocean currents. Currents normally move in certain specific directions. Hence, they aid in the circulation of moisture on Earth. Because ocean currents circulate water worldwide, they have a significant impact on the movement of energy and moisture between the oceans and the atmosphere. As a result, they are important to the world's weather. Many marine species rely on these currents to move them from one location to another whether it is for breeding or food or adaptation purposes. Today, ocean currents are also gaining importance due to the possibility of harnessing alternative energy.

Kelvin-Helmholtz instability

This wave pattern in the clouds, similar to that on the ocean surface, is due to Kelvin-Helmholtz instability, named after Lord Kelvin and Hermann von Helmholtz. To understand this instability, consider two layers with different densities on top of each other. The lighter (less dense) layer sits atop the heavier layer (think of the way less dense oil sits atop water). Not only do these layers have different densities, but they are also moving at different speeds. This leads to what is called "velocity shear" across the interface between the two fluids.

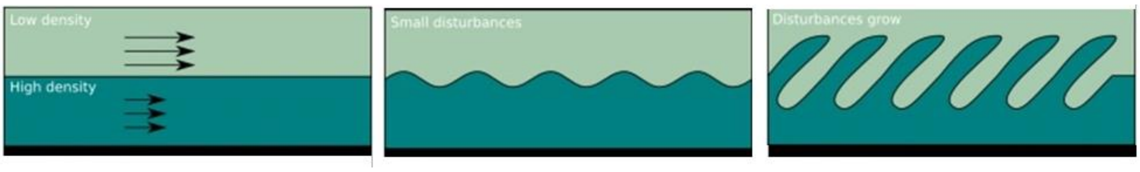

Figure 1. Kelvin-Helmholtz instability

Because of the higher velocities in the layer above, a small disturbance can form along the interface of the two fluids. The higher velocity air can, in a sense, grab the lower velocity/denser air below, allowing these disturbances to grow and eventually break over like an ocean wave crashing ashore. This ultimately causes turbulent mixing of the two layers, which is a more stable scenario than the separated layers previously observed. Kelvin-Helmholtz (KH) instability, characterized by the distinctive finite-amplitude billows it generates, is an important mechanism in the development of turbulence in the stratified interior of the ocean.

METHOD OF RESEARCH

Place and time of research

The research was conducted around the coastal area of Tegal City which were not disturbed by breakwaters. The place for data collection is at 109^{o} 7' 41" east longitude, 6^{o} 59' 8" south latitude. The time of study was carried out at 10:00 – 12:00 Western Indonesian Time In the light of the rainy season.

Ocean Current Observation Method

The Lagrangian method is a method of measuring the mass flow of water by releasing floating objects into the sea, then following the movement of the mass flow of seawater. Figure 2 shows one of the current speed-measuring devices
placed in the sea. Thus the position can be continuously plotted and finally, the current path can be known.
A simple current measuring device that can be used in fairly wide waters (sea) as an alternative to measuring current vectors (magnitude and speed) when you do not have measuring devices such as digital current meters or others.
If the instrument stands upright, it means that the current measuring device is well made, if the tool is tilted, it is necessary to reconsider the ratio of the float and the ballast.

1. Flag
2. Buoy
3. Propeller
4. Ballast

A floating object is a conventional ocean current measuring instrument that drifts with the ocean currents.

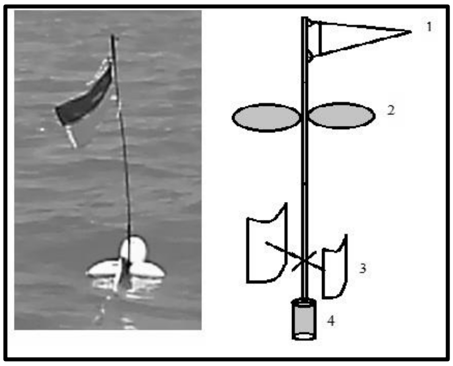

Figure 2. The floating Object

Research Tools used

In this study, there are several tools used to determine the condition of the coastal sea, namely a floating object, anemometer, digital thermometer, the pole measuring sea wave height, roll meter, plastic rope, stopwatch, and GPS (Global Positioning System).

1. Floating Object
   A floating device measuring ocean currents is made and designed in such a way that it can stand on seawater to determine the movement of seawater. In this case, the device is designed in two parts, namely: (1) The tool that sinks along 2.5 m is equipped with a propeller so that it can be carried by the current and a pendulum sufficiently. This pendulum functions so that the floating device can stand upright. (2) A device that floats 1.5 m long is equipped with 3 floating objects and one flag as a sign to make it easier for observers. Around the floating object, a plastic rope and a tape measure are tied, so that when it is released, the position of the floating object can be known.
2. Pole Measuring Wave Height
   This tool is equipped with four buoys, metal iron stakes approximately 3.5 m long that enter the sea waters, at the lower end of which a pendulum is placed to keep it standing upright. The stake of pole equipped with a meter stands upright above the sea waters along the 140 cm.

Figure 3. The Pole Measuring Wave Height

3. Digital Thermometer.
   This thermometer is used to measure the temperature of surface sea waters.
4. Roll Meter

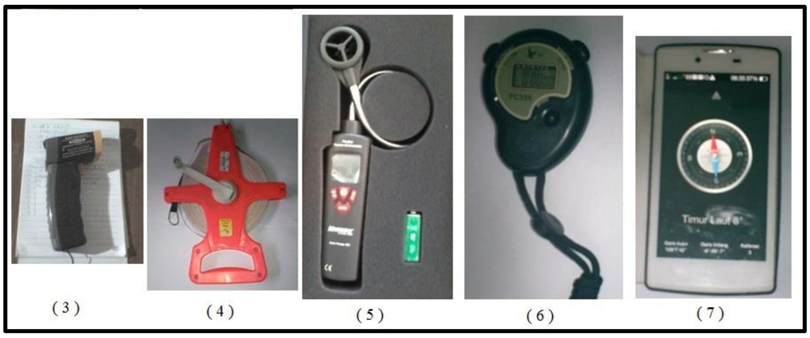

Figure 4. Digital Thermometer, Roll meter, Anemometer, Stopwatch, and GPS

This tool is used to measure the length of the path of the floating object that is made.

5. Anemometer
   This tool is used to measure wind speed and temperature over sea waters carried out on board ships.
6. Stopwatch
   This tool is used to measure the travel time of floating objects made (drifter) and is also used to measure the length of time the waves hit the meter-scale pole.
7. Global Positioning System (GPS)
   This tool is used to determine the position of the observation area of marine waters.

Data Processing and Analysis Techniques

The frequency of wave vibrations at the observation point, f (Hz), observation time interval (t), and wave height (h) are processed by this data to obtain the nature (character) or graphic form/pattern between the number of vibrations (n) and the observation time interval (t). If the form of the graph meets the linear form, the frequency and height data of the waves are used to determine the wave speed, C(m/s). This data together with data on wind speed above sea level (fluid velocity 1), U_1(m/s). Fluid density 1 (air), ρ_1 (kg/m^3) and fluid density 2 (seawater), ρ_2 (kg/m^3). The fluid velocity 2 (ocean currents), U_2(m/s) can be determined using the equation given by Helmholtz:

$$\rho_1(U_1 - C)^2 + \rho_2(U_2 - C)^2 = \left(\frac{g}{K}\right)(\rho_2 - \rho_1)$$

Where: g = acceleration due to gravity = 9.81 m/s; K = wave number = 2π/L and L = wavelength (m).

The speed of ocean currents (U_2) obtained from the Helmholtz equation is compared with the results of the speed of ocean currents obtained from the floating object of sea current measuring instrument, then to find the regularity of the pattern of ocean currents on the natural coast of Tegal City.

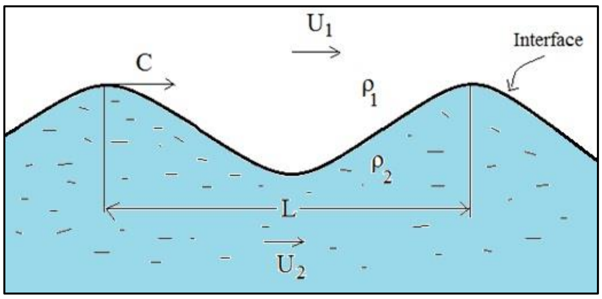

Figure 5. Theory of Ocean Waves by Helmholtz and Kelvin

C: wave speed
U_1: wind speed over sea level (fluid velocity 1)
U_2: fluid velocity 2 (ocean currents)
ρ_1: density of fluid 1 (air)
ρ_2: fluid density 2 (seawater)
L = wavelength.

RESULTS AND DISCUSSION
Research Result Data

Table 1. Data on the State of the Sea at the Coastal Area of Tegal City at position 109° 7' 41" E, 6° 59' 8" S

No	Measured quantity	Quantity Value
1	Sea surface wind speed	2.6 – 3.8 m/s
2	Sea surface air temperature	30.1 °C
3	Sea surface temperature	24.3 – 25.0 °C
4	Sea wave height	15 – 40 cm

Table 2. The Ocean Wave Data at position 109° 7' 41" E, 6° 59' 8" S

No	n	t (s)	H (cm)
1	10	23.61	15
2	8	18.87	30
3	10	24.48	30
4	12	30.0	35
5	10	15.70	25
6	10	21.88	40

Where n = the number of waves, t = The length of observation time (seconds), H = wave height (cm).

Table 3. Ocean Current Data based on the Lagrangian Method

No	Traveled distance of Floating Object (cm)	Traveled Time (second)
1	300	41.31
2	450	63.09
3	550	49.29
4	680	81.18

Research Discussion
Wave frequency, Ocean Wave height

The frequency, height, and speed of ocean waves are observed to get the ocean wavelength (L). This is because the pattern of ocean currents is influenced by wavelength and wind speed.

Table 4. Data on Frequency, Wave Height and Wave Speed

No	n	t (s)	f (Hz)	H (cm)	R (m)	v (m/s)	L (m)
1	10	23.61	0.42	15	0.08	0.20	0.471
2	8	18.87	0.42	30	0.15	0.40	0.942
3	10	24.48	0.41	30	0.15	0.38	0.942
4	12	30.00	0.40	35	0.18	0.44	1.099
5	10	15.70	0.64	25	0.13	0.50	0.785
6	10	21.88	0.46	40	0.20	0.57	1.256

		Average wavelength →	0.92
Average frequency →	0.46	Average speed →	0.42

Where: n = the number of waves, t = wave travel time (s), f = wave frequency (Hz), H = wave height from crest to valley (cm), R = (H/2) = wave height from crest to mean sea level (m), v = wave speed (m/s), L = wavelength (m).

$$K = \frac{2\pi}{L} = \frac{2x(3.14)}{0.92} = 6.86\ m^{-1}.$$

K = wavenumber

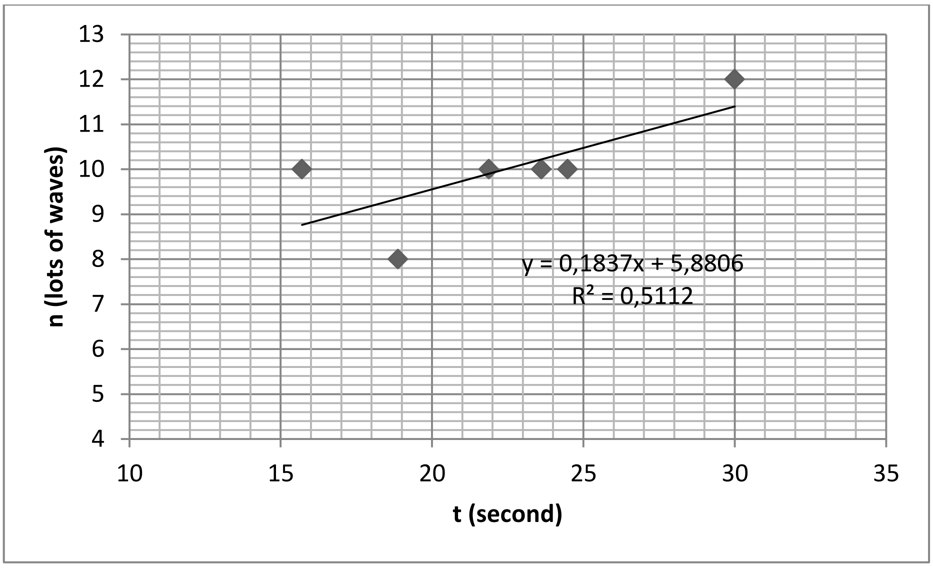

Figure 6. Wave Frequency

Wave Power and Ocean Current Power

(1) Wave Power

The power of the waves generated at the coastal area of Tegal can be observed in the following table:

Table 5. The Power per meter of wavefront

No.	Wave Height			v (m/s)	P (Watt)
	H (cm)	R(cm)	H(m)		
1	15	7.5	0.15	0.20	5.6
2	30	15	0.30	0.40	45.2
3	30	15	0.30	0.38	43.6
4	35	17.5	0.35	0.44	6.8
5	25	12.5	0.25	0.50	39.3
6	40	20	0.40	0.57	115.6
			0.29	0.42	52.8

Where: P = Wave Power (Watt)

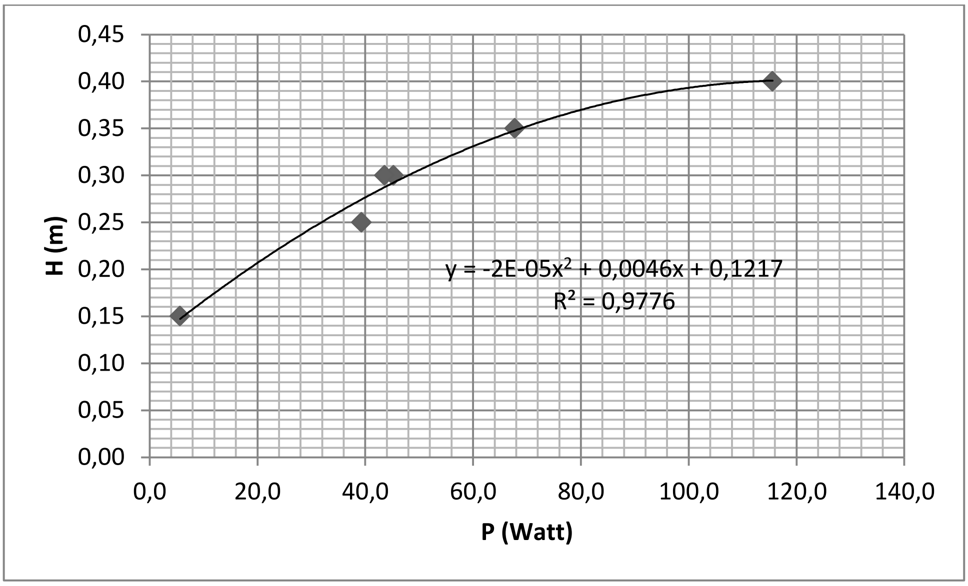

Figure 7. Wave Power

The Ocean Current Power

$$P = \frac{1}{8}\rho g H^2 v$$

ρ = density of seawater = 1026 kg/m^3.
g = gravity = 9.81 m/s^2
H = average wave height = 0.29 m
v = wave speed = 0.42 m/s
P = wave power = 44.4 Watt

Helmholtz's Method of Flow Patterns

The pattern of ocean currents using the Helmholtz method is influenced by the density of the sea surface, the density of the air above it, wind speed, wave speed, gravity, and ocean wavelength.

$$\rho_1(U_1 - C)^2 + \rho_2(U_2 - C)^2 = \left(\frac{g}{K}\right)(\rho_2 - \rho_1)$$

ρ_1 = air density, ρ_2 = density of seawater, C = wave speed, U_1 = wind speed
U_2 = ocean current speed, g = gravity, K = wavenumber = (2π/L).

ρ_1 =	1.225	kg/m^3	U_1 =	3.8	m/s
ρ_2 =	1026	kg/m^3	C =	0.42	m/s
g =	9.81	m/s^2	K =	6.86	m^{-1}

1.225(3.8 – 0.42)^2 + 1026(U_2 – 0.42)^2 = (9.81/6.86)(1026 – 1.225)
13.99489 + 1026(U_2 – 0.42)^2 = 1465.458
1026(U_2 – 0.42)^2 = 1465.458 – 13.99489

$$U_2 - 0.42 = \sqrt{\frac{1451.463}{1026}} = 1.19$$

U_2 = 1.19 + 0.42 = 1.6 m/s

From the results of the calculation of the speed of ocean currents using the Helmholtz method, we get U_2 = 1.6 m/s.

Lagrangian Method Flow Pattern

The lagrangian sea current pattern is obtained by floating objects that can be carried by ocean currents to a certain depth. This study was conducted at a depth of 2 - 3 meters. The direction of ocean currents can be known, namely by looking at the direction of the buoy being washed away by seawater. In this case, the direction of the ocean currents is between heading to the west, leaning to the north, or the northwest. The average speed traveled by the floating object, v = 0.085 m/s. The difference in the value of ocean currents using the Helmholtz method and the Lagrangian method is because the mass of water that is the standard for the Helmholtz method and the Lagrangian method is different. This difference seems to have to be considered by how much seawater mass can be measured of the speed of ocean currents.

Table 6. The Ocean Current Velocity Data Calculation Results of the Lagrangian Method

No	Traveled distance of floating object	Travel Time	Ocean Current Speed
	S (cm)	t (seconds)	v (m/s)
1	300	41.31	0.073
2	450	63.09	0.071
3	550	49.29	0.112
4	680	81.18	0.084
			0.085

CONCLUSION

The Current speed varies depending on the height of the waves at the time of observation, which is between 0.071 m/s – 0.112 m/s with an average value of 0.085 m/s. The result of the Helmholtz method of ocean current velocity is 1.6 m/s. The difference in the value of ocean currents using the Lagrangian method and the Helmholtz method is due to the assumption used, that the mass of seawater that is washed away is different. In the Lagrangian method, the speed of ocean currents is described as the movement of the mass of seawater which is equivalent to the mass movement of the floating object used. In the Helmholtz method, calculating the value of ocean currents, one of the physical quantities used, namely the velocity of the sea surface fluid is the speed of ocean waves so that the mass of seawater used is equivalent to the mass of seawater in its observations.

The Helmholtz method can be used to determine the magnitude of ocean currents and the Lagrangian method can be used to determine the direction of ocean currents at a certain depth. The results of observations of the pattern of ocean currents at the coastal area of Tegal City, show that on the natural coast of Tegal City around the port, the speed of the ocean currents is not too large. This is indicated by sea waves that are not so high. Wave power is 44.4 watts.

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