JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 6 No 2 2022

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online : 2679–3608

Measurement and Analysis of Acoustic Surface Scattering for Oil Concentration

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Received: August 09, 2022
Accepted: October 26, 2022
Published: October 26 , 2022

Abstract

The life of maritime flora and wildlife are substantially impacted by oil's effects, and this has an immediate impact on livelihoods. The impact disrupts the lives of contaminated coastal communities. Because of the potential losses caused by oil pollution, the government enacts policies governing environmental conditions in order to maintain or improve the quality of the polluted sea. The purpose of this study was to calculate the acoustic backscattering value of oil using a single beam echosounder and compare the measurement results from a single beam echosounder with the results of gravimetric analysis. The data acquisition was carried out in March 2021 at the Marine Acoustic Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University, using the SIMRAD EK-15 frequency of 200 kHz and oil used as a source of pollution, namely the dexlite type (density of 880 kg/m3). The results showed that the value of Surface Backscattering Strength (SS) decreased when contaminated with oil, namely -63.76 dB and -65.90 dB, but when oil was added back, the SS value increased to -50.81 dB. The relationship between oil concentration and surface backscattering strength shows a negative correlation between the variables, and the level of the relationship between variables is 0.85.

Keywords: Single Beam Echosounder, Oil Spill, Acoustic Laboratory.

1. Introduction

Marine pollution is the entry or inclusion of living things, substances, energy and/or other components into the marine environment by human activities so that the quality drops to a certain level, which causes the marine environment to no longer comply with quality standards and/or functions (PP No. 19 1999). One source of pollution that is of concern to the public is oil pollution. This is because thousands of tons of oil are spilled into the sea every year due to anthropogenic activities such as ship accidents or leaking oil extraction pipes. and natural events such as natural seepage from seabed structures (Pilzis and Vaisis, 2016). In addition, the impact of oil pollution significantly damages the survival of marine flora and fauna and in a short time affects livelihoods and disrupts the survival of contaminated coastal communities (Rehulina and Hermanto, 2015).

Due to the large amount of loss that can be caused by oil pollution, the government enacts policies governing environmental conditions in order to maintain or improve the quality of the polluted sea (PP No. 19 of 1999). In an emergency, swift, accurate, and coordinated action is required to deal with oil spills in the water in order to stop their spread, reduce their environmental effects, and lessen community losses and harm to the marine ecosystem (PERPRES No. 109 of 2006). Measurement of oil concentration is a crucial element that must be understood for controlling and countermeasuring since it serves as a gauge for the sea condition or the degree of pollution.

The concentration of oil can be determined using traditional techniques, remote sensing, or acoustics. The traditional approach takes a longer time since each water sample has to be analyzed using the gravimetric method in a laboratory (Tanjung et al. 2015). As a result, a strategic option utilizing an acoustic method is considered. According to Manik (2014), the benefits of adopting the acoustic method include quick, real-time computations and estimations with high degree of accuracy and precision. A single beam echosounder, such as Simrad EK-15 is well suited, and was utilized in this investigation because of its broad transducer.opening angle which is excellent in shallow water and can cover a larger region (Simrad.online). The purpose of this study was to calculate the acoustic backscatter value of oil spill using a single beam echosounder and to compare the measurement results with the results of gravimetric analyses.

2. Research Method

2.1 Data Acquisition

The data acquisition was carried out in March 2021 at the Marine Acoustic Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University. Gravimetric analysis was carried out at PT. Petrolab Services, East Jakarta.

This study takes the advantages of echoview (Demo), Microsoft Office, and Matlab softwares to handle acoustic recording data from the SIMRAD EK-15 (200 kHz) instrument. Dexlite oil, with a density of 880 kg/m3, is employed as a source of pollution. Every 5 L up to 15 L of this oil is poured into the water tank, and 1 L of the oil-contaminated water is sampled for gravimetric analysis.

Acoustic equipment installed was first calibrated. The calibration was carried out using a standard target (Foote et al. 1982) of a 3.81 cm diameter ball sphere submerged at a depth of 30 cm in a water tank with a temperature of 26.5^{o} C and a salinity of 0.1 ppt for up to 5 minutes (Figure 1).

2.2. Data Processing

The Volume Backscattering Strength (SVb) value was processed using echoview 4.0 software (Demo). Backscattering data from the SIMRAD EK-15 instrument was analyzed to obtain the Surface Backscattering Strength (SS) value. The threshold used in data processing ranges from -65 dB to -35 dB with Elementary Sampling Distance Unit (ESDU) 5 pings. According to Katsnelson et al. (2015) the value of the acoustic surface backscattering strength (SS) can be obtained using the ring surface scattering model (RSS Model) as follows:

$$S_s = \frac{S_{Vb}\,\phi\,(\frac{c\,\tau}{2})}{\phi} \quad (1)$$

Where (ϕ) and (ψ) are the equivalent beam angles for the surface and volume scattering, c is the speed of sound, and τ is the pulse width. According to Manik (2011), the Surface Backscattering Strength value is obtained from the relationship between the coefficient Svb and the coefficient Ss, and the beam angle integration value for backscattering volume (ψ) is equivalent to the beam angle for the base surface (ϕ). The SS value is obtained using the logarithmic equation:

$$S_s = 10\log\left(\frac{c\tau}{2}\right) + S_{VB} \quad (2)$$

The oil concentration test method is based on SNI 6989.10-2011. The estimated oil concentration can be calculated by the equation :

$$\text{Oil Concentration (SDC) (mg/L)} = \frac{(A-B)x\ 1000}{mL\ test\ sample} \quad (3)$$

where A is Flask weight + extract (mg) and B is Empty flask weight (mg).

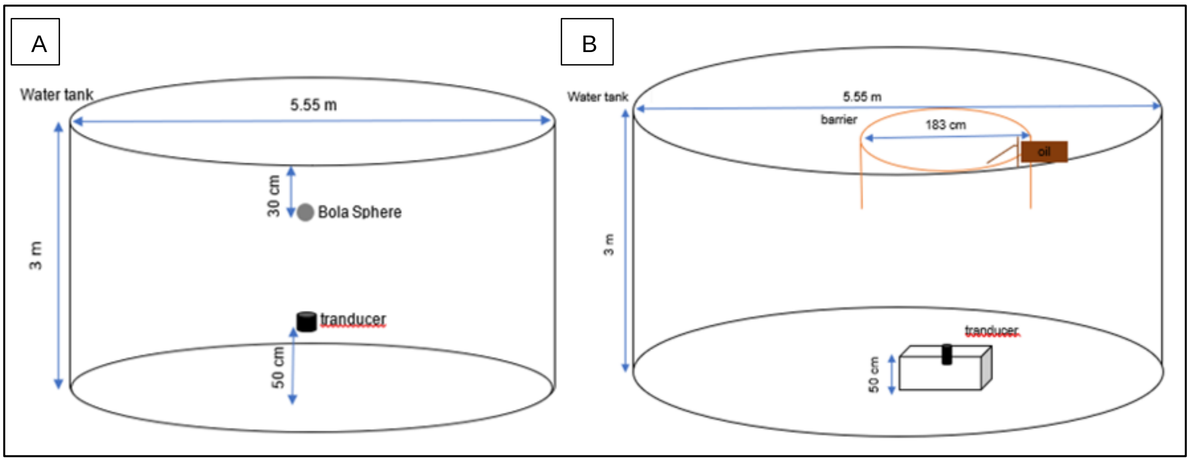

Figure 1. Illustration of echosounder calibration (A) and data acquisition (B). The transducer was set to look upward

3. Result and Discussion

3.1. Echogram

Each acoustic pulse (echo) emitted and reflected by the target contains a variety of information. The results of acoustic recordings can generally be displayed in the form of an echogram containing information about the characteristics of the detected target (Preston and Collins, 2000). An echogram is a graphic display produced by the echosounder as a function of time, the strength of the echo, and the time for an echo to return. The color scale on the echogram shows the distribution of the target strength acoustic reflection value obtained from the recorded raw data. Figure 2 below is an echogram display of acoustic recordings processed using echoview 4.0, which shows the Volume Backscattering Strength (SVb) value.

Based on the acoustic reflection echo recorded in Figure 2, depth of below 1 m is a near field. The near field is important that needs to be considered when recording acoustic data, which is identified as area of energy loss. According to Simmonds and MacLennan (2005), near-field is a distance from a transducer surface to where there is a high intensity or pressure fluctuation. Oil has a lower density than water, and according to the Archimedes principle, an object will float if the density of object is less than the density of liquid (Anjarsari et al. 2015). Based on this principle, the color range that indicates oil is green to red, which ranges from —50 dB to —38 dB.

3.2. Surface Backscattering Strength

The ratio of the sound transmitted intensity and the sound intensity reflected by water surface is known as surface backscattering strength (SS). The peak echo value of the water's surface reflection (SS value) is shown in Table 1. The results of the SS value calculation are shown below. It is known from Table 1 that the SS value is less than the SV value. This is due to the fact that the SS value only accounts for acoustic reflection from the water's surface, but the SV value accounts for reflection from the water's surface to the depth of integration (Hamuna et al. 2017).

Table 1. The calculation results of Surface Backscattering Strength (SS)

Treatment	SV_B(dB)	SS (dB)
0 L	-38.14	-50.35606
5 L	-45.90	-58.11539
10 L	-48.17	-60.39006
15 L	-37.13	-49.34706

Table 1 demonstrates that the SS value changed from -58.12 dB to -60.39 dB when the sample was contaminated with oil, but it rose to -49.35 dB when oil was added. Research on this topic has been conducted by previous researchers. The results of Fuller at al. (2013) showed that the maximum ABS response was obtained at the highest oil concentration of 17 L/L at -62 dB and in experiments using twice as much oil concentration resulted in maximum acoustic backscattering strength (ABS) at -58 dB and -59 dB. The difference between these values and the results of present study could be caused by the use of different instruments and frequencies. Fuller's at al. (2013) study used Teledyne RDI StreamPro ADCP with a frequency of 2400 kHz. According to Chakraborty et al. (2007), the use of dual-frequency acoustic instruments will give different results. A low frequency will give a higher acoustic reflection value than a high frequency on the same bottom of the water. The state of water, which includes its physical and chemical characteristics as well as the state of the water's bottom, is another aspect that is hypothesized to contribute to variations in the SS value.

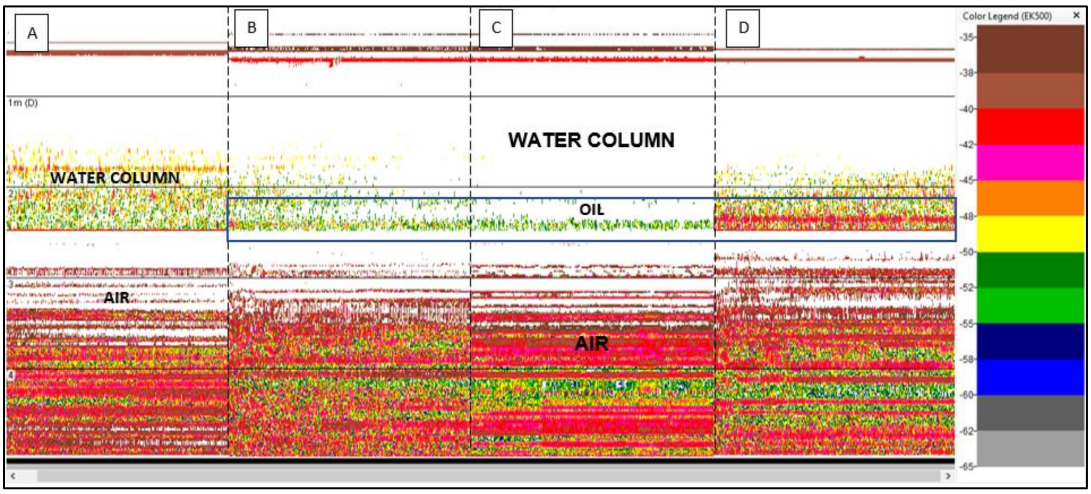

Figure 2. Echogram volume backscattering strength (SVb) of the water-air interface (A), water-oil (5L)-air Interface (B), water-oil (10L)-air interface (C), and water-oil (15L)-air interface (D)

3.3. Correlation Between The Value of Surface Backscattering Strength and Oil Concentration

Oil samples were taken on the water surface with the assumption that the added oil would create a layer above the water surface because oil has a lower density than water (Gumilar et al. 2016). Table 2 shows the value of oil concentration based on gravimetric analysis, which shows a discrepancy in the concentration values to the amount of oil poured. This is in contrary to the Qowiyah's et al. (2001) study where the level of oil found depends on the level of oil spilled in the waters. However, as seen from Figure 2, when 15 L oil was poured, an oil layer is formed below the water surface. The results of the gravimetric analysis were obtained as a comparison of the Surface Backscattering Strength value.

Table 2. Oil concentration based on gravimetric analysis

Treatment	Oil concentration (mg/L)
5 L	30900
10 L	59400
15 L	14500

Correlation between the Surface Backscattering Strength value and the thickness of oil concentration was analyzed using simple linear analysis where the x-axis is the logarithmic oil concentration and the y-axis is the Surface Backscattering Strength (SS) value in dB.

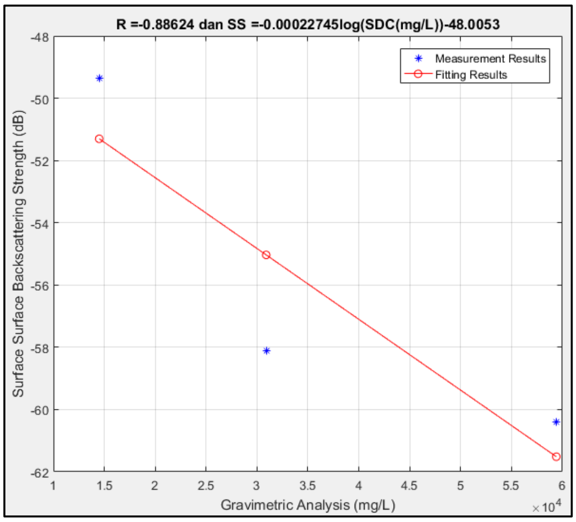

Figure 3. Correlation between oil concentration and surface backscattering strength

Figure 3 shows the correlation between oil concentration and surface backscattering strength. The level of correlation between oil concentration and surface backscattering strength can be seen in the correlation coefficient (R). According to Sugiyono (2018), the correlation coefficient (R) indicates direction and strength of relationship between two or more variables. Drection is expressed in the form of a positive or negative value, while the strength or weakness is expressed by magnitude of correlation coefficient. Figure 3 shows a negative correlation between the variables tested, and the level of relationship between variables is 0.85. This shows that the increase of oil concentration will be followed by the decrease of surface backscattering strength and vice versa. The correlation magnitude of the effect of oil concentration to the surface backscattering strength is 88%, while the other 12% may come from other factors.

4. Conclusion

The results of this study shows that Simrad EK 15 can be used in detecting oil spills. Surface backscattering strength is inversely proportional to the oil concentration. The surface backscattering strength obtained ranges from -58.12 dB to -49.35 dB. There is a difference between the value of the oil concentration and the total oil spill, so further development and field evaluation are needed to improve the reproducibility of the response and validate the surface backscattering strength method as a tool for measuring oil spills.

Acknowledgments

The authors acknowledge the provincial government of West Java (JFLS) for providing assistance with the cost of high-level education.

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