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Visible reflectance characteristics of marine debris in the sandy beach

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Abstract; Marine debris has become a global threat to the coastal and marine areas, and the major causes for the decrease in the quality of aquatic environment. The study was aimed to document the spectral features of several types of marine debris based on criteria and developing spectral libraries which can distinguish between debris and substrate where the marine debris location is found. The marine debris data was collected from the coast of Makassar City, South Sulawesi. The spectral sample was measured using a 4000 A spectroradiometer that works on a wavelength spectrum 340 - 1040 nm. The results showed that the identification of marine debris on the optimal sandy beach can be done at 480-620 nm wavelength.

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1. Introduction

Marine debris has become a global threat to the coastal areas and is one of the causes for the decline in the quality of the aquatic environment [1][2][3]. The information on the spectral reflectance of marine debris can be important information in identifying the distribution of debris in coastal and marine areas. Several studies have tried to exploit hyperspectral data to study marine debris [4][5][6][7][8] and [9] have conducted research on the debris distribution in the coastal area using high-resolution imagery with object delineation techniques taking into account the element of interpretation. More specifically [10] has developed the hyperspectral concept about the introduction of plastic debris based on color, transparency, reflectivity, and the shape of plastic debris at visible wavelengths and short-wavelength infrared (SWIR)

In this study, we were interested in examining how the spectral characteristics of several type of marine debris are in the coastal region, at visible wavelengths during two conditions, sand air-dry (located outside the tidal range) and wet sand conditions (in the tidal range). The objectives of our study are: (1) documenting the spectral features of several types of marine debris based on NOAA criteria and (2) developing spectral libraries to identify marine debris so that it can be distinguished between debris and substrate where the marine debris location is found. This study is expected as a basic information about the optical character of marine debris in the beach area which is generally associated with sands and can be used as a basic reference in the interpretation of satellite images in exposed coastal areas.



2. Methodology

2.1. Spectral Collection

Field data collection was carried out at three stations in the coastal of Makassar City, South Sulawesi (5,195 S, 119,352 E and 5,081 S, 119,429 E) (Figure. 1). All stations were located near the waterways that come from the city of Makassar that would potentially bring marine debris to the sea; Station 1, estuary of Jeneberang River; station 2, Losari Beach and station 3, estuary of Tallo River Marine debris were collected and identified according to NOAA (2015). The marine debris classified as plastics, Styrofoa¹³s, metals, woods, clothing's, and ceramics with a minimum size of each sample of 5 cm x 5 cm. The total number of samples for each type of marine debris is 30 pieces. The spectral value of the sample was measured using the Ocean Optics USB 4000 type spectrometer which works on a wavelength 340-1110 nm (nanometer). Spectral data collection was obtained on September 2018 under generally clear skies. The data collection occurred between 10.00 a.m. until 02.00 p.m. Central Indonesia Standard time. The spectral retrieval process involves spectrometers, light sources, optical fibers, and computers. One spectroradiometer part is connected to the light source and the other part is connected to the object being measured. The position of the light source does not directly face the sun but forms an angle of approximately 45° and 100 millisecond scanning time [11].



Figure 1. Study area are Makassar Coastal Water, South Sulawesi, Indonesia

2.2. Data Analysis

Data analysis used numeric data processing devices, the measurement data was classified by eliminating error values and cutting off visible and near-infrared light waves. Furthermore, [12] data was made into graphical form with smoothing graphs and were statistically analyzed using One-Way Analysis of Variance to evaluate differences of spectral reflectance curves among each sample. The spectral reflectance curves were then compared to spectral reflectance of beach sand during dry conditions (occurring during low tide or beach sand which is not affected by tidal-range) and beach sand during wet conditions (occurs during high tide or beach sand which is still affected by tidal rides) by [12]

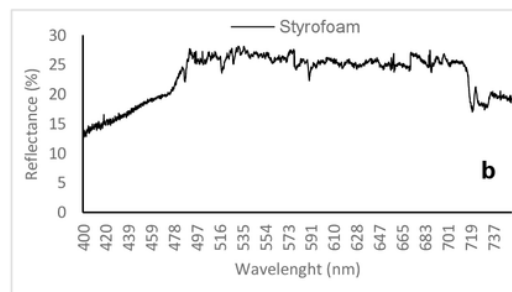
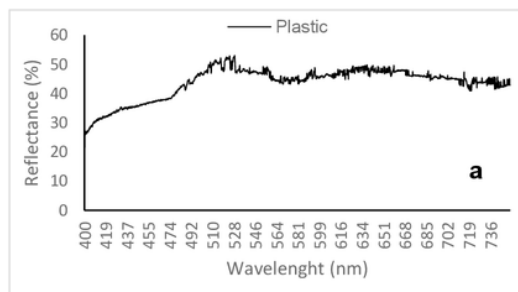
3. Results

3.1. Spectral Analysis

Reflectance spectra were recorded (mean \pm Std, range 0-1) on seven 7 categories of marine debris [13] as shown in (Figure. 2). At the time of measurement, the age and quality of samples were not differentiated because hyperspectral measurement was conducted directly touching the object.

Reflectance curves of plastic, Styrofoam, metal, paper, wood, and ceramic have similar reflectance patterns, except for cloths have no similarity to other types of samples. Based on (Figure. 2a), the type of plastic debris is the highest reflectance value compared to other debris, the peak reflectance is found at the wavelength of 528 nm and the minimum reflectance is at 400 nm with each reflectance value 53.05% and 25.71%. In (Figure. 2d), the type of metal debris has the second highest average reflectance value of the whole measured sample. The highest reflectance value at the wavelength of 605 nm and the minimum reflectance value at a wavelength of 400 nm with reflectance values of 51.61% and 26.85%. (Figure. 2c) shows that the reflectance curve of clothing debris is the lowest compared to other types. The highest reflectance value of clothing debris is found at a wavelength of 531 nm with a reflectance value of 28.13% with a reflectance value of 12.80%. The overall spectral data shows solid objects on average have similar spectral patterns.

Specific differences of each spectral reflectance curve of each marine debris are tested using a variance analyses in three categories of visible wavelengths namely blue band (450 - 510nm), green band (530-590 nm) and red band (630-670 nm) at the level of confidence $\alpha = 0.05$ as in (Table 1). The results of the variance analysis on the blue band showed a difference in spectral reflectance ($p < 0.05$) for the type of plastic with cloth, for other samples it did not show a difference. In the green band, the results of variance analysis ($p > 0.05$) showed no difference between each reflectance curve of all types of marine debris. The same pattern with band blue was found in the red band, where the results of the variance analysis showed a difference in the spectral reflectance curve between the types of marine debris at ($p < 0.05$) except the spectral reflectance curve of plastic with the cloth.



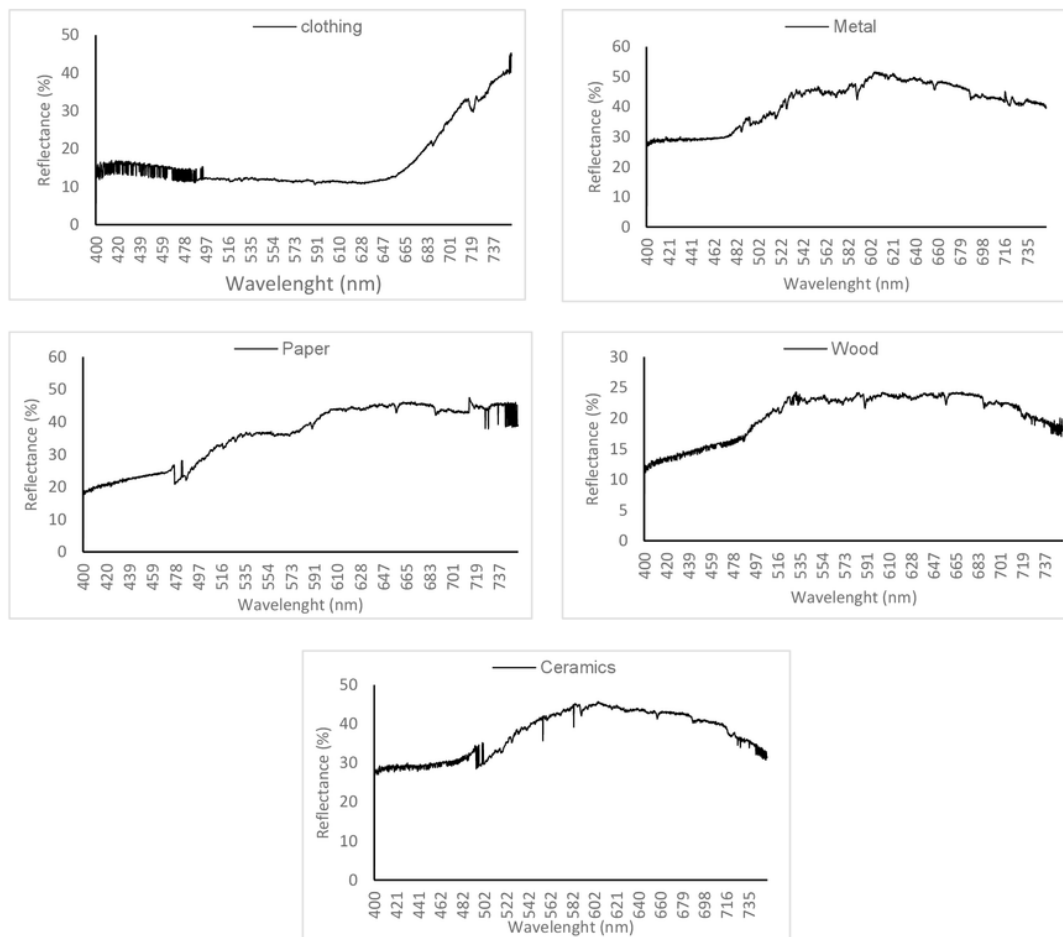


Figure 2. Reflectance spectral of marine debris: (a) plastic, (b) Styrofoam, (c) clothing, (d) metal, (e) paper, (f) wood and (g) ceramics

Table 1. Range of reflectance spectra marine debris on the visible (blue, green and red) wavelength

Type of Samples	Band Blue (450 – 510nm)		Band Green (530-590 nm)		Band Red (630-670 nm)	
	Range	Average ± SE	Range	Average ± SE	Range	Average ± SE
Plastic	34.83 - 49.03	41.68 ± 4.11 ^a	37.46- 61.19	46.08 ± 7.59 ^a	41.90-56.54	47.54 ± 4.54 ^a
Styrofoam	13.34 - 37.74	22.58 ± 7.63 ^{ab}	6.45-37.57	26.65 ± 5.2 ^a	5.43-36.54	25.33 ± 9.97 ^{ab}
clothing	4.69 - 22.05	13.57 ± 4.01 ^b	5.45-21.99	11.65 ± 5.2 ^a	7.60-23.47	13.65 ± 4.95 ^b
Metal	24.37 - 37.09	32.33 ± 6.93 ^{ab}	27.37-55.75	45.45 ± 9.06 ^a	41.57-51.33	48.07 ± 3.25 ^{ab}
Paper	16.59 - 37.78	25.53 ± 6.33 ^{ab}	18.89-47.63	37.44 ± 9.29 ^a	30.08-56.18	45.13 ± 7.79 ^{ab}
Wood	8.15 - 27.1	17.13 ± 5.49 ^{ab}	4.85-34.13	23.13 ± 9.2 ^a	5.32-36.62	23.76 ± 9.4 ^{ab}
Ceramics	21.14 - 44.1	30.68 ± 6.91 ^{ab}	39.87-46.02	41.99 ± 2.01 ^a	35.12-52.13	43.04 ± 4.94 ^{ab}

*The letters (a and b) indicate the result of One-Way Analysis of Variance. The same letter indicate there is no significant difference ($\alpha=0.05$).

3.2. Reference Spectral Analysis

The focus of observing marine debris in this study is debris found in sandy beach areas. There are two phenomena of the sand condition on the beach, in some parts that are not exposed in the tidal range, they tend to have dry sand; whereas, in areas that are exposed in the tidal range, they tend to be wet. In identifying marine debris using spectral reflections of objects from remote sensing technology, it is necessary to compare the spectral reflectance curves of marine debris with the spectral reflectance curve of sand in wet or dry conditions [12]

A comparison of the spectral reflection curves between marine debris and sand based on [12], can be seen in (Figure. 3). In general, the reflectance curves of plastics, metals, and ceramics differ from the sand reflectance curve both in wet and dry conditions. The spectral curves of Styrofoam's and woods are different with the sand reflectance curve when wet but are similar to the reflectance curve of sand when dry. While cloths reflectance curve is similar to sand when wet and lower than sand when dry.

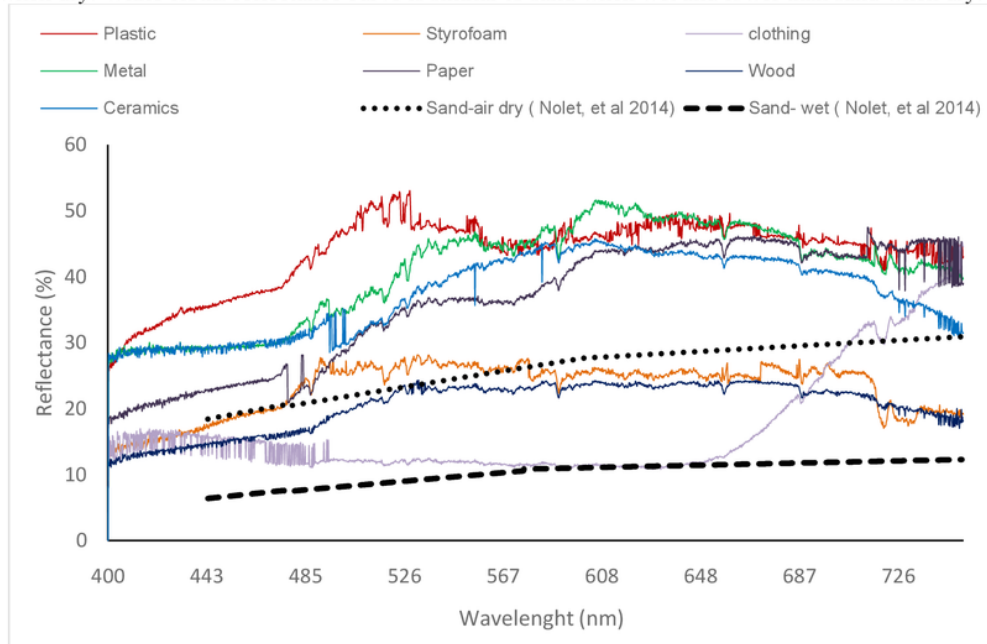


Figure. 3. Comparison of the average value of marine debris (plastics, Styrofoam's, metals, woods, clothing's and ceramics) reflectance with sand reflectance (air dry and wet by [12])

Further description for the identification of marine debris objects based on reflectance at different wavelengths as shown in (Figure. 3). In the Blue Band (450 – 510 nm), ceramics, plastics and metals are very easy to distinguish from sand in wet or dry conditions. Styrofoam, woods and cloths cannot be distinguished from dry sand but are easily distinguished from wet sand. For the Green Band (530-590 nm), it is very easy to distinguish plastics, ceramics and metals from sand in dry or wet conditions. There are difficulty to distinguish between Styrofoam and woods with dry sand, and to distinguish between cloths with wet sand. Furthermore, in the red band (630-670 nm), it is possible to distinguish all type of marine debris in both sand conditions, only cloths that is difficult to differentiate from sand in wet conditions.

4. Discussion

The Tuckey post-hoc analysis revealed that when the entire spectral curves are compared at various wavelengths, there is a significant difference between plastic debris and clothing debris in the blue and red wavelength ($p < 0.05$). While other types of debris do not have a significant difference. This difference is possibly caused by the shape of the object or the object material density [10] [14] The causes may also relate to the main components of the objects [15].

The spectral reflectance curve in (Figure. 2) and the results of the variance analysis in (Table. 1) imply that the reflectance curve of marine debris at various wavelengths has distinctive characteristics. The different characteristics are the difference in spectral reflectance values and the spectral curve pattern difference. These differences in characteristics will be a reference to object recognition in remote sensing technology [16][17].

In general, plastics, metals, and ceramics show similarities in the spectral reflectance curve, in which their maximum reflectance is at a wavelength of 610 nm and their minimum reflectance is at a wavelength of 400 nm. On the other hand, papers and cloths have maximum reflectance at a wavelength of 750 nm. This fact further reinforces the evidence that the density of objects greatly influences spectral reflections at visible wavelengths [10][18].

Our results show that the spectral identification of marine debris in sandy beaches areas is possible, as seen in (Figure. 3). Identification of marine debris according to NOAA criteria [13] in wet sand conditions can be done because the spectral reflectance curve is distinctly differ for each debris type, except for clothing debris. However, in dry sand conditions, it is only possible to identify plastics, Styrofoam's, metals and clothing debris, but it is difficult to recognize papers and wood debris.

The optimal wavelength that can be used to collect debris on a sandy beach is 480 - 620 nm. This spectral reflectance information will be the basis for multispectral classification in the interpretation of satellite images as stated in [17]. The utilization of marine debris reflectance curves can support in the identification and classification of multispectral mapping of the distribution of marine debris in beach areas. However, in the implementation of identification of marine debris can only be done at locations of marine debris accumulated in large quantities and other constraints will greatly depend on the spatial resolution of satellite imagery used [9].

The difference in spectral reflectance of marine debris with sand from this study will be a reference in the multispectral classification method of remote sensing technology. Therefore, mapping of marine debris distribution on a large scale and mapping of marine debris with remote sensing techniques can be an effective solution in the management of marine debris.

5. Conclusion

This study revealed a high reflectance variability of marine debris at the visible wavelength. This encourages the development of marine debris identification with hyperspectral technology. Identification marine debris on sandy beaches are optimum at 480-620 nm wavelength (green and red wavelengths). This value will be a reference for the multispectral classification of remote sensing techniques in mapping marine debris in the sandy beaches.

6. Acknowledgement

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