海洋マイクロプラスチックの劣化の時空間動態に関する研究

[課程博士・論文博士共通]

博士学位論文要約
Summary of Dissertation

専　攻 Major	Applied Marine Environmental Studies	氏　名 Name	CELIK MURAT
論文題目 Title	Studies on spatio-temporal dynamics of marine microplastic degradation		

In recent years, the production of plastic worldwide has exceeded 400 million tons. A significant amount of this plastic is finding its way into the oceans through rivers. Currently, an estimated 0.27 million tons of plastic are floating on the sea surface, with a large amount also moving to the seabed. As plastics leak into the ocean, they are degraded due to the effects of UV, temperature change, and waves, gradually breaking down into smaller particles. While the concentration of microplastics in the ocean is becoming clearer, it is not yet fully understood how their fluctuation of concentration changes or behaves over time. To gain a better understanding of the fluctuation of microplastic concentration in the sea, it is crucial to elucidate the process and movement of microplastics resulting from plastic degradation and miniaturization. Therefore, it is essential to determine the length of time it takes for plastic to deteriorate in the marine environment. Furthermore, the degradation of microplastics on the sea surface must be considered when examining their behavior in the ocean. The carbonyl index (CI) is widely used to evaluate the degree of degradation due to plastic oxidation. This index is calculated from the ratio between the integrated band absorbance of the carbonyl peak and that of the methylene scissoring peak using attenuated total reflection (ATR)-FTIR spectroscopy. This study aims to calculate the CI of various microplastic samples taken from sea areas around Japan, examining the relationship between the properties of the microplastics and their CI. By doing so, it will be possible to clarify the state of deterioration and the fate of plastic in the sea area. To achieve this goal, the 'Specified Area Under Band' (SAUB) technique will be employed with ATR-FTIR spectroscopy. According to this method, the CI was calculated from the ratio between the integrated band absorbance of the carbonyl (C=O) peak from 1,850 to 1,650 cm^{-1} and that of the methylene (CH2) scissoring peak from 1,500 to 1,420 cm^{-1}. This method will allow us to determine the CI of each sample by analyzing the absorbance of specific peaks. Ultimately, the results of this study will provide valuable insights into the behavior of microplastics in the ocean and help to identify strategies to mitigate their impact on the environment.

In Chapter 1, explained the background of the present condition and degradation process of microplastics with expressed the purpose of this study.

In Chapter 2, the purpose of this study is to investigate the carbonyl index (CI) of polyethylene and polypropylene microplastics (MPs) collected in coastal waters around Japan and to explore the relationship between the properties of MPs and their state of plastic deterioration in the sea area. To achieve this goal, neuston net surveys were conducted in July and August 2017 and August 2018 from seven stations around the Japan coast. The CI of MPs was calculated by using the SAUB method, and the results showed that the mean MP CI in all samples was 0.69 and 0.70 for polyethylene and polypropylene, respectively. No significant difference was found in the color or shape of the MPs. The study also found that the polyethylene MPs CI was negatively correlated with the major length of the MPs ($p < 0.05$). Furthermore, the study discovered that large MPs with relatively little deterioration were distributed off the west coast of the Sea of Japan off Shimane Prefecture. In contrast, small MPs were distributed off the east coast of the Sea of Japan off Toyama Prefecture and of the Pacific Ocean off Ibaraki Prefecture. This result implies that the CI and size of MPs in the sea area

correspond to the degree of their degradation. In conclusion, this study provides valuable insights into the behavior of microplastics in the ocean and their impact on the environment. By examining the properties of MPs and their degree of degradation, it is possible to develop effective strategies to mitigate their negative effects on the marine ecosystem.

In Chapter 3, the aim of the study was to calculate the values of the CI of the most commonly used polymers, such as polyethylene (PE) and polypropylene (PP) particles, which are in the size range of 50 µm to 350 µm. This would enable the determination of the degradation behavior of microplastics (MPs) in the environment, especially those that are less than 350 µm in size. To collect these small MPs, a double neuston net was used to collect samples from the offshore regions of Tokai and Tokyo Bay in Japan. After collecting the samples, 59 SMPs were analyzed, with 49 of these particles identified as PE and 10 as PP. The measurements revealed that the mean length of the PE particles was 65.06 µm, while the mean length of PP particles was 94.91 µm. Furthermore, the mean value of CI of PP was found to be 2.52, while the mean value of CI was 2.58 for PE. On the other hand, the CI values of PE particles had a slightly wider distribution range, which was between 2.1-3.1. The study found a moderate but statistically significant correlation ($p < 0.05$) between the length and CI for PE ($r^2 = 0.087$) and a weak correlation ($p < 0.05$) for PP ($r^2 = 0.149$). From the results of Chapters 2 and 3, the study concluded that the CI values of SMPs are generally higher than those of LMPs. This means that the smaller the particle size, the higher the CI value. The findings of this study are significant in helping to understand the environmental impact of MPs and the degradation processes that occur in the environment. By determining the CI values of different types of polymers, researchers can gain insights into the behavior of these particles in the environment and their potential impact on marine ecosystems. Overall, the study highlights the need for continued research into the impact of MPs on the environment and the development of effective strategies to mitigate this impact.

In Chapter 4, the results obtained from the previous chapters were used to discuss the findings on the CI of MPs. The SAUB method was used to calculate the CI of 2950 PE and PP samples collected from seven stations in the sea surrounding Japan. The study found a negative correlation between the length and CI of MPs when expressed as mean values for each station. Additionally, the small MPs (50-350 µm) CI was significantly larger than the CI of larger MPs, indicating that MPs are degraded at the sea surface and become smaller particles. The study concluded that the CI and length of MPs are useful indicators for determining the degree of degradation of MPs in a given area. The standard deviation of the small MPs CI was also found to be smaller than that of larger MPs, indicating that MPs on the sea surface had deteriorated and had sunk into the seawater as fine particles. The findings of this study suggest the need for further research into the behavior of MPs on the sea surface of other areas and the MPs that sink into the seawater. This research would provide valuable insights into the impact of MPs on marine ecosystems and help to develop effective strategies for mitigating this impact. Overall, the study highlights the importance of continued efforts to monitor and regulate the release of plastic waste into the environment.