Comprehensive Studies on Oceanic Transport, Environmental risk, and Advanced Monitoring of Marine Plastic Debris

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[Abstract]

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A total of 8,218 pelagic microplastic samples from the world's oceans were synthesized to create a dataset composed of raw, calibrated, processed, and gridded data which are made available to the public. Using the dataset for validation, a budget for ocean plastic mass was estimated based on a combination of numerical particle tracking and linear mass-balance models. Integrating the time series of worldwide macroplastic emission from both rivers and the fisheries industry over the period 1961–2017 yielded a total mass of 25.3 million metric tonnes (MMT). Overall, 23.4% of ocean plastics were macroplastics on beaches. Meanwhile, 66.7% of ocean plastics were heavier than seawater or microplastics removed from the upper ocean and beaches, which are difficult to monitor under current observation frameworks adopted worldwide. Part of removal from the upper ocean is caused by settling processes into the deep layers. The settling processes were also evaluated using a sediment trap and sediment cores sampled from the actual ocean.

When medaka fish was exposed to microplastics (MPs) (2, 20, 200 μm), MPs (except 2μm MP) were rapidly accumulated in and then eliminated from bodies. From the results of MPs exposure studies, no effect was observed in survival and reproduction of medaka and artemia, while some gene expression levels were changed in the medaka intestine and artemia whole body. Ubiquitous occurrence of hydrophobic chemicals such as polychlorinated biphenyls and polycyclic aromatic hydrocarbons (PAHs) as well as sporadic occurrence of high concentrations of additives such as brominated flame retardants and benzotriazole UV-stabilizers in neuston and beaches MPs were revealed. Medaka was exposed with anthracene and/or MP. As a result, PE-MPs may act as a vector to concentrate and transfer anthracene to medaka upon ingestion, but the presence of these particles may have limited adverse effects on fish under the co-exposure systems of the type used in this study. It was revealed that benthic invertebrates that ingested MPs accumulated chemical compounds such as PCBs and additives associated with MPs, and that they were transferred to benthic fish through the consumption of prey invertebrates that consumed MPs. Another experiment was conducted that fed plastic to chicks of streaked shearwater demonstrated that plastic ingestion has some negative impacts on its organ weight, and that plastic additives were transferred to the tissue of birds. Analysis using a next-generation sequencer revealed different gene expression patterns in the exposed and control groups of the seabird, especially in the thyroid hormone system and bile acid synthesis system.

We developed a method for collecting fine MPs distributed on the sea surface to a depth of 800 m using a multiple open/close net and a deep-sea pump, as well as a pretreatment process for the collected specimens and an efficient microscopic Fourier transform infrared operation method for detecting fine MPs. Furthermore, the effectiveness of coumarin as a fluorescence index was clarified in detection using optical characteristics of MPs, and a detection method based on polarization parameters of MPs was suggested to be effective for detecting MPs in water. It was found that MPs in sediment samples of the trench-trench-trench type triple junction in the Japan Trench and suggested that MPs may have been supplied to the trench via sediment flow from shallower waters close to the coastlines of Japan. In addition, an automatic MPs detection method was developed to clarify particulate or fibrous material and measure the number and length of MPs. We proposed and developed a method for estimating marine plastic debris volumes on beaches by combining unmanned aerial vehicle surveys and image processing based on deep learning.

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