Plastic in the Ocean: Microbial Transformation of an ‘Unconventional’ Carbon Substrate

Sprawozdania

Informacje na temat projektu

VORTEX

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Strona internetowa projektu

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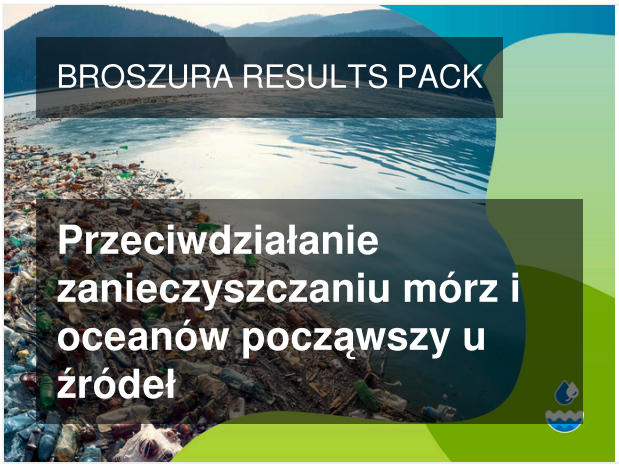
Ten projekt został przedstawiony w...



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Periodic Reporting for period 4 - VORTEX (Plastic in the Ocean: Microbial Transformation of an ‘Unconventional’ Carbon Substrate)

Okres sprawozdawczy: 2022-12-01 do 2024-05-31

Podsumowanie kontekstu i ogólnych celów projektu

Large quantities of plastics are released from terrestrial environments into the marine realm, creating significant environmental problems. The severity of this issue is increasing as the demand for plastic, and consequently the release of plastic debris into the ocean, continues to rise. Most plastics are petrochemical in origin, derived from the polymerization of monomers to create synthetic organic polymers. Their versatile properties have driven mass production to meet the growing demand for plastics in a wide range of applications. Nowadays, plastics are integral to almost all aspects of daily life, including transport, clothing, construction, and packaging materials. Due to waste mismanagement and littering, plastic debris accumulates widely in natural environments, including the ocean, heightening scientific concern and public awareness about plastic pollution.

Research has focused on microplastics (particle size: 1µm – 5mm) and, more recently, nanoplastics (particle size: <1µm), and their potential impact on the ocean environment. Micro- and nanoplastics can originate from primary industrial sources or from the degradation of macroplastics (particle size: >5mm). Various physical, chemical, and biological processes facilitate the fragmentation and degradation of plastics. Due to their small size, microplastics and nanoplastics become bioavailable and can bioaccumulate, although current evidence on biomagnification across marine food webs is ambiguous. Micro- and nanoplastics can negatively affect biota by causing inflammation, oxidative stress, and disruption of hormone signaling. Additionally, plastics often contain additives (e.g. softeners, flame retardants) that may be incorporated and lead to potentially harmful effects on host organisms. It is likely that organisms higher up in the food chain are also impacted by plastic pollution.

The longevity of plastic waste in the environment remains uncertain. Plastics are durable and degrade slowly, leading to the belief that they may persist in the environment for centuries or even millennia. However, floating plastics not only fragment in the marine environment but are also degraded through

photooxidation, which, combined with microbial degradation, might significantly shorten their lifespan. Moreover, plastics are rich in chemical energy, making polymer oxidation reactions exergonic. Therefore, plastic degradation can be a viable strategy for microorganisms to obtain energy and/or carbon. Earlier studies have shown that a diversity of microbes colonize plastic marine debris (PMD), and some evidence suggests that these communities are not merely opportunistic, but that different polymers may select for specific, plastic-related communities. Other studies have found terrestrial microbes that seemingly degrade some plastic polymers directly. Nevertheless, it is currently debated whether such metabolic traits exist in the marine environment and to what extent they contribute to plastic removal from the ocean.

A significant challenge in ongoing research is to clearly link apparent plastic degradation to microbial action and to determine the rate of plastic degradation. The overarching goal of the ERC project VORTEX is to assess the marine degradation of important plastics by applying innovative stable isotope assays in tandem with lipidomics, NGS-based microbial diversity, and functional gene analyses. VORTEX comprises three major objectives and work packages with clear interconnections: (i) to estimate the potential for and kinetics of microbial degradation of the most relevant plastics in the ocean, (ii) to identify and quantify key microbes mediating degradation, and (iii) to determine the boundary conditions that promote or hinder degradation and to identify potential pathways of degradation.

Prace wykonane od początku projektu do końca okresu sprawozdawczego oraz najważniejsze dotychczasowe rezultaty

The first phase of the project was dedicated to assembling the project team. VORTEX now comprises three PhD students, one postdoc, an associated guest postdoc, and a senior scientist (the PI). Additionally, several students conducted theirprojects within VORTEX. Another major task at the beginning of the project was to acquire 13 C-labelled polymers, some of which had to be custom synthesized. These labelled polymers are essential for several of the main scientific tasks in VORTEX, such as tracing labelled polymer into microbial degradation products and biomass. Further activities included the design and construction of field equipment, which was installed in contrasting ocean environments. Most long-term in situ installations were retrieved, one that was on a mooring in the North Pacific gyre (one of the trash vortexes), was lost (the entire mooring was lost). At coastal sites, we also installed experiments to monitor initial colonization, which were subsampled daily. From several colonization experiments, we extracted DNA and conducted community analyses to determine potential unique microbial community patterns.

We organised field expeditions for sampling and experimentation. We isolated microbes from plastic-associated biofilms and tested their ability to degrade plastic, and we are currently investigating the gene expression (transcriptome reconstruction) of one organism. We developed stable isotope probing techniques to determine rates of plastic degradation.

During years 3-6 (including an extra year applied for), we set up lab analysis workflows to quantify rates and the assimilation of plastic-derived carbon into lipid biomass and individual cells. The results

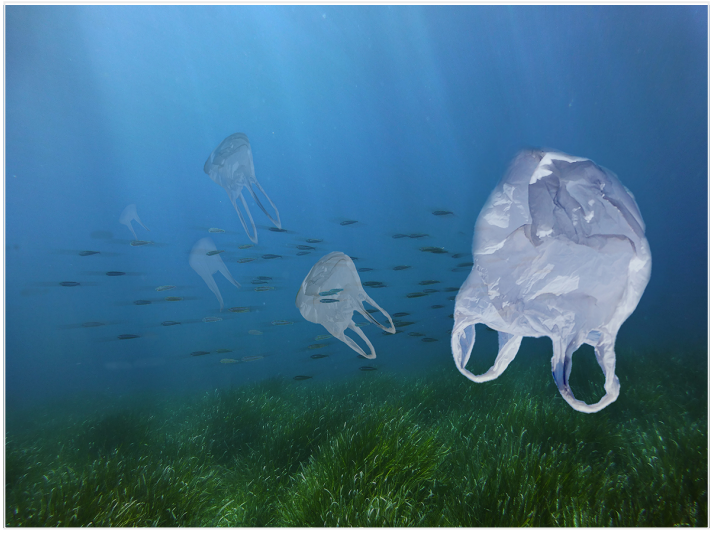
of these studies were published in top journals of the field (e.g. ISME Communications), and several are in review. In total, we have published over 12 papers, with six more currently in preparation, review, or accepted.

Innowacyjność oraz oczekiwany potencjalny wpływ (w tym dotychczasowe znaczenie społeczno-gospodarcze i szersze implikacje społeczne projektu)

In addition to our 'regular' work on plastic degradation by microbes, we also started to investigate coupled photooxidation and microbial degradation. We furthermore teamed up with colleagues from Utrecht University and developed a method to identify and quantify nano plastic in the ocean environment. Both attempts have been published successfully.

We also began collaborations with a biotech startup (FairFusion) for which I act as a counsellor for question related to microbiology. This companay aims at developing a plastic type that is degradable in both terrestrial and ocean environments and but which has initial properties similar to conventional plastic. We also started a collaboration with the OR foundation. This foundation seeks to improve the living circumstance of the local community in Accra, Ghana. We are, on the other hand interested in the wealth of microbes in the Accra Lagoon, as this contains very active plastic degraders. This collaboration is a bit in its infancy still (it started ~1 year ago) but both the scientific results (related to degradation kinetics) as well as the societal advancements (natural clean up activities of lagoon) are substantial.

In addition to the scientific work, VORTEX was also very active in public outreach activities. Team members are frequently interviewed by local, national, and international media to comment on questions related to marine plastic pollution and potential microbial degradation of plastic. A BBC camera team followed a cruise led by the project leader. The results of the filming constituted a substantial part of a two-hour documentary that aired in July 2020 on BBC4 (The Ocean Autopsy).



artist impression on the fate of plastic in the ocean

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