Pathways for degradation of plastic polymers floating in the marine environment

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Each year vast amounts of plastic are produced worldwide. When released to the environment, plastics accumulate, and plastic debris in the world´s oceans is of particular environmental concern. More than 60% of all floating debris in the world's oceans is plastic and the total amounts are increasing each year. Plastic polymers in the marine environment are exposed to sunlight, oxidants and physical stress, and over time they weather and degrade. The degradation processes and products must be understood to detect and evaluate potential environmental hazards. So far the chemicals generated by degradation of the plastic polymer itself have not been well studied from an environmental perspective. We reviewed the degradation pathways and chemicals that are formed from the six most widely used plastic types (polyethylene - PE, polypropylene - PP, poly(vinyl chloride) - PVC, polystyrene - PS, poly(ethylene terephthalate) - PET and polyurethane - PU) from literature of polymer engeniers. Since many studies report degradation experiments conducted under conditions that are not environmentally relevant, we made extrapolations for plastic floating in the ocean´s surface. Generally degradation can proceed by photo-induced oxidation, hydrolysis or by biodegradation. The potential degradation pathways and products depend on the polymer type. Degradation of polymers with a carbon-carbon backbone will preliminary be initiated by UV-radiation. After photo-initiation PE, PP and PS form free radicals and react with oxygen to form peroxy radicals, leading to chain scission. UV-radiation initiates dechlorination of PVC, forming hydrolitic acid and C=C double bonds in the main chain. Lower molecular weight fragments of these polymers are more susceptible to biodegradation and therefore abiotic degradation precedes biodegradation. Degradation of polymers with heteroatoms in the main chain, such as PET and PU, also proceeds mainly by photo-oxidation, hydrolysis, and biodegradation. Degradation of plastic polymers can lead to smaller fragments, like monomers and oligomers, and to the formation of new end groups, such as carboxylic acids.