Development of a research method for the assessment of microplastic degradation from the coastal belt of the Baltic Sea

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ABSTRACT

The presence of microplastics in the environment has been the subject of numerous studies and research in recent years; however, its monitoring and characterization, as well as the consequences of its occurrence, remain insufficiently understood. Scientific research at a global level has mainly focused on the sources of microplastics and their presence in individual products. An analysis of the literature data reveals that the lack of analytical standards related to adopting measurement methods and establishing the size and form of microplastic particles is a primary challenge. To date, no international, standardized procedures have been developed to regulate all aspects of monitoring (i.e., sampling, sample preparation, identification, characterization, degradation assessment, etc.), making data comparison challenging. Consequently, a study was undertaken to expand knowledge regarding the degradation of microplastics in the environment, particularly from the marine coastal belt.

The scientific objective of the dissertation was to develop a research method (research tool) for evaluating the degree and form of degradation, as well as the susceptibility of microplastics to degradation. An analysis was carried out, taking into account the effects of key environmental factors, such as UV radiation, temperature, biological and chemical factors, and mechanical forces on the degradation of microplastics. Microscopic techniques were applied to accurately determine the types of mechanical damage to the surfaces of microplastic samples. To ensure the data was computationally relevant, the planimetry method was employed, utilizing calibrated microscope cameras and dedicated software to measure the area of each characteristic element corresponding to mechanical damage on the sample surface.

The paper hypothesizes the need for advanced microscopic surface analysis in assessing the degree and susceptibility of microplastic degradation, enabling the identification and quantification of mechanical damage. The study demonstrated that mechanical damage to the surface of microplastics accelerates further fragmentation and initiates additional degradation processes by increasing the surface area exposed to factors such as UV radiation and microbial activity. It was found that mechanical degradation had a moderate impact on the largest number of samples tested. Significant variation in the degree of mechanical degradation was observed depending on the type, with mechanical forces related to cracking and cavities being predominant. The least amount of degradation occurred on microplastic surfaces affected by macroscopic erosion. The classification of mechanical degradation types, applied for the first time in research procedures, combined with advanced microscopic methods, offers the potential for quick and reliable analysis of the degree and susceptibility of microplastic degradation.

Another scientific problem was to confirm whether it is possible to develop a research method that enables the determination of the degree and form of microplastic degradation by integrating information about the properties of the plastic, sample shape, color saturation, biofilm presence, and results from mechanical damage analysis. Analysis of data collected during field and laboratory tests allowed for the development of decision-making algorithms that, by taking into account the interaction of these factors, enable the assessment of microplastic degradation under different environmental conditions. Based on this, a research method was developed that links information on plastic properties and measurement data (shape, color saturation, biofilm presence) with the analysis of mechanical damage. The interpretation of test results and validation of the research tool using environmental sample data confirm that it is possible to determine the degree and form of microplastic degradation, as well as its susceptibility to decomposition. The cumulative value for the degree of degradation and susceptibility to degradation of the tested microplastic samples aligned with the properties of plastics reported in material data sheets. The study results were consistent with literature data, indicating that, in terms of shape, flakes, foams, and films are more susceptible to degradation, while granules are the most resistant form. The characteristic thermal stability of synthetic materials and the moderate effect of biological factors on microplastic degradation in coastal marine ecosystems were also confirmed.

The final hypothesis posited that environmental factors (UV radiation, mechanical damage, chemicals, and microorganisms) impact microplastic degradation to varying degrees. Analysis of the test results indicated that most microplastic samples exhibit medium to high susceptibility to degradation. The degradation of plastics with high resistance to breakdown primarily occurs under the influence of chemical agents and photodegradation, while samples with high susceptibility to degradation are mainly destroyed by mechanical forces and through oxidation by atmospheric oxygen. The research tool incorporated a detailed categorization of degradation factors (impact, abrasion, temperature, acids, alkalis, oils, organic solvents, UV, other atmospheric factors, biological factors); however, interpretation of the analysis on the effects of these factors on microplastic particle degradation showed that it is impossible to assign a specific degree and form of degradation to any single factor.

The identification of factors and understanding of degradation processes can help determine the rate and manner of particle breakdown, which may have implications for the development of effective removal methods, as well as strategies and technologies aimed at reducing the release of microparticles into the environment and minimizing plastic production and use.