

Evaluation of Radiation Effects on Paper and Wood Based on Changes in Cellulose Degree of Polymerization and Oxidation

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Keywords: Radiation-induced cellulose degradation, Chain scission rate, Absolute molecular weight, Carbonyl content, Material stability

Paper and wood are organic materials that are vulnerable to biological deterioration caused by various microorganisms, including fungi. Paper- and wood-based cultural heritage materials are generally preserved under controlled humidity conditions to prevent microbial damage. However, biological deterioration can still occur under unexpected circumstances, such as flooding, changes in storage conditions, or other disaster-related events. In such cases, various disinfection methods may be considered, and non-contact disinfection using ionizing radiation, such as gamma-rays or X-rays, can be a potential alternative. Appropriate irradiation doses for the biological control of insects, fungi, and other organisms have been relatively well established in previous studies. However, it remains difficult to quantitatively evaluate the extent to which paper and wood themselves are affected by irradiation at these doses. In this study, radiation-induced effects were evaluated by focusing on changes in cellulose, which is a major structural component common to both paper and wood. Radiation-induced damage to cellulose is mainly associated with glycosidic bond cleavage caused by radiolysis, resulting in a decrease in the degree of polymerization, as well as oxidation of hydroxyl groups in cellulose. These molecular-level chemical changes may occur prior to macroscopic changes in the mechanical strength of paper or wood; therefore, they can serve as sensitive indicators for evaluating the stability of materials after radiation treatment. In this study, the degree of polymerization and chain scission rate of cellulose were evaluated based on changes in absolute molecular weight, while changes in C=O content were analyzed to assess oxidative modification. The results showed that, even at an irradiation dose of approximately 10 kGy, which is commonly applied for fungal control and is often reported to cause no significant loss in mechanical strength, gradual changes in cellulose degree of polymerization and oxidation were observed with increasing irradiation dose. In wood samples, a higher lignin content appeared to suppress cellulose oxidation. These results indicate that changes in cellulose degree of polymerization, chain scission rate, and oxidation can be useful indicators for quantitatively evaluating the material stability of paper and wood after radiation treatment.

Acknowledgement

This research was supported by the 2021 Cultural Heritage Smart Preservation & Utilization R&D Program of the Cultural Heritage Administration, National Research Institute of Cultural Heritage (Project name: Development of alternative technology for fumigation using radiation for emergency preservation in response to disasters in cultural heritage, project number: RS-2021-NC100701).