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Kinetics of Free Radicals Decay Reactions in Cellulosic-Based Heritage Materials Disinfected by γ-Radiation

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Disinfection by γ-radiation of cultural heritage artefacts and archived materials has been successfully applied in recent years. Radiation processing used for cultural heritage disinfection has several advantages when compared to conventional methods (e.g., chemical gases) mainly related to the safety, efficiency, reliability, capacity, process time and safety for users and the environment. However, more research is still required to study undesirable effects (side-effects) which may appear in sensitive materials as a function of the absorbed radiation dose. Some conservators and restorers are frequently worried about possible long-term effects in irradiated materials (post-effects). During the irradiation process, some energetic and unstable chemical species called free radicals appear in the treated matter. They disappear in different ways, interacting either with each other or with the artefact compounds thus becoming responsible for disinfestation and irradiation side-effects.

The kinetics of free radical decay reactions depend on the absorbed dose, the properties of irradiated material among others. In this study, contemporary paper samples were irradiated using γ-radiation from ^{60}Co with different absorbed doses. The absorbed dose range was chosen taking into account the effective values to promote insect eradication, fungal disinfection and sterilization. The decay kinetics of the cellulose free radicals induced by irradiation was analyzed using electron paramagnetic resonance. Several spectra were obtained at room temperature for each applied absorbed dose immediately after irradiation as reference measurements. To understand the free radical decay process, additional spectra were obtained for different decay times up to almost 50 days after irradiation. De-noising treatment of the original obtained spectra signals were performed using wavelets.
Free radical populations, proportional to the spin concentrations, were found by integrating the electron paramagnetic resonance signal curves. Comparison of spectra was done by normalizing the calculated area corresponding to cellulose spin concentration, taking first measurement after irradiation as 100%. Further analyses and calculations were made to study the half-life and the kinetics models of the free radicals created. diffraction was carried out to identify crystalline phases and the effect of ionizing radiation on the crystalline structure of cellulose in paper. Scanning electron microscopy and scanning electron microscopy energy dispersive

spectrometry were performed to analyze structure modifications induced by ionizing radiation, identifying cellulose fibre agglomeration zones and to quantify chemical elements.

Results show that for the sterilization dose, 80% of the cellulose free radicals induced by ionizing radiation disappear in almost 40 days and for disinfection dose in 8 days. It can be concluded that if no modifications (side-effects) appear in the irradiated material after the radical decay time, the material will stay stable for the remaining lifetime. Results showed that the proposed method using electron paramagnetic resonance is suitably to study the behaviour of radicals on cellulosic-based cultural heritage materials.

Country/Organization invited to participate

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