

## TRACE ELEMENTS FOR CHARACTERIZATION ARTIFICIAL AGING PAPER

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The identification and quantification of the constituent elements of the paper provides a first strong indication of its origin, age and the used technology for its production. This knowledge is quite important for the protection and conservation of paper and also to the forensic science in judicial problems encountered in forgery. Elemental content is one of the characteristics of the paper that might be changed during forgery processes, however this hypothesis need to be confirmed. Artificial aging processes are used in forgery to produce old manuscripts and at the same time are extremely important in the long-term effects of conservation treatments and the mechanisms of specific deterioration processes because most of them are responsible for paper degradation.

During artificial or accelerated aging process the material is subjected to extreme conditions in a climate-chamber trying to speed up the natural aging processes.

Under normal conditions of storage, aging processes on paper are very slow, but eventually and inevitably they still lead to well-known aging effects such as yellowing and loss of strength. The most common reaction is the hydrolytic degradation of the cellulose molecules, the building blocks of paper, in which the presence of water (moisture) plays an essential role. According to standard reaction-kinetic principles, the rate of the hydrolytic process is determined by the temperature, the acidity (pH value), and the amount of moisture present in the paper. The moisture content is again dependent on the (relative) humidity in the storage environment. The second deterioration process is the oxidative degradation of cellulose, primarily induced by the presence of oxygen in the environmental air. The third main mechanism of deterioration is the process of thermal degradation. This mechanism concerns the breakage of chemical bonds as a consequence of the temperature-dependent movements of the cellulose molecules and their constituent atoms. Deterioration of paper-based materials is also due to air pollution, biological attack and the presence of microorganisms like bacteria and fungi. Artificial accelerated aging paper methods were used to study the cellulose alteration in paper, involving several mechanisms which may influence the paper elemental constitution. Different kinds of modern paper and papyrus were submitted to several weathering processes; intense ultraviolet and solar lights, humidity, high temperature, oxidization by  $\text{NO}_4\text{I}$ , and biodegradation by cellulosomes. In this work, energy dispersive X-ray fluorescence (EDXRF) was used to quantify S, Cl, K, Ca, Mn, Fe, Cu, Zn, As, Sr, Ba and Pb and X-Ray diffraction spectrometry was used to compare the phase differences in the original paper samples and after each aging treatment.

Different elemental compositions were observed in modern papers and in papyrus which allows distinguishing them. With a ternary diagram based on elemental composition, we can perfectly identify each kind of paper sample.

The obtained results concerning the used artificial aging processes in paper show that only the oxidization by  $\text{NO}_4\text{I}$  and biodegradation by cellulosomes affected the elemental content of paper, for S, Cl, Ca and Sr.