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RADIATION APPLICATION FOR PAPER PRESERVATION: GAMMA IRRADIATION AT EUCALYPTUS PULP SHEETS

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ABSTRACT

Ionizing radiation has been proposed in order to protect information and books that may be lost due to fungi and or insects infestation. In general restaurators are very worried about the maintenance of original properties of items to be treated. The selected technology must consider two points: type of biological contamination and contamination control. Fungi is one of the principal organism which grows well on papers. Once this infestation is installed on the paper it will signify spots, resistance loses and deterioration. The organisms feces introduces enzymes, organic acids and pigments to the contaminated material. Ionizing radiation from gamma sources were applied at laboratory sheets manufactured with commercial cellulose pulp. The subject of this present paper was to investigate the ideal radiation dose that is safe for keeping the paper quality. Laboratory sheets (75 g/m^2) were prepared in a TAPPI sheet former. Bleached sulphate Eucalyptus pulp, refined in laboratory PFI mill to 31°SR, was the raw material. The formed sheets were irradiated at IPEN's ^{60}Co Gammacell with 3 kGy up to 25 kGy. No significant changes were detected in paper samples irradiated up to 9 kGy. This is the radiation dose to be suggested. During irradiation the applied dose rate was 0.817 Gy/s.

1. INTRODUCTION

Paper Restaurators deal with contaminated material which needs to reduce the consequential damage at important items often (paints, sculptures, books and documents). Paper is an example of material constantly exposed to dust, light and biological contamination. All these factors are related to material degradation. Important information and books may be lost due to the damages related to fungi and or insects infestation. The fungi contamination on papers is common and after infestation its control are done basically by one of the following method: cleaning, ethylene oxide and ionizing radiation. Fumigant agents and temperature are also applied in order to control biological contamination on paper and artistical items. Examples of damage caused in books by biological infestation are shown in Fig. 1.

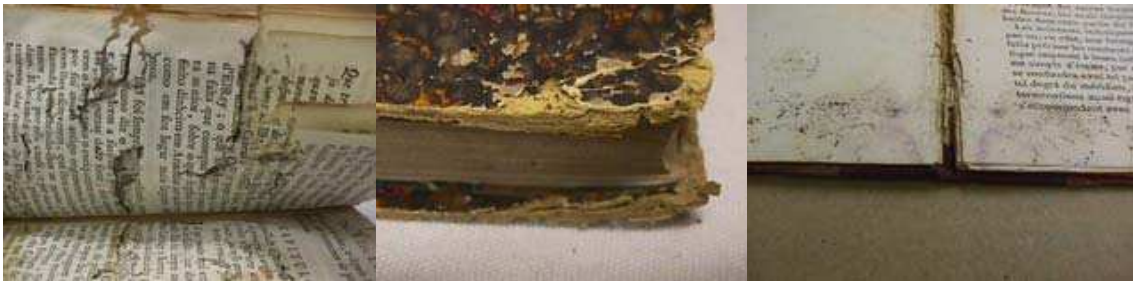

Figure 1. Damage related to humidity and biological contamination.

The research on the application of ionizing radiation to books or paper in general dates to 1960 [1]. The radio-resistance of the most significant microbial stocks was tested in Brazil [2]. The in-depth study on the possible application of irradiation technology for book disinfection has witnessed a long time pause, caused by the spreading of the sterilization treatment through fumigant gases (mainly ethylene oxide), efficiently used against microorganisms as well as insects. Nonetheless research and irradiation services are common for polymers, packaging, painting, etc. The sterilization treatment has been offered as an easy "service to the customer" to be found even among the different firms working in the field of disinfection, disinfestation and deratization of dwelling and in tertiary sector [3].

Distinct groups and researchers are using radiation for preservation of papers and artistical items. It is a general concern for contributing with preservation technologies and books decontamination. At Nuclear and Research Institute, IPEN, we started a research to verify the safety radiation doses for inactivate anthrax contamination for USA Mail. Irradiated items were: printing paper, envelope paper, CDs, disk. As anthrax is a very resistant organism and spores are often less radiosensitive in this case it was tested higher doses than 50 kGy, as an exception. For commercial process and general fungi contamination it can be suggested radiation doses close to 10 kGy.

This particular study was dedicated only to cellulose matrix in order to understand if radiation may cause damage to the fibers and affect paper resistance.

2. MATERIAL AND METHODS

The research was carried out using only laboratory eucalyptus fiber paper sheets. The laboratory sheets of 75 g/m^2 were prepared in a TAPPI sheet former, using industrial bleached sulphate Eucalyptus pulp. The samples were refined in laboratory PFI mill engine to 31° SR. The sheets were divided into groups and submitted to radiation processing. After radiation the sheets were tested for resistance and color measurements using standard methods. Results were compared to those obtained for the control group. A picture of the laboratory sheet samples and dosimetric system is presented as Fig. 2. The material was irradiated at IPEN's ^{60}Co Gammacell with 3 kGy to 25 kGy. The material was irradiated with cobalt gamma source (dose rate was 0.817 Gy/s). The properties of paper sheets were tested after irradiation and compared to unirradiated samples according to ISO methods.

The sheet samples were prepared as indicated in ISO 5269-1:2005 standard method and tested according to standard methods (Table 1). at the Pulp and Paper Laboratory of the Institute for Tecnhological Research, São Paulo. The irradiation of the samples were done at Centro de Tecnologia das Radiações, Instituto de Pesquisas Energéticas e Nucleares.

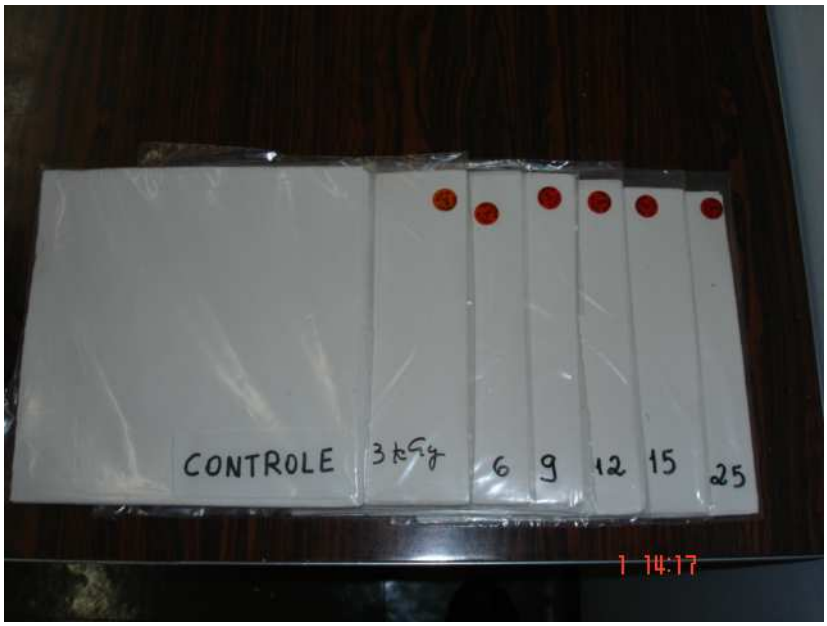

Figure 2. Laboratory eucalyptus sheet grouped after irradiation

2.1. Analysed Properties

The irradiated and non irradiated laboratory sheets were conditioned and tested at (23±1) ºC and (50±2)% relative humidity [4]. Table 1 presents the properties tested on those sheets. The mechanical properties are related to the paper durability and the appearance with the sense of vision.

Table 1. Tested properties and applied standard methods

Properties		Method
Mechanical	Tensile strength	ISO 1924-2 [5]
	Zero span tensile strength (Pulmac equipment)	TAPPI T 231 cm [6]
	Tearing resistance	ISO 1974 [4]
Appearance	Diffuse blue reflectance factor -ISO brightness	ISO 2470 [7]
	Colour by CIE L*, a*, b* system	TAPPI T 527 cm [8]

3. RESULTS AND DISCUSSION

All the results were organized at Table 2 which contains the measurements, average and their standard deviation for all the physical-chemical parameters. Most of them are related to the paper resistance and few with appearance (brightness and color).

Table 2. Gamma radiation effects on mechanical and appearance properties of laboratory sheets (eucalyptus pulp).

TEST		RADIATION DOSE (kGy)						
		0	**3.0**	**6.0**	**9.0**	**12.0**	**15.0**	**25.0**
Grammage (g/m^2)		82.0 ± 2.4	83.7 ± 2.4	80.3 ± 3.8	79.9 ± 2.4	82.6 ± 2.8	83,1 ± 3,4	82.2 ± 2.8
Tear resistence (mN)		832 ± 86.0	844 ± 90.0	829 ±108.0	819 ± 76.0	785 ± 42.0	819 ± 86.0	785 ± 60.0
Tear index (mNm^2/g)		10.1 ± 1.0	10.1 ± 1.0	10.3 ± 1.4	10.3 ± 1.0	9.5 ± 0.6	9.9 ± 1.0	9.5 ± 0.8
Tensile strength (kN/m)		5.51± 0.6	5.54 ± 0.8	5.33 ± 0.6	5.21 ± 0.5	5.30 ± 0.4	5.24 ± 0.7	5.17 ± 0.7
Tensile index (Nm/g)		67.2 ± 6.8	66.2 ± 9.6	66.4 ± 7.4	65.2 ± 5.8	64.2 ± 5.4	63.1 ± 8.8	62.9 ± 9.0
Zero span tensile strength (kN/m)		9.56 ± 0.7	10.10 ± 1.2	9.37 ± 0.5	9.47 ± 0.8	9.15 ± 0.9	9.18 ± 0.5	8.95 ± 0.9
Zero span index (Nm/g)		117 ± 8.0	121 ± 14.0	117 ± 6.0	119 ± 10.0	111 ± 10.0	110 ± 6.0	109 ± 12.0
Brightness (%)		83.2 ± 0.8	82.9 ± 0.6	81.9 ± 0.6	80.7 ± 1.4	81.0 ± 1.0	80.5 ± 0.6	80.2 ± 1.0
CIE Lab Coulor	L*	95.3 ± 0.2	95.4 ± 0.2	95.0 ± 0.2	94.8 ± 0.2	94.0 ± 0.2	94.8 ± 0.2	94.7 ± 0.2
	a*	-0.01	-0.01	0.06 ± 0.02	0.12 ± 0.1	0.04 ± 0.04	0.03 ± 0.1	0.07 ± 0.1
	b*	4.16 ± 0.5	4.39 ± 0.30	4.65 ± 0.3	5.06 ± 0.6	5.12 ± 0.21	5.31 ± 0.3	5.40 ± 0.5

Note: Index value is the properties divided by the grammage.
L) the gray axis; a) the yellow-blue axis; b) the green-red axis (all parameters from three-dimensional colour system)

For this research the selected radiation dose started from 3 kGy, 6, 9, 12 until 15 kGy. Nonetheless the 25 kGy was also included in order to see if the behavior on eucalyptus pulp would be different comparing to the effects of lower doses. Although we are sure that the doses for paper disinfection must be as low as possible it must be emphasized that when paper is used for packing medical devices or pharmaceutical pieces the dose for sterilization probably will be 25 kGy.

Some authors who combined techniques concluded that using irradiation and time exposition, the 14 kGy radiation dose may result in less effects if compared to aging assays [9]. These results confirmed our believes once we are suggesting radiation doses close to 9 kGy.

Magaudda [3] also irradiated pure cellulose and concluded that no significant harmful effect has occurred on the mechanical and physical properties of pure cellulose. According to him it is encouraging to prove that, once using the necessary dose for an efficient treatment (roughly 0.2-0.5 kGy-thousand of Grays-for insects; 3-8 kGy for micro-fungi).

After the September 11^{th} (2001) the US Government required that all the commercial irradiator (^{60}Co) were dedicated only for post material decontamination, during the first weeks after the event attack. This was the way they decided for controlling the anthrax dispersion in the country and abroad. In Brazil the consulate decided also to irradiate the packages from USA before open and distribute the mail and other packages. After that the electron accelerator (EA) was also included

as radiation sources for this subject, Bouchard et al, 2006[10]. The obtained results with EA have shown that irradiation at the used dosage to treat mail by the US Postal Service depolymerizes and oxidizes the cellulose. Depolymerization is responsible for a decrease of paper strength while oxidation induces darkening of the paper. Irradiating at high electron beam energy is less damaging than using lower energy. Moreover, linear relationships have been found between the number of chain scission (CSN) in cellulose and the irradiation dosage as well as between CSN and Zero-Span Breaking Length. These relationships make the strength loss predictable.

Several research groups acting at international level confirmed the efficiency of ionizing radiation, contributing to a better knowledge of the effects on biodeteriorating organisms and on the intrinsic properties of paper. As concerns the modification caused by irradiation on the mechanical resistance of paper, some authors state that the basic properties of paper are not significantly modified at doses up to 10 kGy. Others have achieved completely different results.

Regarding our results, it can be observed that irradiation did not affect the paper grammage. Tear resistance, tensile index and zero span index values were reduced by radiation but no significant changes were detected in paper samples irradiated up to 9 kGy. Most of the time the material process may be irradiated with lower radiation dose than 9 kGy.

4. CONCLUSION

When radiation is the elected preservation technology the main factors to be taken into account are type of contamination, radiation dose and the dose-rate as well as the protection against further contamination. Radiation begins to influence mechanical properties at 9 kGy and appearance properties at 12 kGy, but the changes observed are small and no real damage occurs at the irradiated material, at conditions used in this study. There is no doubt that radiation is a technique to be considered for fungi contamination treatment.

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