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Preparation of radiation monitoring labels to γ ray

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ABSTRACT

The current work describes the investigation of film and gel samples, which combine poly (vinyl alcohol) (PVA) and gelatin containing thymolphthalein dye (TP). Under the effect of gamma radiation, two different media prepared as a label film and gel dosimeter its color changed from blue to colorless. Results demonstrated that the new detector systems for application in the low and high dose ranges were from 1 to 6.5 kGy in case of film and from 0.5 to 100 Gy as gel. The response of these dosimeters shows excellent post-irradiation stability at different storage time. These dosimeters are independent of the relative humidity at the time of irradiation in the range of relative humidity from 0 to 60%. Uncertainty of this radiation dosimeter was calculated as well as a comparison between two radiation dosimetry systems and suggest their possible application for both low and high dose dosimetry applications in medicine and industry.

1. Introduction

Dosimetry plays an important role in the quality control of radiation processing [1]. Radiation indicators based on their radiation induced colour change used for identification of irradiated and unirradiated products in radiation sterilization and food irradiation [2]. Due to their sensitivity towards various influence factors stable to temperature and humidity changes, linearity in dose response, these are used for quantitative purposes [3]. Indicators like tetra bromophenol blue can exist in two tautomeric forms having different colors in the dose range from 1 to 8 kGy [4]. Gel dosimetry is gaining more acceptances in providing quality assurance of radiation treatments, various gel dosimeters were previously prepared for low-dose applications based on a radiochromic dye of leuco crystal violet (LCV) [5]. Fricke–gelatin–xylenol orange (FGX) in the dose range 5–100 Gy [6], and some less toxic acrylate monomer [7]. FGX has been used in many applications such as studies of physical parameters in radiotherapy, dosimetry of small fields and development of equipment for reading dosimetric systems [8–10]. Gafar and co-workers [11,12] developed a two new gel dosimetry systems based on the addition of Toluidine blue–O and fuchsine acid cyanide dye to gelatin, which are useful for radiation processing in the range of 1–150 Gy and 1–170 Gy; respectively. However, these gel samples depend up on TP (thymolphthalein) dye, which diffuses with gelatin through a weak hydrogen bond [13]. Upon gamma irradiation, it turns from blue to colorless; it was characterized by UV–vis spectrophotometry for Gy level or low-dose dosimetry applications. While upon irradiation, this bond breaks and the effect of gamma transfer to TP. In addition, gelatin-enhanced the sensitivity of the dyed gel mixture [13]. Its preparation was easy, low cost and with easy quality control and include greater stability than Fricke-based gels, this gel continues to be stable over 30 days and more sensitive towards gamma rays from 0.5 to 100 Gy. This paper presents a comparison between

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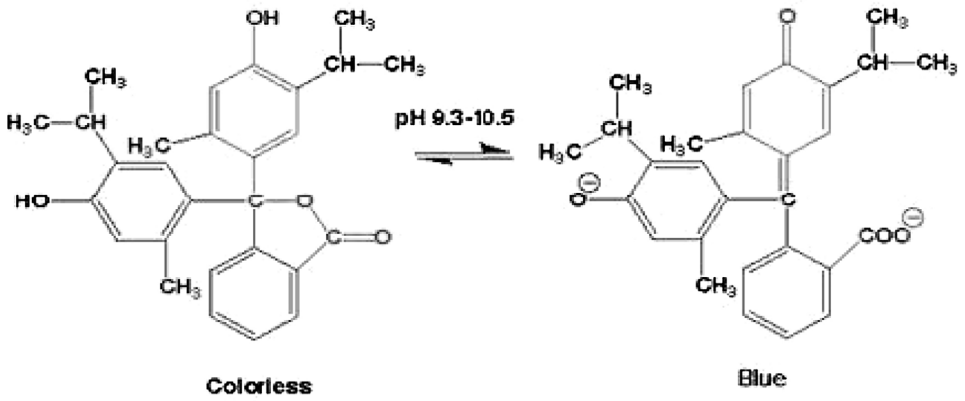

Scheme 1. Thymolphthalein indicator dye (two tautomeric forms).

two-dosimetry systems developed one is applied for high dose "film dosimeter" and the other "gel dosimeter" is applied for low dose dosimetry applications.

2. Materials and methods

2.1. Preparation of films

The dosimeter film was prepared by casting a water-soluble poly (vinyl alcohol) fully hydrolyzed (99–100%, J. T. Baker Chemical Co., U.S.A.), aqueous solution containing the sodium trichloroacetate TCA (Fluka Chemika, England) and thymolphthalein dye (Chemapol, Czech Republic). The solution was kept well stirred at room temperature for about 48 h; then left to cool. To each 30 ml of PVA solution 0.44, 0.66 and 1 "phr* = part per hundred parts of resin" of dye stock solution were added and kept stirred for about 3 h at room temperature ±25 °C in order to obtain a uniformly dyed solution. The TCA was added in a concentration ranged from 0.16, 0.33, and 0.66 phr to solution containing 0.66 phr of TP The dyed PVA solution was poured onto 15 × 15 cm horizontal glass plate. Thermal and atmospheric conditions for casting from polymer solution were strictly controlled for producing optimum quality and clarity of the film. The thickness of the obtained films was found to be 0.060 ± 0.005 mm.

2.2. Preparation of gel samples

Gelatin from porcine skin (300 blooms, G2500, Sigma-Aldrich) was dissolved in distilled water and then the dye TP, was added from a stock solution. The mixture was continuously stirred in a water bath. The solution was blue. Since the reaction rate depends on temperature, the water bath was maintained at 70 ± 5 °C for 4 h. Samples were dripped from pipette into 1 cm thickness glass test tube and immediately placed in a refrigerator at approximately 4 °C for 4 h. Three different concentrations of the dye 0.44, 0.66 and 1 phr* and gelatin concentration are 20% w/w of gelatin (the mass of gelatin relative to the mass of the final gel). The gelatin is a polypeptide of a structure in which various amino acids are linked by peptide bonds, (—NH—CO—) which is similar to a hydrogen bond. Scheme 1 shows the two tautomeric basic and acidic forms of TP indicator dye.

2.3. Apparatus

The absorption spectra of both unirradiated and irradiated films and gels were measured in the wavelength range of 200–800 nm using a UVIKON 860 spectrophotometer. The film thickness was measured using a Digitrix-Mark II thickness gauge (precision ± 1 μm, 1 σ). Irradiation was carried out using the ^{60}Co Gamma Cell GC-220 Excel (manufactured by MDS Nordion, Canada) with absorbed dose rate of 6.44 kGyh^{-1}. Gamma irradiation was carried out in the dose range of 0–6.5 kGy (in case of film dosimeter). However, the gel dosimeters were irradiated from 0.5 to 100 Gy by ^{137}Cs source (Gamma Cell 40, Atomic Energy of Canada) with the dose rate of 27 Gyh^{-1} (in case of film dosimeter). The source was calibrated by Fricke reference standard dosimeter according to ASTM [14].