TISSUE EQUIVALENT MATERIALS FROM SPC-SPI/NaOH/IA-PAE BONDED MANGROVE WOOD CHARACTERIZED FOR RADIATION THERAPY DOSIMETRY

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Abstract

The present research focuses on dosimetric measurements in tissue equivalent phantoms based on renewable materials, designed using soy protein-based adhesives, mangrove *Rhizophora spp.* wood, sodium hydroxide, and a bio-based cross-linking agent (itaconic acid polyamidoamine-epichlorohydrin resin) with an ionization chamber and GafchromicTH EBT3 radiochromic film dosimeters. The measurements were performed under exposure to photons of 6 and 10 MV, and electron beams of 6 and 15 MeV. The particleboard samples were exposed to a dose of 100 cGy and field size (10 x 10 cm²) at a 100 cm SSD. The dosimeters were irradiated at measurement depths of 1.5, 2.5, and 3.0 cm, respectively, inside the phantom slabs. The particleboards presented superior physical and mechanical properties, and dimensional stability surpassing acceptable standards. The dose measurements revealed exceptional agreement with both water and solid water. Also, comparison between the measured dosimetric properties is well within $\pm 2\%$, $\pm 2\%$, $\pm 10\%$ and $\pm 5.5\%$ for photon and electron energies of the maximum dose for the field size tested. This study had successfully shown that SPC-SPI/NaOH/IA-PAE bonded *Rhizophora spp.* particleboards are promising tissue equivalent phantom materials with merit for medical applications.

Keywords: Tissue Equivalent Materials, Particleboard Phantom, EGSnrc PEGS4, SPC-SPI

Research Highlights

- SPC-SPI-*Rhizophora spp.* particleboard phantoms were developed incorporating NaOH/IA-PAE resins.
- Monte Carlo simulation with EGSnrc PEGS4 was employed to provide comparison data.
- Dosimetric properties were evaluated using an ionization chamber and GafchromicTH EBT3 radiochromic film dosimeters.
- The fabricated particleboards could be employed as suitable materials for tissue equivalent phantoms in radiation therapy dosimetry.

Research Objectives

This research aims to design convenient bio-based tissue equivalent phantom materials under exposure to high energy photon and electron beams for medical applications. This study is very relevant since no research work has been undertaken to optimize the properties of mangrove *Rhizophora spp.* particleboards developed using SPC-SPI/NaOH/IA-PAE bio-based adhesives (SPC/SPI–soy protein concentrate/isolate, NaOH–sodium hydroxide, IA-PAE–itaconic acid

polyamidoamine-epichlorohydrin) as suitable tissue equivalent phantom materials for radiation therapy dosimetry. The purpose ultimately was to establish and assess the dosimetric characteristics of the phantoms with the aid of an ionization chamber and GafchromicTH EBT3 radiochromic film dosimeters. The significance of this work is in the use of biodegradable, biocompatible, renewable, and low-cost bio-based materials to construct high-quality phantoms with comparable dosimetric properties to those of acceptable standard phantoms. This research points to the possibility of using SPC-SPI/NaOH/IA-PAE and mangrove wood as potential tissue equivalent materials for use as phantoms in both clinical and investigative aspects of radiotherapy dosimetry.

Methodology

Fifteen weight percent of itaconic acid polyamidoamine-epichlorohydrin resin was incorporated into each of the soy protein bio-based adhesive (30 grams of SPC and 12 grams of SPI) and stirred for 15 minutes. The homogeneous mixture was then separately dissolved into 70 grams and 88 grams of distilled water, and then stirred for 30 minutes. The resulting mixture was then alkalized with ten weight percent of sodium hydroxide solution and moderately stirred for another 30 minutes.

The sample mixtures were mixed uniformly with the mangrove *Rhizophora spp.* wood particles and the resultant mats hot-pressed for 20 minutes at 20 MPa and 170°C. For each of the SPC and SPI samples, a total of thirty particleboards with appropriate standard dimension at 1.0 g/cm³ were manufactured.

The effective atomic number (Z_{eff}) of the samples were determined using energy dispersive X-ray (EDX) analysis (1). Monte Carlo simulation with EGSnrc PEGS4 was employed to analyze the histories of photon interactions (2). Percentage depth dose values were calculated for all cases and compared with those of water and solid water (3).

Results

The particleboard phantoms displayed excellent physical and mechanical properties with reduced dimensional stability surpassing acceptable standard limits (4). The most common elements found in the particleboard phantoms were in accordance with the main elements required in tissue equivalent phantom materials. Additionally, the values of the Z_{eff} are identical to those of water (5) and in good agreement with previous studies (6,7). This can be clarified on the basis of more weight fraction of higher atomic number constituent elements. The particleboard samples were observed to have comparable probability of interactions within the 6 MeV to 15 MeV photon energy range. The comparison between the dosimetric properties evaluated at all depths indicates good consistency with deviations within $\pm 2\%$, $\pm 2\%$, $\pm 10\%$

and $\pm 5.5\%$ of the maximum dose for the field size tested. Moreover, both phantoms displayed a relatively homogeneous dose from the surface to a particular depth, after which the dose falls off almost immediately with increasing depth. These results indicate that NaOH/IA-PAE can be used to modify SPC-SPI/*Rhizophora spp.* particleboards, hence raising the possibility of being promoted as tissue equivalent phantom materials.

Findings

It was found that the relative difference measured in the depth-of-dose maximum using the ionization chamber for 6 MV and 10 MV photons, agreed excellently with those of water and solid water phantoms. In addition, when GafchromicTH EBT3 radiochromic films were utilized, the computed D_{max} for the particleboard samples lie within $\pm 2\%$ and $\pm 9\%$, respectively. The electron beam PDD curves suggest an enhanced surface dose to that of water and solid water with no significant difference. These results show that the fabricated particleboards can serve as convenient tissue equivalent phantom materials for use in clinical radiotherapy.

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