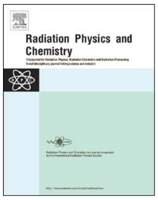
Radiation Physics and Chemistry 136 (2017) 23–29

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem



Dosimetric evaluation of *Rhizophora* spp. binderless particleboard phantom for diagnostic X-ray energy

M.W. Marashdeh[a,b,*], A.A. Tajuddin[b], S. Bauk[c], R. Hashim[d]

[a] *Department of Physics, College of Sciences, Al Imam Mohammad Ibn Saud Islamic University (IMSIU), P.O. Box 90950, Riyadh 11623, Saudi Arabia*
[b] *School of Physics, UniversitiSains Malaysia, Minden 11800, Penang, Malaysia*
[c] *Radiation Biophysics Laboratory, UniversitiSains Malaysia, 11800 USM Penang, Malaysia*
[d] *Division of Bio-resource, Paper and Coatings Technology, School of Industrial Technology, UniversitiSains Malaysia, 11800 USM Penang, Malaysia*

ARTICLE INFO

Keywords:
Diagnostic
X-ray energy
Rhizophora spp.
Binderless particleboard
Phantom

ABSTRACT

This research aims to evaluate the suitability of using binderless particleboard made from *Rhizophora* spp. mangrove wood as a dosimetric phantom for X-ray in the diagnostic energy regions. Comparative measurements of percentage depth and surface doses in *Rhizophora* spp. binderless particleboard phantom and similarly shaped Perspex and water phantoms were performed. Measurements were conducted in the diagnostic X-ray energy range of 50 kVp to 90 kVp. Results showed that the binderless particleboard phantom can be used for dosimetric measurements. For the X-ray beam at 90 kVp, the binderless particleboard and water phantom showed data agreement of 1.6%, 2.7%, and 4.3% at depths of 1, 2, and 4 cm, respectively, whereas the measurements in water and Perspex were 1.8%, 2.7%, and 4.4%. The surface dose differences were due to difference in the backscattering material. The doses measured at the surface were within 0.4% for binderless particleboard and water and within 0.9% for Perspex and water.

1. Introduction

The performance testing mechanism of a continuous use of X-ray imaging system has to be refined to ensure repeatability and accuracy. Imaging system quality and radiation dose assessment are necessary for diagnostic radiology practice. Therefore, the radiology phantom is a vital tool for diagnostic testing and image quality optimization in diagnostic radiology (Hintenlang, 2004). Generally, the phantom is made of a tissue equivalent material to mimic the attenuation characteristics in human body.

Phantoms are used by the majority of diagnostic radiology departments for patient simulation in quality assurance programs. The most often used materials of interest in a radiographic phantom are water, aluminum and copper (Carrier and Blais, 1987). In a study by Shrimpton et al. (1981), depth dose profile measurements in Alderson Rando phantom were assessed, and the results were compared with those of a similarly shaped water phantom. The assessment was performed under three different diagnostic energy range kV settings. The percentage depth dose (PDD) and lateral beam profile measurement were analysed with the use of different detectors (Harrison, 1981; BJR, 1983; Scrimger and Connors, 1986; Niroomand-Rad et al., 1987; Aldrich et al., 1992; Kurup and Glasgow, 1993; Gerig et al., 1994; Aukett et al., 1996). Limited information has been published on solid phantom use for kilovoltage x-ray beam dosimetry. Stern and Kubo (1995) examined the relative dosimetry for polystyrene and solid water (RMI Gammex, Middleton, Wisconsin). These two phantom materials were found to possess a dosimetric agreement of 3% with a diagnostic X-ray range between 40 kVp and 150 kVp. Moreover, Hill1 et al. (2005) employed RMI-457 Solid Water and Plastic Water to assess relative and reference dosimetry in kilovoltage X-ray in the 75 kVp to 300 kVp energy range. Percentage depth doses for the 300 kVp X-ray beam were in agreement within 1% when compared with the data for water.

According to Spelic et al. (2004), the radiographic phantom used for the 1995 survey was reflective of a standard reference patient. The phantom was produced using a polymethyl methacrylate material with 1.18 g/cm^3 of density.

A large number of studies have examined different types of natural materials as water-equivalent materials. An important study revealed that mangrove wood, *Rhizophora spp.*, results are similar to those of water-equivalent materials (Che Wan Sudin et al., 1988). Previous studies thus led to the assumption that *Rhizophora* spp. wood had properties comparable to those obtained with other standard phantom materials used for radiation dosimetry (Bradley et al., 1991; Tajuddin et al., 1996; Banjade et al., 2001).

---

[*] Corresponding author.
E-mail addresses: mwmarashdeh@imamu.edu.sa, mwmarashdeh@gmail.com (M.W. Marashdeh).

http://dx.doi.org/10.1016/j.radphyschem.2017.03.030
Received 27 December 2016; Received in revised form 10 March 2017; Accepted 16 March 2017

Mwmarashdeh et al. (2012) proposed another option for employing *Rhizophora spp*. wood as the binderless particleboard. This approach guarantees the distribution density regularity of the final product made of the same material type, which also positively affects the phantom used for medical radiation by ensuring that the final product does not have any negative health effects (Hashim et al., 2009, 2010).

This work employs Perspex and *Rhizophora spp*. binderless particleboard phantoms for kilovoltage X-rays beam dosimetry. Comparisons of relative dosimetry were conducted with the use of percentage depth dose data and surface dose measurement in binderless particleboard and Perspex phantoms. The results were compared with the water measurement. The mass–energy absorption coefficients of these phantoms were likewise determined.

2. Materials and methods

2.1. Preparation of phantoms

Three types of phantoms, namely, water, Perspex, and binderless particleboard made from *Rhizophora* spp. wood were used in this study. The first phantom was the binderless particleboard, which was directly obtained from the *Rhizophora* spp. trunks from one of the mangrove reserve forests in Kuala Sepetang, Perak, Malaysia. The binderless particleboard phantom was fabricated with particle size of < 50 μm according to Marashdeh et al. (2012). An oven was used to reduce the moisture content of the chips to 6–7% of their original weights at 200 °C and 19.3 MPa of pressure for 10 min. The boards were cooled at room temperature for 24 h. All boards had a target density of 1.00 ± 0.02 g/cm^3. This phantom consisted of 18 boards (1 cm thick) and 4 boards (0.5 cm thick).

Another phantom was represented by the Perspex phantom which consisted of a series of acrylic slabs. This phantom has an overall dimension of $(20\times20\times20)$ cm^3. Its shape and dimensions are similar to that of the binderless particleboard phantom to achieve scatter conditions that are similar to that of the first phantom (Fig. 1).

The important phantom slab from the binderless particleboard and Perspex phantoms is the slab that contains the thermoluminescent dosimeters (TLDs) with nominal dimensions of $0.32\times0.32\times0.09$ cm^3, assumed the effective point of measurement for the TLD to be at the middle of its thickness, which are used for measuring the depth–dose on exposure to an X-ray beam. This slab features five cylindrical holes with a 0.5 cm diameter and a 0.15 cm depth. The holes were drilled parallel to the central beam axis of the incident X-ray beam. The distance between the holes is equal to 2 cm in each slab as shown in Fig. 2. Surface dose measurements were made within the uppermost phantom slab and was taken as the mean of 5 TLD readings.

In the case of the water phantom, a (20×20) cm^2 water tank with a height of 21 cm was utilized. This tank had a similar shape and dimension with the binderless particleboard and Perspex phantoms to produce a similar scattering effect. Perspex with a 0.5 cm thickness was used as the tank material. The water phantom consists of two Perspex segments that measure $(5\times0.7\times21)$ cm^3. These segments were placed in the middle of both sides of the tank. Perspex slices that are approximately 1 mm thick were fixed between two Perspex segments to fix the TLDs in the central axis of the beam. The TLDs were wrapped into thin plastic sachets to prevent water from reaching the TLDs. The positions of the TLDs were similar to that in the previous phantoms.

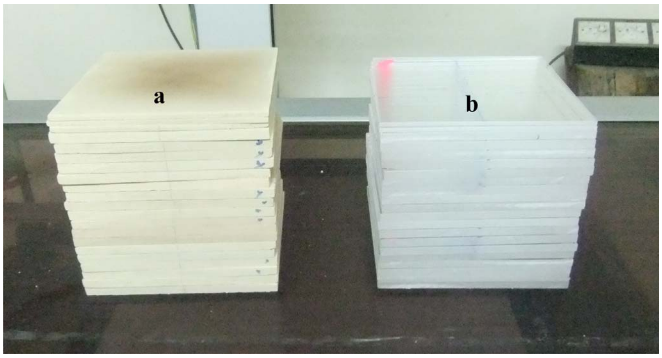


Fig. 1. a) *Rhizophora* spp.binderless particleboard phantom, b) Perspex phantom.

2.2. Mass–energy absorption coefficient determination

The data on solid phantom use for kilovoltage x-ray beam dosimetry remains limited. Relative kilovoltage X-ray dosimetry with the use of Solid Water (RMI Gammex, Middleton, Wisconsin) and polystyrene has already been examined (Stern and Kubo, 1995). Their calculated mass–energy absorption coefficient values (μ_{en}/ρ) for both Solid Water and polystyrene were in agreement to within 3% over the X-ray energy range between 40 kVp and 150 kVp. The mass energy-absorption coefficient, (μ_{en}/ρ), measures the average incident photon energy fractional value transformed to charged particle kinetic energy because of such interactions. A number of parameters, such as absorber, absorber dimensions, physical density ρ, photon energy, and effective atomic number $(\overline{Z})$, rely on the available energy for chemical or biological production, as well as other impacts attributed to ionizing radiation exposure (Hubbell, 1982).

Each phantom material's mass–energy absorption coefficients, (μen/ρ) phantom, were compared as a function of photon energy based on the standards outlined by the National Institute of Standards and Technology (NIST) (Hubbell and Seltzer, 1996). Eq. (1) determines the mass–energy absorption coefficient for a material (μen/ρ):

$$(\mu_{en}/\rho)_{\mathrm{material}} = \sum_{i} w_i(\mu_{en}/\rho)_i \tag{1}$$

where (μen/ρ)i is the mass–energy absorption coefficient of the *i*th atom, and w_i is its relative chemical weight. NIST standards served as basis for the individual element coefficients as a function of X-ray beam energy.

Table 1 presents the relative densities and elemental composition of the phantoms used in this study. However, element composition quantity variations for the three phantoms could affect dosimetric properties. This is especially true for lower energy X-rays, for which the photoelectric effect is an important interaction process. Table 1 also reveals that effective atomic number $(\overline{Z})$ of binderless particleboard phantom was 7.00, which is highly close to that of water (7.22) (AAPM, 1983). The effective atomic number $(\overline{Z})$ of Perspex phantom is 6.24 (Hill et al., 2010). Thus, binderless particleboard has potential in being used as a phantom material in medical physics application compared with Perspex material.

2.3. Determination of half value layer and effective energy of the x-rays beam

The quality of the X-ray beam is described explicitly by the spectral energy distribution, which is difficult to measure or compute. Spectral distributions are rarely used to describe radiation quality. Instead, radiation quality is usually described by the half-value layer (HVL) of the beam (McKetty, 1998; Meyer et al., 2004). The HVL of an X-ray beam is measured by placing aluminum samples of increasing thickness in the beam and measuring the decreasing intensity to half with the dosimeter.

A PTW 77337 parallel plate thin window ion chamber connected to a PTW UNIDOS electrometer was used in this experiment. The ionization chamber was positioned 100 cm away from the X-ray source, which is the same distance between the phantom and X-ray source. The X-ray unit was set at 80 mAs. The ionization chamber was exposed to X-ray photons three times without using an aluminum filter, and the average values were recorded. Then, pure aluminum (99.9%) layers were placed near the X-ray tube, and the measurement of the dose was