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Gamma Ray Attenuation in Hevea Latex and its Application to DRC Measurement

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ABSTRAK

Kertas ini melaporkan suatu pengukuran kandungan pepejal getah Hevea dengan menggunakan teknik pengecilan sinar gama. Nisbah komponen bagi jumlah isipadu air dan bahan pepejal getah dalam lateks ditentukan dengan menggunakan pengesan Si(Li) yang mempunyai peleraian tinggi bagi sinar gama bertenaga rendah. Keputusan ini dibandingkan dengan Kaedah Piawai dan didapati pekali korelasi ialah 0.998. Berdasarkan kepada tindak balas sinar gama dengan jirim, bersandarkan kepada nombor atom bahan pada suatu tenaga tertentu, teknik ini berkeupayaan mengesan bahan asing dalam lateks tetapi penyelidikan yang mendalam masih diperlukan untuk menentusahkan keadaan ini.

ABSTRACT

This paper reports the measurement of the total solid content (TSC) of fresh Hevea latex by the gamma ray attenuation technique. The component ratios of the total volume of water and solid material in multiphase system of latex were determined by the measurement of attenuation coefficient of latex with high energy resolution Si(Li) detector at low gamma ray energies. The result was compared against the Standard Laboratory Method and the correlation coefficient was found to be 0.998. Based on the behaviour that the interaction of gamma ray with matter at a given energy depends upon the atomic number of the material, the present technique may be able to detect adulterants in the latex, but investigations are needed to verify this.

INTRODUCTION

Accurate measurement of dry rubber content (DRC) of field latex is essential to latex processing factories for economic reasons. As the DRC of latex varies widely according to clone types, soil conditions, seasonal variations, weather, tapping systems and yield stimulation use (De Jonge, 1965; Abraham, 1970 and Ng, Ping and Lee, 1970) the actual rubber content must be determined. Some of the methods such as Rapid Method, Chee Method and Hydrometric Method are commonly used in determining DRC but their accuracies however vary from 1% to about 12% deviation from a Standard Laboratory Method (Chin, 1979). Recently our colleagues have successfully introduced a new measuring instrument to determine DRC based on the microwave attenuation technique (Kaida, 1982 and Kaida and Mahdi, 1983). The instru-

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ment is inexpensive, simple, portable, rapid and accurate to less than 1% deviation to the Standard Laboratory Method. The only disadvantage of this instrument is its inability to detect foreign materials present in the latex.

Gamma ray attenuation technique has been used in multiphase system of oil-water-air to determine the component ratios of the pipeline flow system (Abouelwafa and Kendall, 1980). We have employed a similar principle of physics to determine the attenuation of gamma ray in Hevea latex. Low energy gamma rays have been selected to give the attenuation which is mainly due to photoelectric absorption and Compton scattering. The DRC has been derived from the measurement of the component ratios of latex at different concentrations. The measurement with Standard Laboratory Method is used for comparison. This present technique is able to produce results of a level of 2% unit of DRC. Based on the behaviour that gamma ray attenuation coefficient of rubber materials varies with their atomic compositions (Elias *et al.*, 1983), it is believed that this technique may be able to detect adulterants added to the latex provided that their effective atomic numbers are different from the effective atomic number of rubber.

Gamma Ray Attenuation in Latex

The attenuation of monoenergetic gamma ray photons in a good geometry experiment is described by the following relationship

$$I = I_o \exp(-\mu d) \tag{1}$$

where I and I_o are the transmitted and incident intensities of the gamma ray respectively, d is the absorber thickness and μ is the linear attenuation coefficient of the absorbing materials. The total attenuation coefficient depends upon the energy of the incident gamma rays and atomic number of the material. For a compound material, the attenuation coefficient is related to its atomic composition and is given by

$$\mu(Z, E) = \sum_i \sigma_i (Z, E) N_i \tag{2}$$

where σ_i is the atomic cross-section for removal of gamma ray photons from the beam by atom of type i, N_i is the number of atoms of type i per unit volume, Z is the atomic number of the material and E is the energy of the incident gamma ray photon. Consider Hevea latex as a mixture consisting many components which distribute uniformly throughout the irradiated volume. The attenuation coefficient of the mixture can be employed as

$$\mu_{mix} = (N_o / A) \sigma \rho_{mix} \tag{3}$$

where N_o is Avogandro's number, A is the atomic mass number, ρ_{mix} is the density of latex and σ is the atomic cross-section for the removal of gamma ray photons. Since the density of the mixture can be written in the form

$$\rho_{mix} = \sum_{i=1}^{n} \alpha_i \rho_i \tag{4}$$

where α_i is the fraction of the total volume occupied by the ith component of the mixture, equation (3) becomes

$$\mu_{mix} = \sum_{i=1}^{n} \alpha_i \mu_i \tag{5}$$

where μ_i is the linear attenuation coefficient of element i. Equation (5) describes the gamma ray attenuation coefficient of a multicomponent system of a mixture at a given energy. For simplicity, we consider Hevea latex as consisting of a two-component system of water suspension, that is water and solid material (rubber and non-rubber solid). Equation (5) simply becomes a two-component system of a mixture and can be reduced to

$$\mu_{mix} = \alpha_1 \mu_1 + \alpha_2 \mu_2 \tag{6}$$

where α_1 and α_2 are the fractions of the total volume occupied by water and solid material respectively and μ_1 and μ_2 are the attenuation coefficients of water and solid material respectively. The above model assumes that the latex suspension layer of thickness d may be considered as consisting of two separate layers of thickness, d_1 and d_2, of water and solid material respectively, i.e. $d = d_1 + d_2$. Equation (1) can now be written for latex as

$$I = I_o \exp(-\mu_1 d_1) \exp(-\mu_2 d_2) \qquad (7)$$

The volume fractions of water and solid material can easily be shown as

$$\alpha_1 = \frac{d_1}{d} = \frac{\ln(I/I_2)}{\ln(I_1/I_2)} \qquad (8)$$

$$\alpha_2 = \frac{d_2}{d} = \frac{\ln(I/I_1)}{\ln(I_2/I_1)} \qquad (9)$$

Where I_1 is the transmitted gamma ray intensity when the sample thickness d is full of water (i.e. $d = d_1$, I_2 is transmitted gamma ray intensity when the sample thickness d is full of solid material (i.e. $d = d_2$) and I is the transmitted gamma ray intensity when the sample thickness is full of latex.

In practice α_1 and α_2 may not be determined from equation (8) and (9) simply because the intensities of gamma rays I_1 and I_2 could not be measured directly from the use of latex as sample. By measuring at two different energies for various concentrations of latex, the values of μ_1 and μ_2 can be evaluated. The attenuation coefficients of latex for two gamma ray energies E_1 and E_2 can now be written as

$$\mu_{mix}(E_1) = \alpha_1 \mu_1 (E_1) + \alpha_2 \mu_2 (E_1) \qquad (10$$

$$\mu_{mix}(E_2) = \alpha_1 \mu_1 (E_2) + \alpha_2 \mu_2 (E_2) \qquad (11)$$

The component ratios of α_1 and α_2 by latex could be obtained by solving equations (10) and (11).

MATERIALS AND METHODS

Field Hevea Brasiliensis latex samples were collected from the Universiti Pertanian Malaysia farm during normal tapping. These samples were taken in five working days at different locations. On each day at least 10 rubber trees were randomly selected to obtain the required amount of bulk sample. The samples were immediately diluted with distilled water in the laboratory. This was to prepare the samples with low DRC. The samples with DRC ranging from 5% to 35% were put into small plastic bottles and sealed to minimise the loss of water due to evaporation. For each concentration, at least three samples were prepared from different bulk samples. The height of each sample in the bottle was kept to 2 cm. They were then ready for the attenuation measurement on the following day. DRC measurements by the Standard Laboratory Method were carried out based on Malaysian Standard MS 3:35:1975 (SIRIM, 1975).

The linear attenuation coefficients of the samples of different DRC were determined separately by transmission measurements of the collimated gamma ray beam. The experimental arrangement employed a lithium drifted silicon Si(Li) solid state detector, a preamplifier, an amplifier and a multichannel analyser (MCA) as in the earlier experiment elsewhere (Elias *et al.*, 1983). The radioactive source of Am was available at low intensity of about 1.0×10^6 Bq which emits low energy photons at 17.7 keV and 26.4 keV. The counting time of about 20 minutes has been employed although this could easily be reduced by the use or a radioactive source of higher activity. The sample was placed half-way along the beam which has a fixed geometry corresponding to 5 mm in collimator diameter and 8 cm source-detector distance.

RESULTS AND DISCUSSION

A total of 27 samples of various DRC levels was used in the experiment. These samples were prepared from five bulk samples of latex. Their linear attenuation coefficients of gamma ray are shown in *Figure 1.* Each point on the graph represents an average reading from three different samples of the same DRC. Using a least square curve fitting method, two straight lines were drawn to represent the attenuations of latex at gamma ray energies 17.7 keV and 26.4 keV respectively. These lines were used to calculate the linear attenuation coefficients of water and solid material of latex. Their values are shown in Table 1. Solid natural rubber samples supplied by the Rubber Research Institute of Malaysia

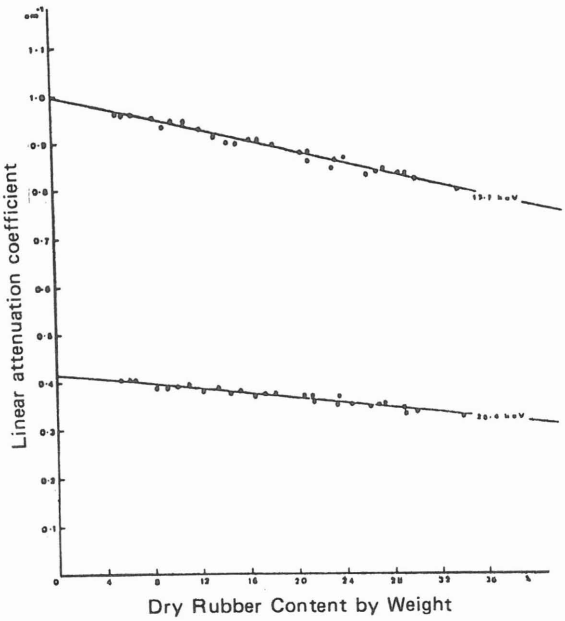

Fig. 1: Gamma ray attenuation coefficients of Hevea Latex versus DRC by weight (%)

TABLE 1
Calculated values of linear attenuation coefficients of water and solid materials

	Linear attenuation coefficient μ (cm^{-1}) + 0.005	
Component materials	E = 17.7 keV	E = 26.4 keV
Water (in latex)	0.998	0.418
Solid material (in latex)	0.464	0.163
Distilled water	0.996	0.442
Natural rubber (RRIM samples)	0.479	0.216

(RRI) and distilled water were used for comparison. We have a good agreement at the lower energy but a deviation at higher gamma ray energy. The reason for this could be due to uncertainty in the counting statistics at the higher energy with the use of a weak radioactive source. The attenuation coefficients of solid material of latex was slightly lower than that of RRIM rubber sample. This difference may be considered insignificant in view of their differences in atomic compositions. Nevertheless, if their complex compositions are known, we simply cannot ignore these two competing values as they are found in similar manner for water of latex and distilled water. We were unable to determine the linear attenuation coefficients at higher DRC concentrations due to the fact that the basic components of freshly tapped natural rubber latex constitute about 20% to 48% solid materials other than water (Chin, 1979). Latices with higher DRC values may be obtained by centrifuge but could not be employed here because water is not easily separated from latex. The measurement would give false attenuation coefficients at higher concentrations if serum were to be separated from the bulk samples.

The attenuation coefficients of water and solid material were then used to determine the volume fractions of water and solid material using equations (10) and (11). Here, 32 more DRC and attenuation measurements were performed using field latices taken from other bulk samples. *Figure 2* shows the plot of percentage of the actual DRC against the DRC measured by the attenuation technique. The correlation coefficient is 0.998 and the standard deviation is about 2% unit of DRC. All calculations were performed on the UNIVAC computer system of the Computer Centre, Universiti Pertanian Malaysia.

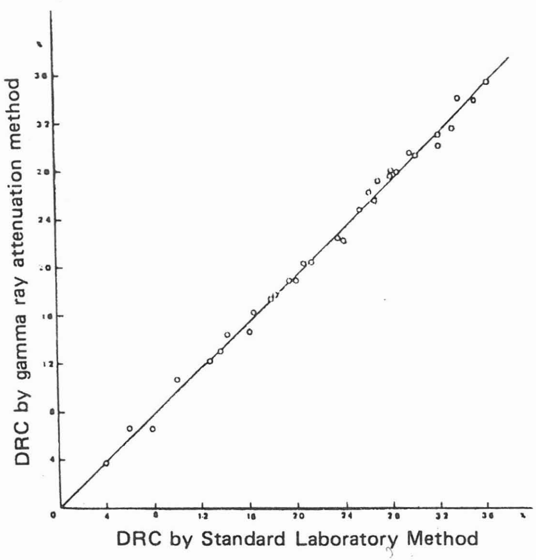

Fig. 2: The correlation of DRC measured by gamma ray attenuation method versus DRC by Standard Laboratory Method.

CONCLUSION

We have demonstrated the measurement of the component ratios of the total volume of water and solid material in multiphase system of latex by gamma ray attenuation technique. The method proposed in this preliminary work gives an indication that the possibility of non-destructive and direct determination of TSC of the Hevea latex which could be improved to determine DRC in the presence of adultrants in latex if the multiphase system is applied. However, more investigation is required to establish the capability of this technique in cooperation with a simple detection system which could replace the present sophisticated one.

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