

Preparation and study the mechanical properties of HEC/PVA composites by sound waves

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Abstract:

The HEC/PVA composite membranes of hydroxyethyl cellulose and poly vinyl alcohol were prepared by casting method, the appropriate weight of HEC was variable (0.1, 0.15, 0.2, 0.25 and 0.3 gm) dissolved in (25ml) of distilled water under stirring and heat (70◦C) for (30 min.) then add the PVA with different weights (0.2, 0.4 and 0.6 gm) for each HEC weight. In order to evaluate the mechanical properties of HEC/ PVA composite the ultrasonic measurements were performed at the samples , these properties are ultrasonic velocity, compressibility, acoustic impedance and bulk modulus, were made at fixed frequency (f =15KHz), another acoustic mechanical properties were measured and calculated at a same time such as the ultrasonic wave amplitude before and after absorption by composite were measured using oscilloscope ,then we calculated absorption coefficient , transmittance and the reflected pressure ratio of the sound. It was found that there is significant relationship between ultrasonic velocity and material properties also results show that adding PVA affects on the density then the absorption of the ultrasonic waves inside the composites samples.
Keywords: hydroxylethel cellulose ;polyvinyle alcohol; mechanical properties; casting method.

Introduction:

The main structural component of plants is cellulose, which is renewable and biodegradable. It is the most abundant natural biopolymer in the world. Natural cellulose fibers are synthesized mainly in plants such as grasses, reeds, stalks, and woody vegetation by photosynthesis. The natural fibers are attractive to replace man-made fibers such as glass and aramid fibers as reinforcement and fillers to make environmentally friendly products because they have many advantages such as renewable, low cost, low density, low energy consumption, high specific strength and modulus, high sound attenuation, nonabrasive, relatively reactive surface [1], Cellulose derivatives such as hydroxyethyl cellulose) are biocompatible [2] and have been applied in drug delivery formulations [3,4,5,6] Despite these successful applications and their very low cost, cellulose derivatives have been relatively underutilized in the bioengineering field [7,8]. HEC is derived from cellulose. It is an important industrial polymer with a wide range of applications in flocculation, drug reduction, detergents, textiles, papers, foods, and drugs [9].
HEC is used primarily because it has high viscosity, is non-toxic, and is non-allergenic. The numerous hydroxyl and hydroxyl groups in HEC enable water binding and moisture sorption properties. HEC hydro-gel has a high water content, good biodegradability, and a wide range of applications due to its low cost [10]. Because of its polymeric structure and high molecular weight, it can be used as filler in bio-composite films [11]. HEC is able to improve the mechanical and barrier properties of pea starch-based films [12]. because of its pronounced visco-elastic and structure-forming properties, HEC employed as a flow enhancer, a stabilizer, and also as an agent for binding, suspending and thickening. [13]. Polymer systems are made up of chemical bonds along the polymer chains and physical bonds across the polymer chains. The former includes covalent bonds and the latter results from hydrogen bonding, dipolar bonding, or van der Waals forces. The type of physical bonding has huge effects on the physical properties of polymers. Particularly with the systems in which hydrogen bonding has a dominant effect, the physical properties are strongly dependent not only on the molecular weight and concentration of polymer but also the kind of. Polyvinyl alcohol (PVA) is a semi crystalline polymer whose produce inter- and intra-molecular hydrogen bonding [14]. The purpose of this research was to investigate the physical and mechanical properties of polyvinyl alcohol (PVA) and hydroxylethel cellulose (HEC) composite materials, the (PVA) polymer reinforced in the HEC polymer as filler. The composites were characterized by sound wave at fixed frequency (3500Hz).(PVA) and(HEC) composites were prepared by film casting method.

Experimental:

Materials:

Table (1) the material under study (The materials were used as received without further purification.)

Material	Solvent	Assay %	Density (gm/cm^3)	Molecular formula	Company	Country
PVA	Water	99.8	1.19-1.31	$(C_2H_4O)_x$	Gerhard Buchman	Germany
HEC	Water	99.9	variable	-	Panreac	Spain

Sample Preparation:

The HEC/ PVA composite membranes were prepared by casting method, the appropriate weight of HEC was variable (0.1, 0.15, 0.2, 0.25 and 0.3 gm) dissolved in (25ml) of distilled water under stirring and heat (70◦C) for (30 min.) then add the PVA with different weights (0.2, 0.4 and 0.6 gm) for each HEC weight, the resulting solution was stirred continuously until the solution mixture became a homogeneous viscous appearance at room temperature for (30 min.). The HEC/PVA composite polymer membranes are obtained by leaving the mixture solution in a petre dish at room temperature for 4 weeks and then the composites samples were in the circle shape with (6.5 cm) diameter and the density of the samples were measured by the weight method.

Measurements:

The sound wave measurements were made at fixed frequency (f=15KHz) using technique of sender-receiver type (SV-DH-7A/SVX-7 velocity of sound instrument)

Theoretical calculations:

The absorption coefficient (α) was calculated from Lambert – Beer law [15]:

$$A/A_o = e^{(-\alpha x)} \ldots\ldots (1)$$

Where (A_o)is the initially amplitude of the sound waves, (A) is the wave amplitude after absorption and (x) is the thickness of the sample, the transmittance (T) is the fraction of incident wave at a specified wavelength that passes through a sample was calculated from the following equation [16]:

$$T = I / I_o \ldots\ldots\ldots (2)$$

Where (I_0) is the initially intensity of the sound waves and (I) is the received intensity. The sound wave velocity was calculated using the following equation [17]:

$$V= X / t \ldots\ldots (3)$$

Where (t) is time that the waves need to cross the samples (digital obtained from the instrument).

Attenuation is generally proportional to the square of sound frequency so the relaxation amplitude (D) was calculated from the following equation [18]:

$$D = \alpha / f^2 \ldots\ldots\ldots (4)$$

The wavelength (λ) can change only when the speed of the wave changes inside the samples we can calculated it by the equation [19]:

$$\lambda = v / f \ldots\ldots. (5)$$

Bulk modulus (B) of a composite is the substance's resistance to uniform compression, it is defined as the pressure increase needed to decrease the volume; it was calculated by Laplace equation where (ρ) is the density [20]:

$$B = \rho v^2 \ldots\ldots (6)$$

Compressibility (β) is a measure of the relative volume change of a fluid or solid as a response to a pressure (or mean stress) change, it was calculated by the following equation [21]:

$$\beta = (\rho v^2)^{-1} \ldots\ldots (7)$$

The acoustic impedance of a medium (Z), it was calculated by equation [22, 23]:

$$Z = \rho v \ldots\ldots (8)$$

The reflected pressure ratio of the sound is determined by the equation:[24]

$$R/A_o = (Z_1-Z_2) / (Z_1+Z_2) \ldots\ldots (9)$$

Results and discussions:

The influence of PVA concentrations on properties of HEC based films; The HEC were using as matrix and PVA were using as filer using casting method, the mechanical properties of the films were measured using sound waves at frequency (15kHz). Film thickness ranged from (50-130 μm). The Density of HEC/PVA films is shown in Figure (1), it is decreasing when adding PVA, since the HEC is high viscosity; there will be interaction causing association between the three type of molecules (PVA molecules, HEC molecules and solvent molecules) this interaction causing entanglement action then reduce the density as shown in figure (1) [25, 26]. The sound wave velocity results shown in figure (2) that it is decreasing with concentration because when wave are propagated thought it the resultant periodical changes of wave pressure causes molecules to flow into vacancies in the lattice during compression phase and to return to their original positions in the lattice during rarefaction, so when concentration increases the velocity decreases [27,28], the velocity results also shows that it depend on the density because whenever we add PVA the density reduce and the velocity increase. The specific acoustic impedance is decreasing with increase of concentration as shown in figure (3), this caused when concentrations increasing there are rearrangements of the polymer network by breaking chains bonds, it was probably that water clusters grew and came into contact with hydrophobic regions of the membranes resulting in a gradual change with stronger hydrogen bonds. [29] figure (3) also shows that added (0.6 gm PVA) to (HEC) has higher specific acoustic impedance since there are more degradation. The compressibility of samples was calculated using Laplace equation, the results in figure (4) Shows that the compressibility are increasing with increasing concentration this could be attributed that the waves propagation made polymer chains that randomly coiled to be each close together, this change confirmation and configuration of these molecules, so there are more compression happen of these molecules through sound wave propagation [30,31], this compression fills the vacancies between polymer molecules and restricted the movement of these molecules this lead to reduce the elasticity of the composite with adding PVA as shown in figure (5) , figure (6) shows that absorption coefficient is increasing with concentration this attributed to the fact that when polymer concentration increase there will be more molecules this lead to more attenuation against wave propagation, the attenuation can be attributed to the friction and heat exchange between the particles and the surrounding medium as well as to the decay of the acoustic wave in the forward direction due to scattering by the Particles [18]. The transmittance is decreasing with increasing concentration as shown in figure (7) this attributed that the polymer molecules absorbed the sound waves according to Lambert-Beer Law which is biased on concentration [32]. The relaxation amplitude is increasing with increasing concentration as shown in figure (8) this attributed that the displacement of excited molecules became small because moment of inertia for polymer macro molecules reduce [33]. The output ultrasonic wavelength are decreasing with the increase of concentration as shown in figure (9) this attributed that when concentration increase the molecules will be close together and there are more interaction so there are more attenuation according to compression and rarefaction of wave propagation by these molecules. The reflected pressure ratio of sound for this composites decreases with adding PVA as shown in figure (10), this attributed to the incident wave is moving against composite molecules with velocity and static pressure in which the speed of sound change suddenly at the contact surface, if the speed of sound decrease the reflected pressure increase, the entanglement interaction of the molecules.[24]

Conclusions

1. Adding PVA to HEC decreasing the density.

2. The density decreasing the sound wave velocity.

3. Adding PVA made the composite good absorber medium to the sound waves.

4. The composite can be applied in deferent industries such as reducing sound noise in factories, airplanes, coating wall buildings and teaching room.

5. The composite is not good reflector to sound waves so it can be use as coating to moving subjects that want be observed by some sound detectors.

6 – this composite has good mechanical properties so it may use as resistant materials against environment

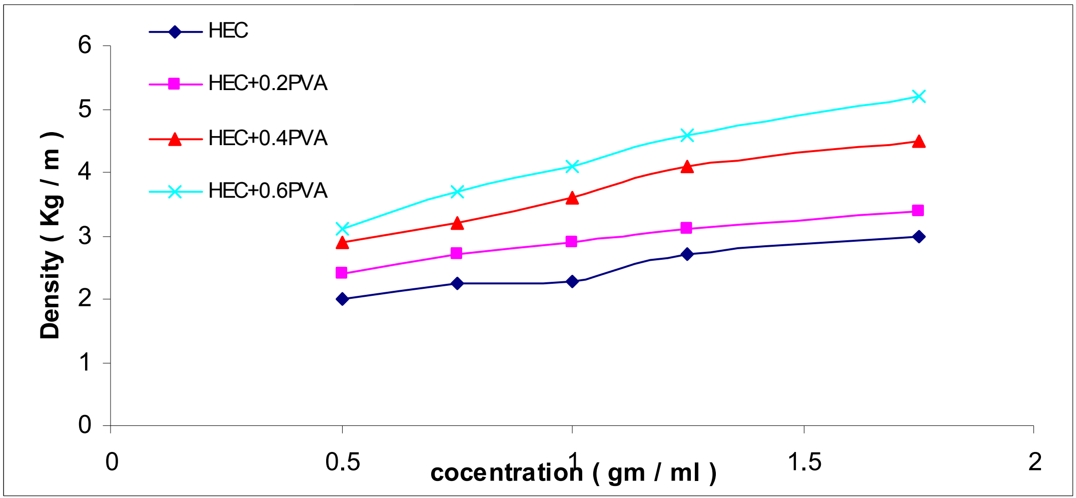

Fig. (1) The density due to the HEC concentration

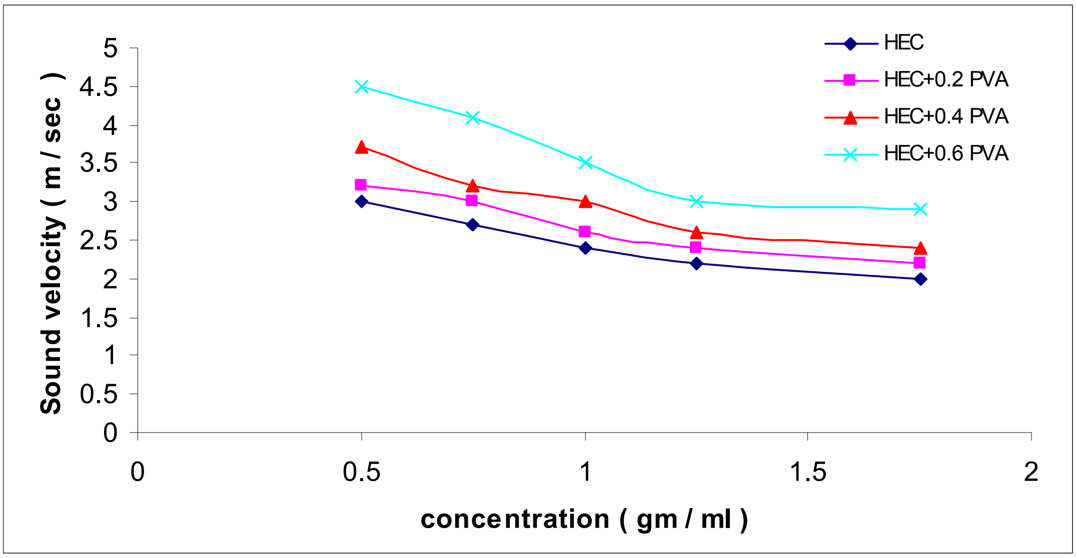

Fig. (2) The velocity of sound due to the HEC concentration

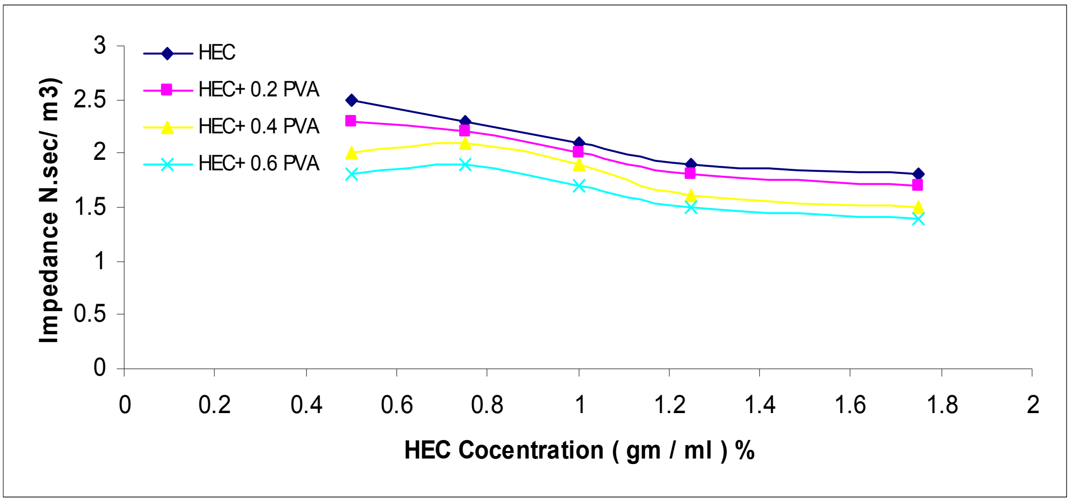

Fig. (3) The acoustic impedance due to the HEC concentration

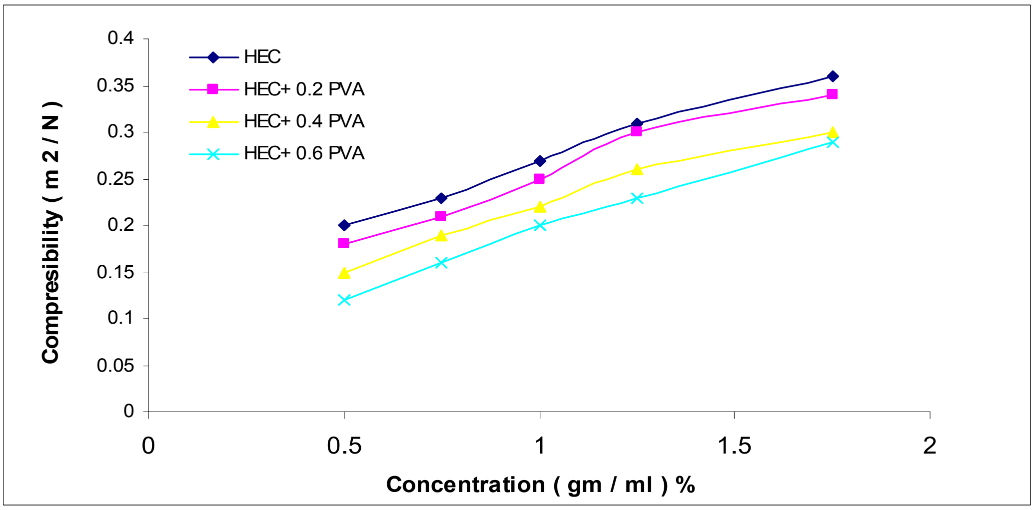

Fig. (4) The compressibility due to the HEC concentration

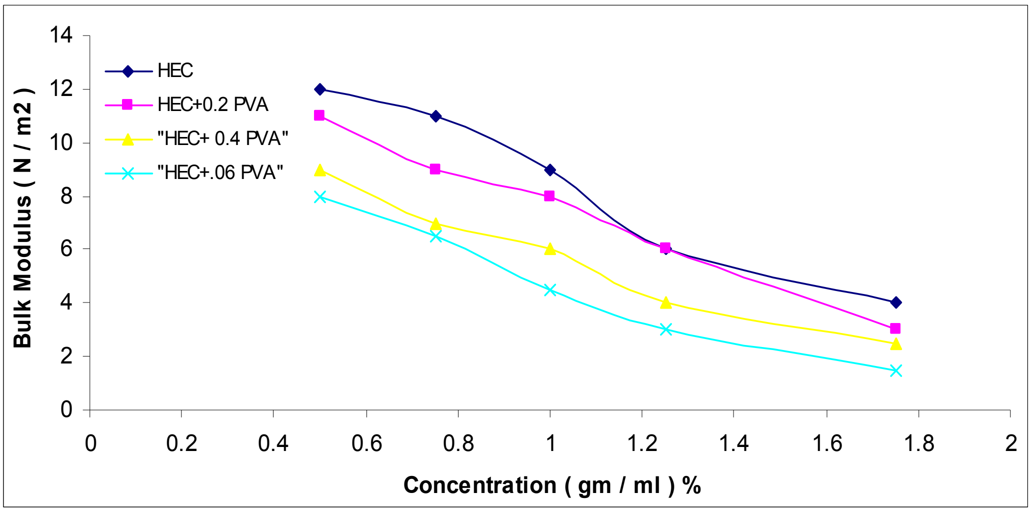

Fig. (5) The bulk modulus due to the HEC concentration

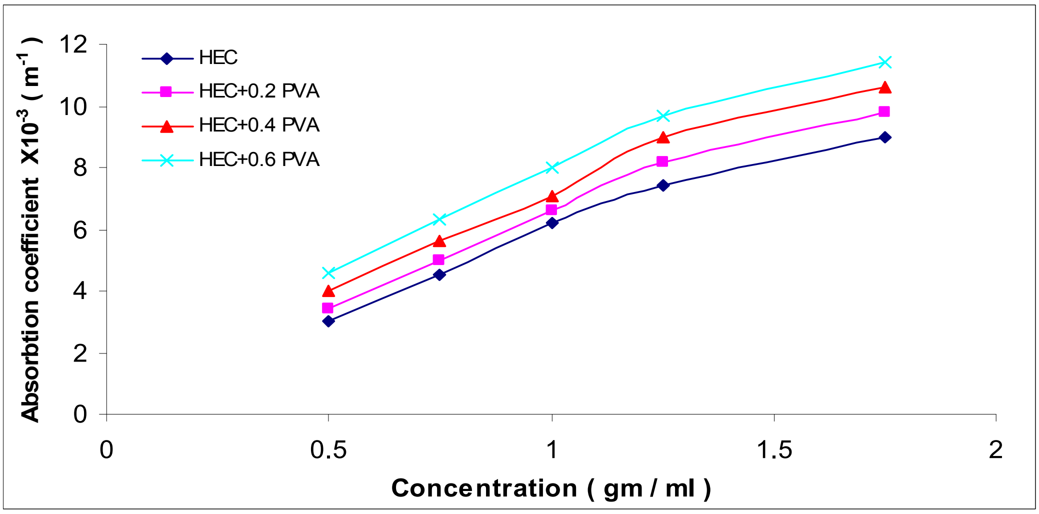

Fig. (6) The absorption coefficient due to the HEC concentration

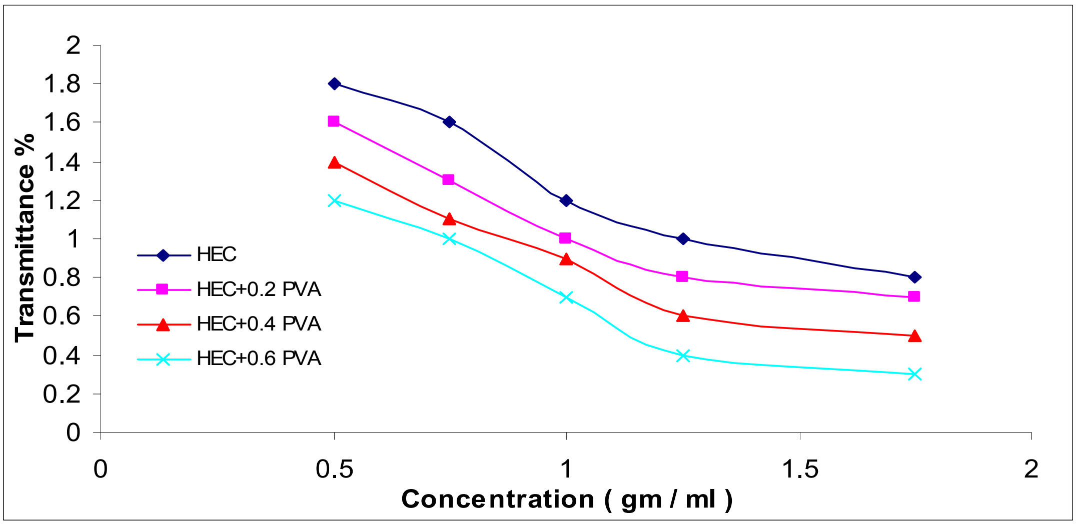

Fig. (7) The transmittance due to the HEC concentration

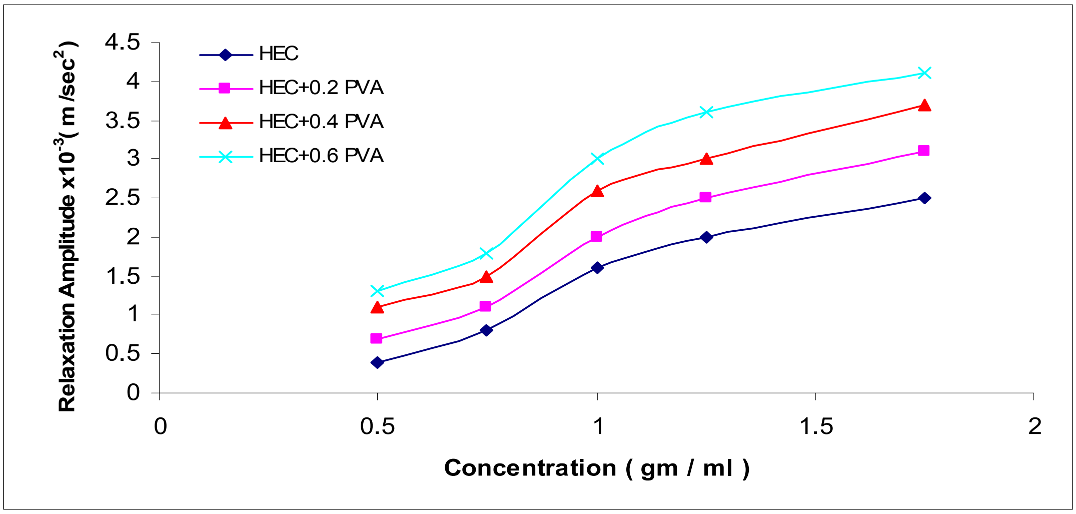

Fig. (8) The relaxation amplitude due to the HEC concentration

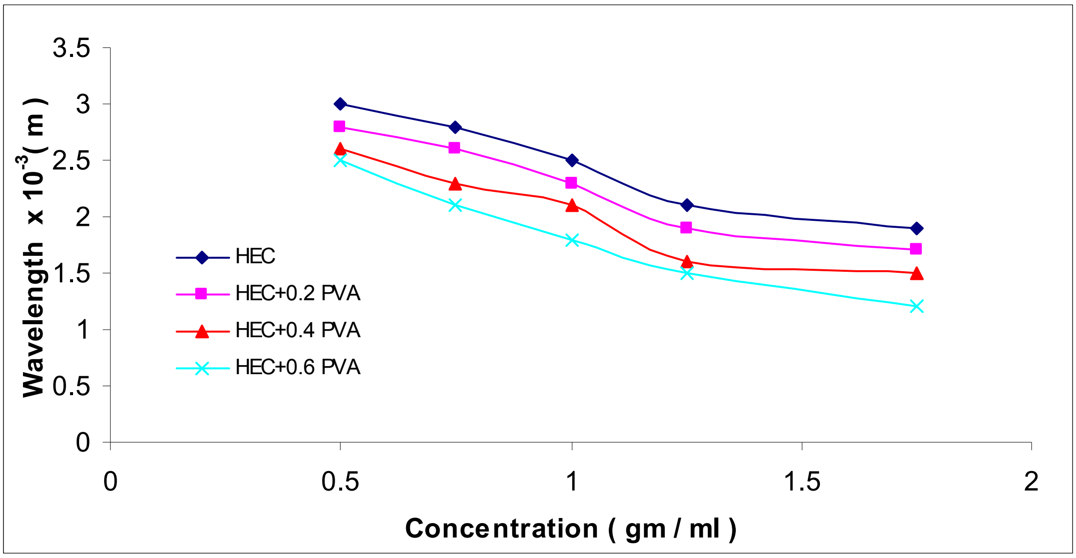

Fig. (9) The wavelength due to the HEC concentration

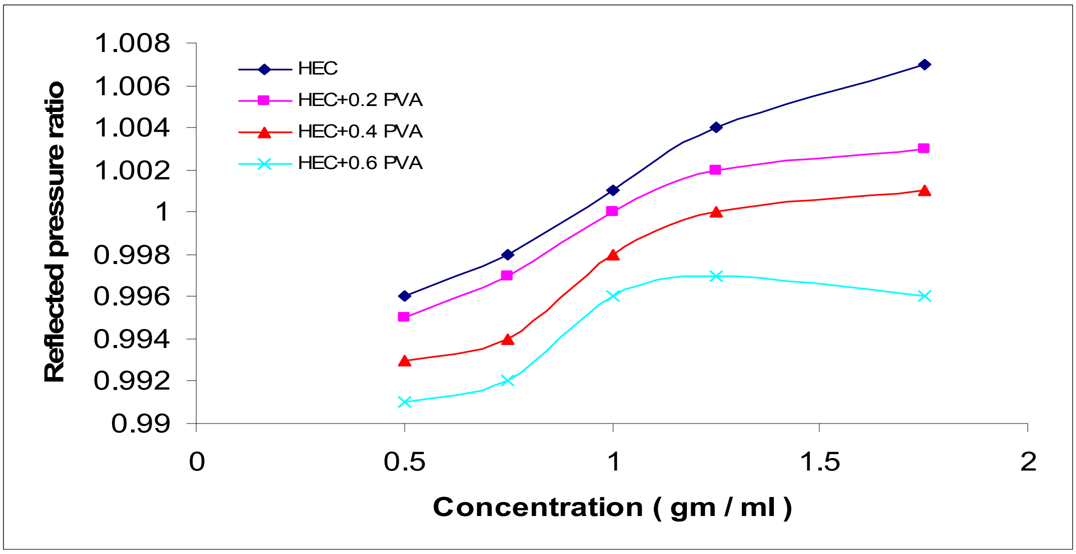

Fig. (10) The reflected pressure ratio due to the HEC concentration

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