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LOCALLY AVAILABLE BLACK MATERIALS FOR USE AS FLAT-PLATE SOLAR ABSORBER

A. A. OKON, U. A. UKPONG and G. T. AKPABIO

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ABSTRACT

The transmittance with wavelength was measured for black dye, charcoal, coal tar, lamp black and black paint. The absorptance for each of the samples was determined as black dye 0.96, charcoal 0.9; coal tar 0.97, black paint 0.94, and lamp black 0.97. The result shows that charcoal has the highest absorptance and would make the best choice for the locally available black materials for use as flat plate solar absorbers.

KEY WORDS
Transmittance, Absorptance, Infrared, Solar energy and Wavelength.

1.0 INTRODUCTION

The sun is the principal source of solar energy. Solar energy, the only inexhaustible energy source has varieties of applications, for example heating of houses and water, generation of electricity, etc. (Akpabio 1999). Solar energy can be converted to heat for hot water supply and space heating using efficient collectors or absorbers.

A flat plate solar collector is a device designed to convert solar energy to heat, which is used in heating liquids. The basic collector, consisting of a flat plate suitably blackened (Meinel and Neinel 1977) is the absorbing surface for transferring the absorbed energy to the fluid.

The efficiency of the flat plate depends on the radiative properties of the black absorber. Most of the well known absorbers are either costly or absorbed poorly (Duffie and Beckman 1974). Hence, the need to look for locally available black materials for use as flat plate solar absorbers.

The behaviours of various evaporator liner were studied. It was discovered that charcoal has a lot of overriding effect over coal-tar, epoxy black paint, black rubber and [illegible]

[illegible]

2.0 THEORETICAL CONSIDERATION

When a beam of monochromatic radiation of intensity I passes through an absorbing but non-scattering medium of thickness dx, it suffers attenuation in the direction of propagation according to the equation.

$$dI_\lambda = -k_\lambda \rho I_\lambda dx \qquad (1)$$

where ρ is the density of the medium and k_λ is the mass absorption cross-section for radiation of wavelength, λ.

The term 'cross section' is used to denote the amount of energy removed from the original beam by the particle of a medium. The product of the absorption cross section and the particle number density is defined as the absorption coefficient, (Liou 1980).

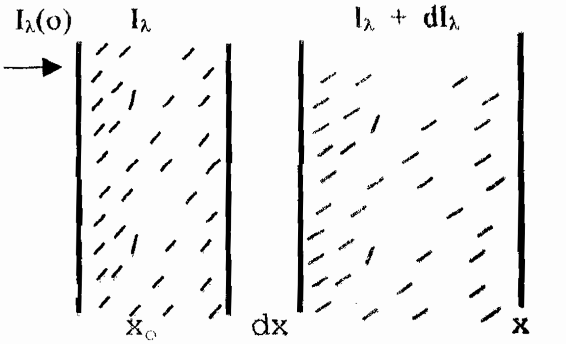

Fig 1: Passage of radiation through absorbing [illegible] non scattering medium.

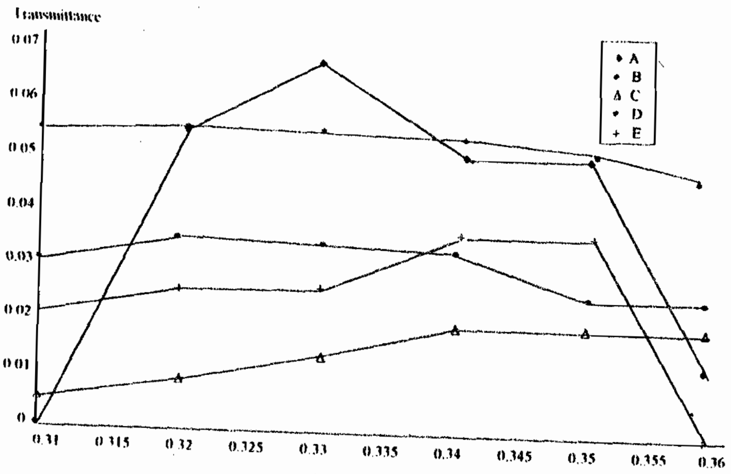

Fig. 2: Graph of Transmittance against Wavelength

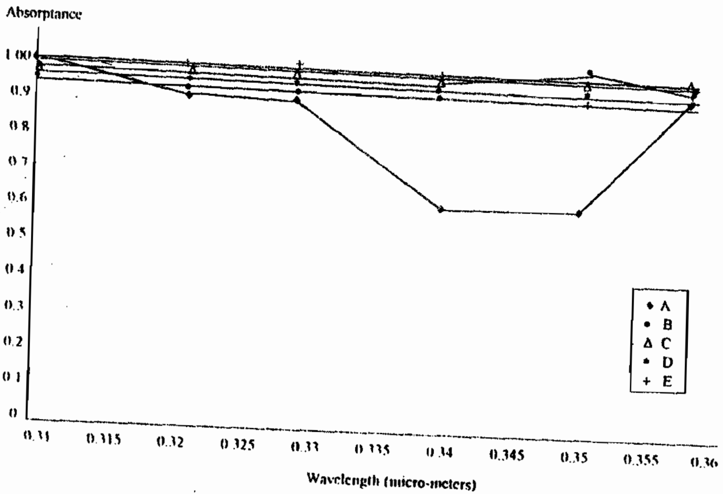

Fig. 3: Graph of Absorptance against Wavelength

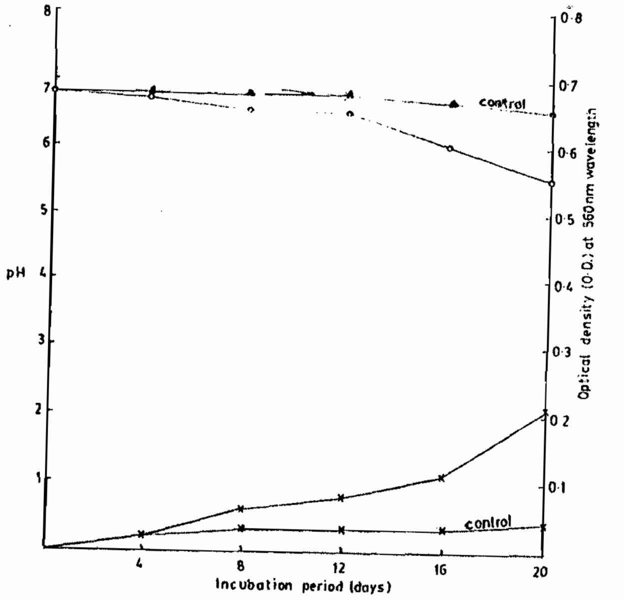

Fig. 4: Growth profile (pH; o and O.D; x) of sarcina IU8 on crude oil medium. Uninoculated crude oil medium served as control (▲)

Equation 1 can also be written in the form (Robinson 1964)

$$\frac{d_{\lambda}}{k_{\lambda}\rho dx} = - I_{\lambda} \qquad (2)$$

If as in Fig. 1, the radiation passes horizontally through the medium and the incident intensity at x = 0 is $I_{\lambda}(0)$, then the intensity at a distance x is obtained by integrating eqn. 2 and is given by

$$I_{\lambda}(x) = I_{\lambda}(0) \exp\left(-\int_{0}^{X} k_{\lambda}\rho dx\right) \qquad (3)$$

In a homogeneous medium k_{λ} is independent of the distance x and the path length x, is defined (Meyer and Jurgen 1972) as:

$$U = \int_{0}^{X} \rho\, dx \qquad (4)$$

Eqn. 3 can now be written in the form

$$I_{\lambda}(x) = I_{\lambda}(0)\ e^{-k_{\lambda}U} \qquad (5)$$

$$\frac{I_{\lambda}(x)}{I_{\lambda}(0)} = e^{-k_{\lambda}U} \qquad (6)$$

The term on the left hand side of eqn. 6 is the monochromatic transmitivity, Tr_{λ} of the medium

$$Tr_{\lambda} = e^{-k_{\lambda}U} \qquad (7)$$

The monochromatic absorptance, A_{λ} can be defined in terms of the transmitivity as:

$$A_{\lambda} = 1 - Tr_{\lambda} \qquad (8)$$

Also, the optical thickness τ_{λ} of the medium between x = 0 and x = x is defined as:

$$\tau_{\lambda}(0,x) = \int_{0}^{X} k_{\lambda}\rho dx \qquad (9)$$

Substituting eqn. 9 into eqn. 5 gives

$$I_{\lambda}(x) = I_{\lambda}(0)\ e^{-\tau} \qquad (10)$$

or

$$\frac{I_{\lambda}(x)}{I_{\lambda}(0)} = e^{-\tau(0,x)} \qquad (11)$$

i.e.

$$Tr_{\lambda} = e^{-\tau(0,x)} \qquad (12)$$

$$A_{\lambda} = 1 - Tr_{\lambda} = 1 - e^{-\tau(0,x)}{}_{\lambda} \qquad (13)$$

3.0 MATERIALS AND METHOD

The locally available materials for analysis include black dye, charcoal, coal tar, black paint and lamp black. Each of these samples (thickness 1.5mm) was mounted on a glass slide and the slide is then slot into infrared spectrophotometer. The infrared rays was then made to pass through each sample. With this method, the transmittance, hence, absorptance for each sample was determined.

Table 1 shows the wavelengths and the corresponding values of average transmittance and absorptance. Fig. 2 shows a plot of transmittance against wavelength for sample A to E. Fig. 3 shows a plot of absorptance against wavelength for sample A to E.

The material analysed include black dye, coal-tar, charcoal, lamp black and black paint mounted on a glass slide respectively. Each of them was placed in infrared spectrophotometer such that its infra red rays passes through it.

The transmissivity for each sample using infra red spectrophotometer for wavelength range of 2.5 to 25 micron meter and grating spectrophotometer for wavelength of 0.1 to 1.0 micro m (the infra red rays is between the wavelength range 10^{-6} m and 10^{-3}m; Rogers, 1983). Since we are considering the infra red spectrum, it becomes necessary to average the transmittance and absorptance for the discussion of the results. This is presented in Table 1

Table 1 and Fig. 2 show that the material with the least transmittance is charcoal 0.0145, charcoal also has the highest absorptance of 0.99 as shown in Table 1 and Fig. 3, this is followed by coal tar and lamp black. Black paint is found to have the least absorptance of 0.95. Charcoal is therefore chosen as the choice of locally available material for use.

4.0 CONCLUSION

Table 1 and Figs. 2 and 3 show that charcoal has the highest absorptance and would therefore be a better choice than black dye coal tar, lamp black and black paint for locally available black material for use as flat plate solar absorber.

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Table 1: Average Transmittance and Average Absorptance.

Sample	Code	λμm	T_λ	A_λ
Black dye	A	0.31-0.63	0.0372	0.96
Coal tar	B	0.31-036	0.033	0.97
Charcoal	C	0.31-0.36	0.0145	0.99
Black paint	D	0.31-0.36	0.0562	0.94
Lamp black	E	0.31-0.36	0.034	0.97.