Transmittance and Extinction Coefficient of Sea and Well-Water in Mombasa County, Kenya

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Abstract. Using a laser transmitter in the range of 200 nm to 1200 nm, transmittance and total extinction coefficients were determined for two different but close related optical media which are ocean water and shallow well water in Mombasa County, in Kenya. The results were interpreted using Lambert–Beer's law as applied for very small ranges of concentrations. It was established that the total extinction coefficients for two forms of water showed linearity with values of total extinction coefficients found to be μt = 7.734 $(g/ml)^{-1}$ mm^{-1} and μt = 127.6 mm^{-1} at a wavelength of 638 nm for ocean water and shallow well water respectively.

Keywords: Lambert–Beer's law; attenuation; nanoparticles; energy radiated; seawater; absorption; scattering.

INTRODUCTION

In optical applications, water is usually assumed to be transparent to electromagnetic radiations within the visible spectrum. Somehow, it is taken as opaque to wavelengths above the visible spectra and those below it. Based on this assumption, visible light in water undergoes refraction and attenuation [4]. The amount to which refraction take place is called refractive index [1] which is subject to its state of salinity and temperature. The refractive index increases with increasing salinity and decreasing temperature. In scientific studies, refractive index of a sample of seawater used in this study was at a constant temperature. In real cases, water may have some cloudiness caused by suspensions of dissolved nanoparticles materials [10] such that when a light beam incident on it undergoes through two different phenomena, absorption, and scattering [9]. Absorption hampers propagation while scattering which is caused by the refractive index mismatch at microscopic boundaries [13]. Finally, some decrease is evident due to ray re-direction as a result of the photon absorption leading to a concept of extinction or energy attenuation of the incident light energy [8].

THEORETICAL PRINCIPLES

In any form of a fluid, intensity of radiation with respect to wavelength λ decreases in the direction of the light beam [14]. Ideally, the decrease at the infinitesimal thickness, *x*, is proportional to the intensity of energy radiated, *I*, as [6]:

$$dI_\lambda = -\chi_\lambda I_\lambda dx \tag{1}$$

The coefficient of proportionality, χ, is called the absorption coefficient, which can be obtained by integrating Equation (1) in the limits ($x = h$ and $x = h + L$), to obtain [11]:

$$\chi_\lambda = \frac{2.30}{L}(\log I_{\lambda,h} - \log I_{\lambda,(h+L)}) \quad (2)$$

From Equation (2) a factor of 2.30 is applied because the logarithm used is of base-10, L is the thickness of the layer within which the energy of the radiation is reduced from $I_{(\lambda,\ h)}$ to $I_{\lambda,(h+L)}$. The absorption coefficient depends upon the unit of length which L is expressed. The decrease of intensity in water depends upon the amount of radiation that is absorbed and scattered. Purified water has its scattering due to water molecules [4, 8, 15]. The scattering effect is not easy to separate as it includes absorption coefficient which is a factor of wavelength, discrepancies has been reported and due to these discrepancies, the absorption in pure water is still in dispute as portrayed in Table 1.

Table 1 – Reported absorption coefficients [6]

Author (s)	Year	Absorption coefficients
Hüfner and Albrecht	1891	0.048
Ewan	1895	0.030
Aschkinass	1895	0.020
Sawyer	1931	0.015

Lambert-Beer's law for low concentrations empirically relates to light absorption and scattering of the material as [5]:

$$I = I_o \exp(-\mu_t \times c \times r) \quad (3)$$

so that:

$$\mu \times c = \ln(\frac{I_o}{I}) \times \frac{1}{r} \quad (4)$$

where I_0 – is the intensity of the incident light; I – is the intensity of the transmitted light; r – is the thickness of the sample; c – is the concentration of the sample; μt – is the total extinction coefficient of the sample.

EXPERIMENT PROCEDURES

A laser source emitter transmitting at a spectral range from 200 nm to 1200 nm was employed directed to a 20 mm thick transparent glass sample carrier. A sensitive multi-range meter able to measure currents up to 20 nA was used. Two samples of ocean water and another sample of shallow well-water were used.

RESULTS AND DISCUSSION

By geographical definition, a water well can be defined as an excavation or structure created in the ground by digging, driving, boring, or drilling to access groundwater in underground aquifers [8]. This implies that if it ever gave the result to water, then the water is drawn by a pump, or using containers, such as buckets, that are raised mechanically or by hand. Deeper wells are excavated by hand drilling methods or machine drilling. Drilled wells can access water at much greater depths than dug wells [5]. Therefore, there are two broad classes classified as shallow or unconfined wells completed within the uppermost saturated aquifer at that location, and as deep or confined wells, sunk through an impermeable stratum into an aquifer beneath. Well, water is known to contain naturally occurring minerals, such as calcium, iron, and sulfur [3]. These present excess quantities over water molecules. Therefore, the results obtained were plotted and represented graphically. Transmittance against concentration for ocean water and well water was represented in Figures 1, 2.

Transmittance as an optical property of the surface of a material is defined as the effectiveness in transmitting radiant energy as received at and past the surface [14]. Therefore it is indeed the fraction of incident electromagnetic power that is transmitted through a sample, in contrast to the transmission coefficient [10]. Therefore, it is well defined when taken as the ratio of the transmitted to the incident electric field which thus includes internal transmittance which is the energy loss by absorption as compared to total transmittance which is due to absorption, scattering, reflection, and related optical properties.

As observed in Figure 3 and Figure 4 show that the transmitted intensities decrease exponentially with concentration for both ocean water and shallow well-water. In photometry [1], luminous intensity is a measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle, based on the luminosity function, a standardized model of the sensitivity of the human eye. Thus, the graph depicts the luminous intensity of the two samples.

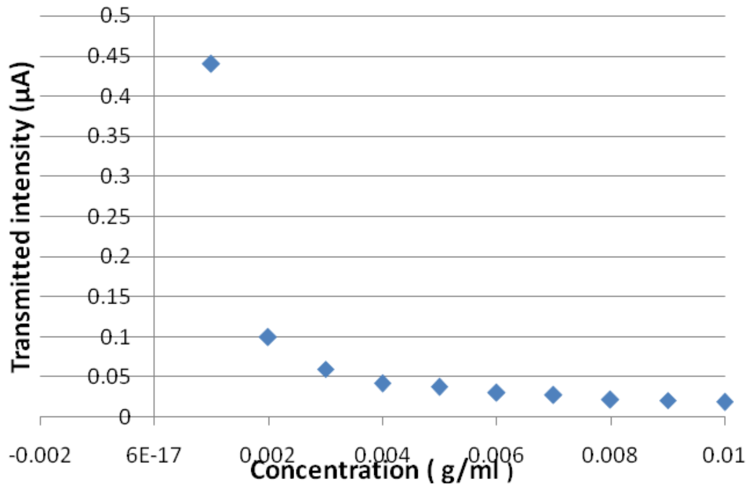

Figure 1 – Transmitted intensity versus concentration for ocean water

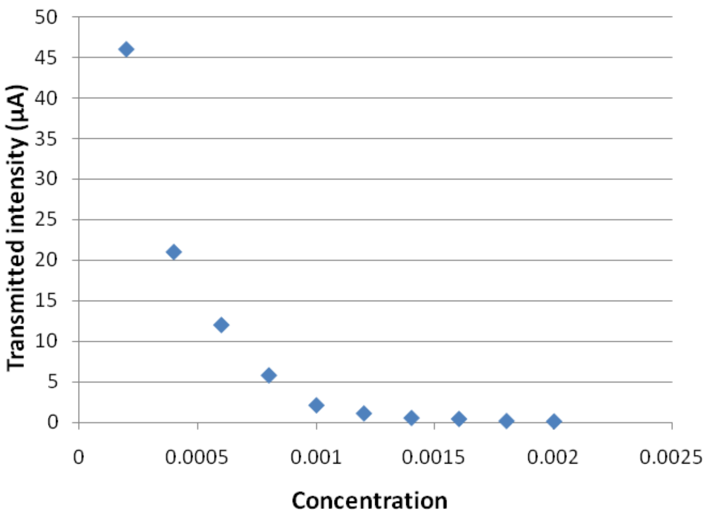

Figure 2 – Transmitted intensity versus concentration for shallow well-water

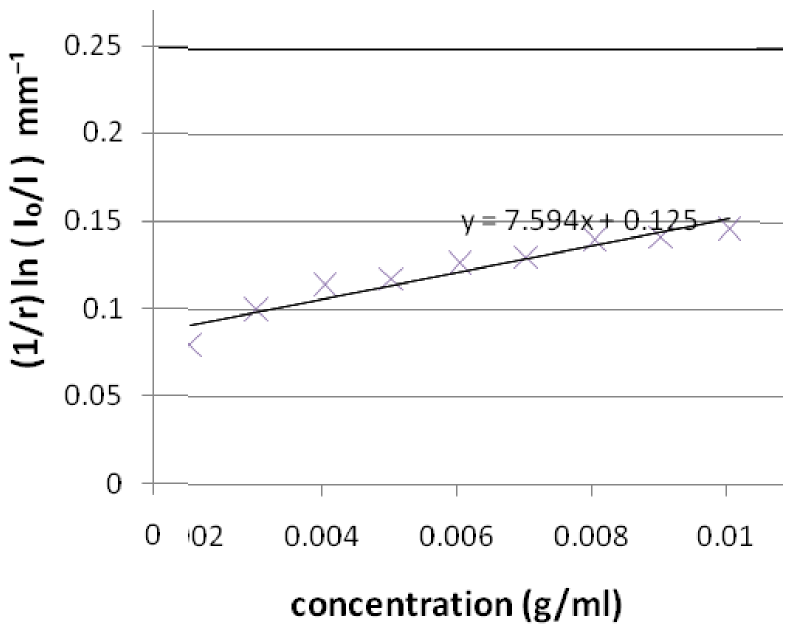

Figure 3 – Relationship of (1/r) ln (I_0/I) versus concentration for ocean water

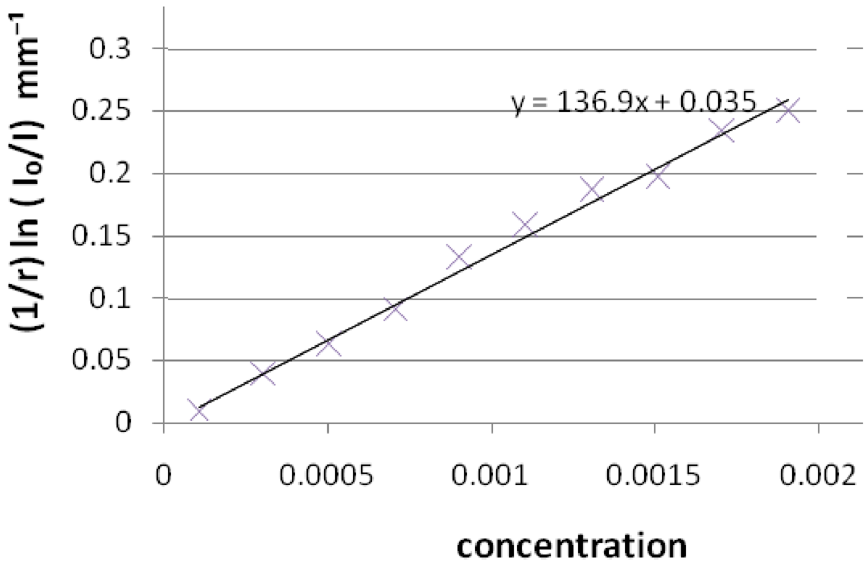

Figure 4 – Relationship of (1/r) ln(I_0/I) versus concentration for shallow well-water

The exponential decrease confirms the applicability of Lambert-Beer's law in the range of concentrations considered in this analysis which states that that absorbance of a material sample is directly proportional to its thickness. Based on absorbance, Beer's law is stated that absorbance is proportional to the concentrations of the attenuating species in the material sample [7]. Therefore, if a compound absorbs light, then its absorption spectrum is a unique property of that compound. This implies that the molecular structure is responsible for the absorption properties and thus the most common feature of absorbing compounds are conjugated double bonds, often as an aromatic ring.

As observed in Figure 1 and Figure 3, the results of ocean water was for measurements of concentrations ranging from 0.002 g/ml to 0.010 g/ml in steps of 0.001 g/ml whereas Figure 2 and Figure 4 are for referring sampled shallow well water for concentrations ranging from 0.0002 to 0.0020 in steps of 0.0002. From the results linear fitted measurements were taken and the slope obtained represents the total extinction coefficient μt. Thus the intercept noted is very small relative to the slope value. Therefore, the total extinction coefficient, μt, of 7.734 $(g/ml)^{-1}$ mm^{-1} for diluted concentrations of ocean water at 638 nm and total extinction coefficient for shallow well water was μt = 127.6 mm^{-1} at 638 nm. These reported values of total extinction coefficient depended on wavelength [12] only. Therefore, the linearity of the result shows that Equation (1) related well in the range of concentrations considered in this study [15]. It was not established whether the extinction coefficient for ocean water depends on the place of ocean water considered just as well water.

CONCLUSIONS

It was established that the total extinction coefficients for two forms of water showed linearity of the results obtained in Figures 3, 4. This was in agreement with Lambert-Beer's law in the range of concentrations considered in this study. From these results, values of total extinction coefficients for ocean water and shallow well water were found to be μt = 7.734 $(g/ml)^{-1}$ mm^{-1} and μt= 127.6 mm^{-1} at a wavelength of 638 nm respectively.

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