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Analytical Study of Water Purity Using Low Power He:Ne Laser

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Abstract

In this research, an analytical study of water using laser source transport through some samples of water tubes was presented. He–Ne laser with measured maximum output power 2.83 mW was used to determine the purity of water by measuring its output power when it was passing through tube of water. This tube was initially filled by water and then by distill water contain different ratio of salts and clay. For each case, the output power would be measured and calculated its attenuation which was occurred when laser was passing through the water. The attenuation happened in the laser beam when transport through the water sample that contain NaCl due to the absorption process. The attenuation happened in the laser beam when transport through the water sample that contain clay due to the scattering process. Water tap mostly contain different ratio of salts and clay so the attenuation accurse in laser beam is due to absorption and scattering process, and it can be compared these results with that produce when mixing NaCl solution sample with the clay sample.

1- Introduction

The beam attenuation coefficient α(λ) is used to characterize the optical transmission properties of water. The beam attenuation coefficient is a measure of the decay of the unscattered light and is defined as:

$$p_1(\lambda) = p_o(\lambda) e^{-\alpha(\lambda) L} \quad (1)$$

where, $p_o(\lambda)$ is Initial beam radiant power, $p_l(\lambda)$ is Measured beam radiant power, and L is the water path length. The beam attenuation coefficient is the sum of the absorption coefficient α(λ) and the scattering coefficient s(λ)[1]

$$\alpha(\lambda) = a(\lambda) + s(\lambda) \quad (2)$$

In distill water, the scattering phenomenon is negligible. Therefore, the attenuation coefficient is equal to the absorption coefficient,

$$\alpha(\lambda) = a(\lambda) \quad (3)$$

where α is usually given in units of cm^{-1} and can be defined in terms of transmittance by [1,2]:

$$\alpha(\lambda) = \frac{1}{L} \ln \frac{1}{T(\lambda)} \quad (4)$$

where T (λ) is the transmitted of under water beam is defined by

$$T(\lambda) = \frac{p_l(\lambda)}{p_o(\lambda)} \quad (5)$$

The colors of an object typically arise because materials selectivity absorbs light of certain frequencies while freely scattering or transmitting light of other frequencies. Thus if an object absorbs light of all visible frequencies, it is black. Nonmetallic materials may be opaque or transparent to visible light; and, if transparent, they often appear colored. When a beam of light is passed through matter in the solid, liquid or gaseous state, its propagation is affected in two important ways [3]. In the first place, the intensity will always decrease to a greater or less extent as the light penetrates farther into the medium. In the second place, the velocity will be less in the medium than in free space. The loss of intensity is chiefly due to absorption. Then absorption is a way of interaction of the electromagnetic radiation with matter, energy absorbed and transformed to other type, the absorption coefficient $\mathbf{a}(\lambda)$ cm^{-1} is a property of matter [4]

The intensity of transmitted or non absorbed radiation I` continuously decreases with distance L that the light traverses and it obeys to [4]

$$I' = I_o \exp^{-aL} \quad (6)$$

where I_o is the intensity of incident radiation.

Absorption in liquids and solids is mush move complicated than in gases [5]. In liquids the absorption lines have such large widths that they overlap water, for example, is obviously transparent in the visible, but absorbs in the near infrared. Its absorption curve in wide enough in fact, that it extends into the red edge of the visible as shown in figure 1 [1].

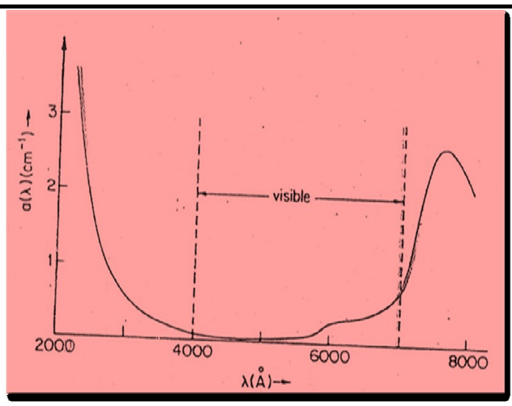

Fig. 1 absorption coefficient of water [1].

The scattering by particles is closely connected both with reflection and with diffraction and it depends on the wave scattered from an object as smaller or greater than a wavelength of light [4]. The scattered intensity is proportional to the incident intensity and to the square of the volume of the scattered particle. The most intensity result, however, is the dependence of scattering on wavelength. With a given size of particles, long waves would be expected to be less effectively scattered than short ones, because the particles present obstructions to the waves which are smaller compared with the wavelength for long waves than short ones. In fact, the intensity is proportion to $\frac{1}{\lambda^4}$. Figure 2 gives a quantitative plot of this relation [4].

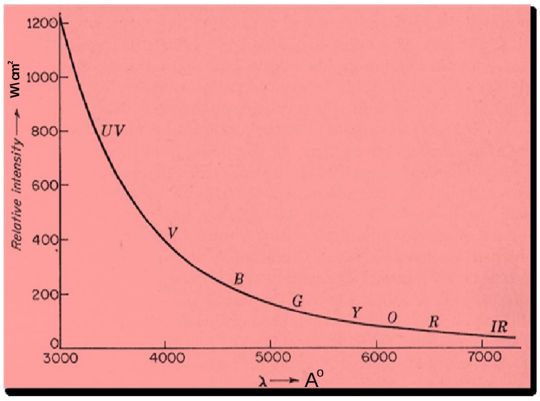

Fig. 2 intensity of scattering against wavelength [4].

So when light I_o enters a medium. The intensity (***I***) of the beam emerging from the other and will be less than I_o, (***I***) depends on the length L of the column according to exponential law, it is a measure of rate of loss, light from direct beam. The decrease of intensity of (***I***) in this case due to absorption only, but result from the fact that some light is scattered by pollutants and thus removed from the direct beam, so that exponential law is become

$$I = I_o e^{-(\alpha + s)L} \quad (7)$$

where α is the absorption coefficient, and *S* is the scattering coefficient. Since that the intensity of the scattering light increases with increasing frequency; blue; light is scattering more than red, with the result of the scattering light is blue. Note that for red laser and distilled water the scattering effect is negligible [2].

2- Experimental Work and Results.

The set up of the laser beam transition in water as shown in figure 3 was built as follows:

Fig. 3 the experimental set up.

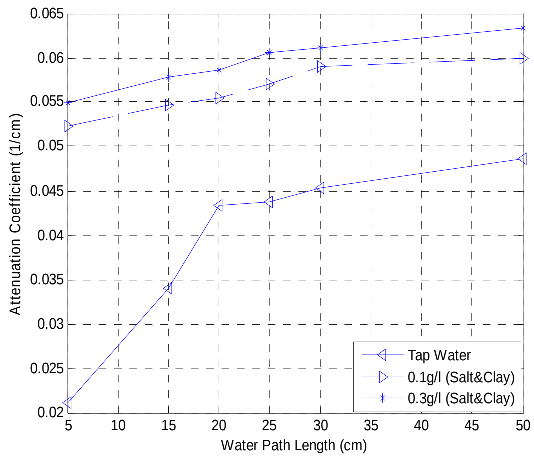

Fig. 4 the variety of attenuation coefficient against the water path length.

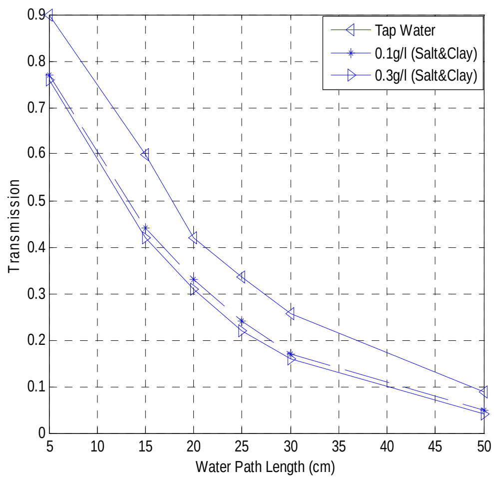

Fig. 5 the variety of laser transmission against the water path length.

1. setup is constructed from He-Ne laser system which used as a light source to pass through the sample of water. At the end of the tube a powermeter is placed. The power of the beam is p_o, gives intensity I_o.
2. take the glass tube of length (60 cm) and the diameter (4 cm) open at both ends. Closed one end is by sealing piece of plane glass window by silicon jelly. A glass tube was filled with water that has been used for the study of attenuation coefficient behavior for specific concentrations of clay or sodium chloride (NaCl) solution. After the beam of intensity I_o passes vertically through the water sample in the tube then falls on the detector head at the other end of the tube.
3. with the aid of photometer device the intensity of transmitted laser beam from the water solution can be measured. Different readings for different water path length were taken for each concentration.
4. the output power of the laser, which was passing through the tube of water filled by tap water and distill water contains 0.1g/l of salt and clay and 0.3g/l of salt and clay was measured. Its attenuation coefficient and transmission were calculated for different water path length by using eq.(1). These results are shown in figures 4 and 5, and tables 1, 2, and 3.

Table 1: the results of the output power and its attenuation and transmission values for different water path length.			
water path length (cm)	Power (mW)	Attenuation coefficient (cm^{-1})	Transmission $= I / I_o$
5	2.56	0.02	0.9
10	2.20	0.025	0.77
15	1.70	0.033	0.6
20	1.20	0.042	0.42
25	0.95	0.044	0.335
30	0.73	0.046	0.257
50	0.25	0.0485	0.088

Table 2: the result of the output power and its attenuation and transmission values for water contained 0.1g/l salt and clay for different water path length			
water path length (cm)	Power (mW)	Attenuation coefficient (cm^{-1})	Transmission $= I / I_o$
5	2.19	0.051	0.77
10	1.66	0.0533	0.57
15	1.25	0.0545	0.44
20	0.94	0.055	0.33
25	0.68	0.0576	0.24
30	0.48	0.059	0.17
50	0.13	0.061	0.05

Table 3: the result of the output power and its attenuation and transmission values for water contained 0.3g/l salt and clay for different water path length.			
water path length (cm)	Power (mW)	attenuation coefficients (cm^{-1})	Transmission $= I / I_o$
5	2.14	0.056	0.76
10	1.62	0.0562	0.57
15	1.19	0.0578	0.42
20	0.88	0.058	0.31
25	0.63	0.060	0.22
30	0.45	0.061	0.16
50	0.12	0.063	0.042

5. the output power of the laser, which was passing through the tube of water filled by distill water contain 0.1g/l and 0.3g/l concentrations of salt, was measured. Its absorption coefficient and transmission were calculated for different water path length. Results are shown in figures 6 and 7, and tables 4 and 5.

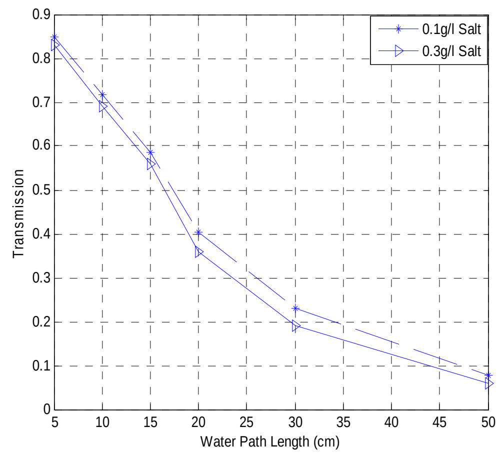

Fig. 6 the variety of absorption coefficient against water path length of distill water contained 0.1g/l and 0.3g/l of salt.

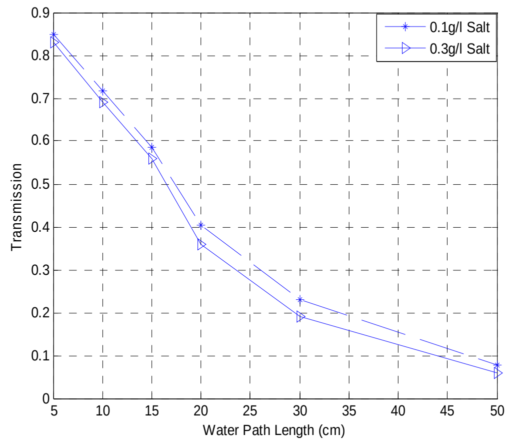

Fig. 7 the variety of laser transmission against water path length of distill water contained 0.1g/l and 0.3g/l of salt.

Table 4: the output power and its absorption and transmission values for water contained 0.1g/l salt for different water path length			
water path length (cm)	Power (mW)	Absorption coefficient (cm^{-1})	Transmission $= I / I_o$
5	2.43	0.031	0.85
10	2.03	0.033	0.717
15	1.66	0.0356	0.586
20	1.14	0.045	0.403
25	0.87	0.047	0.31
30	0.65	0.049	0.23
50	0.22	0.051	0.077

Table 5: the result of the output power and its absorption and transmission values for water contained 0.3g/l of salt for different water path length.			
Water path length (cm)	Power (mW)	absorption coefficient (cm^{-1})	Transmission $= I / I_o$
5	2.35	0.035	0.83
10	1.98	0.0357	0.69
15	1.59	0.0384	0.56
20	1.13	0.0459	0.36
25	0.82	0.0495	0.28
30	0.55	0.0546	0.19
50	0.18	0.055	0.06

6. the output power of the laser, which was passing through the tube of water filled by distill water contains 0.1g/l and 0.3g/l concentrations of clay was measured. Its scattering coefficient and transmission were calculated for different water path length. Finally, the results of the last sample of water are shown in figures 8 and 9, and tables 6 and 7.

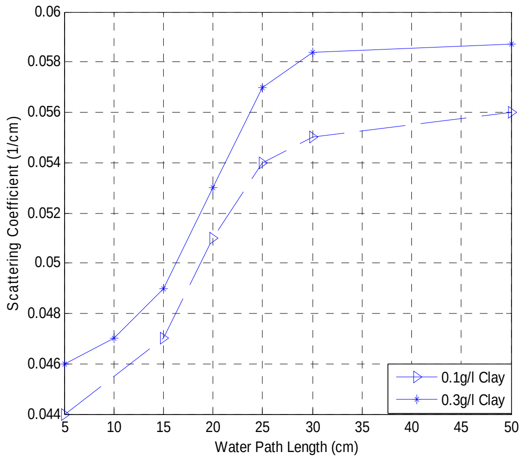

Fig. 8 the variety of scattering coefficient against water path length of distill water contained 0.1g/l and 0.3g/l of clay

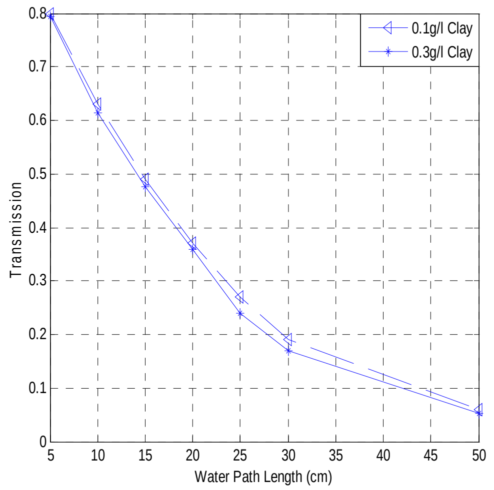

Fig. 9 the variety of laser transmission against water path length of distill water contained 0.1g/l and 0.3g/l of

Table 6: the result of the output power and its scattering and transmission values for water contained 0.1g/l of clay for different water path length.			
Water path length (cm)	Power (mW)	Scattering coefficient (cm^{-1})	Transmission $= I / I_o$
5	2.27	0.044	0.8
10	1.78	0.047	0.63
15	1.39	0.047	0.49
20	1.06	0.051	0.37
25	0.75	0.054	0.27
30	0.54	0.055	0.19
50	0.17	0.056	0.06

Table 7: the result of the output power and its absorption and transmission values for water contained 0.3g/l of clay for different water path length.			
Water path length (cm)	Power (mW)	scattering coefficient (cm^{-1})	Transmission $= I / I_o$
5	2.25	0.046	0.795
10	1.74	0.048	0.615
15	1.35	0.049	0.477
20	1.01	0.053	0.36
25	0.68	0.057	0.24
30	0.49	0.0584	0.17
50	0.15	0.0587	0.053

3- Conclusions

1. The laser output power, that was measured when it was passing through tube contain tap water, will suffer from attenuation. This attenuation came from the scattering and absorption of particles such as salt and clay particles, which was occurring in tap water at different ratio.
2. In distill water; the laser beam does not suffer any attenuation because of the distill water was considered as a pure transparent medium.
3. In distill water contained salts; the attenuation in output power would be occurred according to absorption coefficient of salts particles dissolved in water.
4. The attenuation would be occurred due to scattering coefficient of clay particles, when laser beam was passing through distills water contained clay. Since, these particles did not dissolved in water and would scatter the light from its direct beam.
5. The application of this research is to design a device placed on water supply measured the purity of water.

4- References

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دراسة تحليله لنقاوة الماء باستخدام ليزر الهيليوم :نيون ذو القدرة الواطئة

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الخلاصة:

أن الهدف من البحث هو أجراء دراسة تحليلية لأنتقال أشعة الليزر (هيليوم-نيون ليزر ذو قدرة خارجة مقاسة عملياً بحدود 2.83mW) خلال مروره داخل نماذج مختلفة من الماء وهذه النماذج هي ماء الحنفية وماء مقطر يحتوي على نسب مختلفة من محلول ملح الطعام و الغرين. في كل حالة يتم قياس قدرة الليزر الخارجة ومن خلالها يتم أحتساب مقدار التوهين الحاصل في أشعة الليزر أثناء مرورها خلال النماذج المختلفة. أن التوهين الحاصل لشعاع الليزر خلال مروره في النموذج الحاوي على ملح الطعام ناتج عن عملية الامتصاص أي قياس معامل الامتصاص من للنماذج الحاوية على تراكيز مختلفة، أما التوهين الحاصل لشعاع الليزر خلال مروره في النماذج الحاوية على الغرين فيكون نتيجة لعملية الاستطارة أي قياس معامل الاستطارة. ماء الحنفية غالبا مايحتوي على نسب مختلفة من ملح المعام والغرين لذلك فأن التوهين الحاصل لشعاع الليزر عند مروره خلاله يكون ناتج عن عملية الامتصاص والاستطارة فلذلك يمكن مقارنتها مع النتائج الاخرى الناتجة عن أضافة ملح الطعام والغرين الى الماء المقطر.