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GRAVEL MEDIA REMOVAL EFFICIENCY IN MICROIRRIGATION SYSTEMS USING LASER TRANSMISSION AND OVEN DRYING TECHNIQUES

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ABSTRACT

The micro irrigation systems have been widely used around the world for crop production. The main disadvantage of micro irrigation is emitter clogging, especially when using canal water with soil born suspended particles. In order to alleviate this problem, the media filters are introduced to reduce the suspended soil particles, which cause the emitter clogging. The gravel filter capability to remove the suspended soil particles is called removal efficiency. Removal efficiency is calculated in accordance with the recommended equation of the American Society of Agriculture Engineering (ASAE). The removal efficiency of the gravel media filter mainly depends on the concentration of the suspended soil particles in irrigation water before and after filtration. It is a unique character of the gravel media used, where, gravel media size and shape are the most important factors. Laser transmission technique is used to determine the removal efficiency of different gravel media types (sizes), gravel depth and suspended soil particles concentration. Such measurements were carried out using He-Ne laser (632.8 nm). Comparison between the conventional method (oven drying) and the laser transmission technique for determining filter removal efficiency was performed. The results show that the values obtained via laser transmission technique is very close to that of the conventional method. However, the laser technique can be easily applied in the field (in situ measurements).

Keywords: Microirrigation, gravel media, media filter, removal efficiency, oven drying, laser transmission technique.

INTRODUCTION

Since the last decade, the trickle irrigation system has been considered to be one of the most important irrigation systems applied in the newly reclaimed desert land in Egypt (Kasem,1983). It is well known that, suspended solids in the water supply include soil particles ranging in size from coarse sand to fine clays, living organisms including algae, bacteria and a wide variety of miscellaneous water borne mater. (Henderson,1976).
Trickle irrigation system has been introduced at large scale in the newly reclaimed areas in Egypt. (El Naggar,1995).

The gravel filter capability to remove the suspended soil particles is called the removal efficiency and is calculated in accordance with the American Society of Agriculture Engineering (ASAE) using the following equation:

Where, Er, $S_{Outflow}$ and S_{Inflow} are the Removal efficiency, outlet concentration of suspended soil particles in mg/L and inlet concentration of suspended soil particles in mg/L respectively.

$$Er = \left(1 - \frac{S_{Outflow}}{S_{Inflow}}\right) * 100 \rightarrow \quad (1)$$

The removal efficiency of the gravel media filter depends on the concentration of the suspended soil particles in irrigation water before and after filtration. Gravel media size and shape are the most important factors (ASAE Standard, 1990).

The conventional method used to measure the removal efficiency is called oven drying. This method depends upon the drying of the suspended particulates samples from the in and out flows at 105 ^{0}C in oven for 24 hours and evaluates the efficiency by substituting the weights of the dried samples in equation 1.

The present study aimed to evaluate a method exploits laser as a fast, a real time (in situ) in situ technique to measure the removal efficiency during treatment of the irrigation water.

MATERIALS AND METHODS

1. Gravel:

The selection of commercially available gravel media filter depends on the differences between different types of gravel media in particle size distribution from G_1, G_2, G_3, G_4, G_5 and G_6

The hydraulic properties for the gravel media filter by dry sieve analysis are given in Table 1.

Table 1: The hydraulic properties for gravel media filter by dry sieve analysis

Dry sieve / Gravel type	8 > mm	8 – 4 mm	4 – 2 mm	2 – 1 mm	1 < mm	Total
Gravel 1	3.62	95	1.33	0.05	-	100
Gravel 2	-	25.84	58.86	11.52	3.78	100
Gravel 3	2.55	60.56	26.94	8.03	1.92	100
Gravel 4	1.98	57.83	29.98	8.57	1.64	100
Gravel 5	2.29	42.86	42.24	11.00	1.61	100
Gravel 6	0.89	39.46	45.09	12.79	1.77	100

2. Particulates concentration:

Selected concentrations of suspended particulates (ppm) ranging from W_1 = 100,W_2 = 200,W_3 = 300 and W_4 = 400 ppm) have been used throughout the experimental investigations.

3. Depth of gravel:

To find out the more effective depth of the gravel media in the filter for greatest removal efficiency, two gravel depths have been used namely L_1: is 30 cm, and L_2: is 50 cm.

4. The laser used:

The Helium Neon laser probably is the most familiar type of lasers and the least expensive. The power of the laser used was 6 mW. (Lehecka, 1990).

Typical He – Ne laser parameters:

Laser Wavelengths λ	632.8 nm
Pumping Method	Electric discharge
Mode of operation	CW
Output power	6 mW

The experimental setup of measuring incident and transmitted laser light intensities are shown in Fig 1.

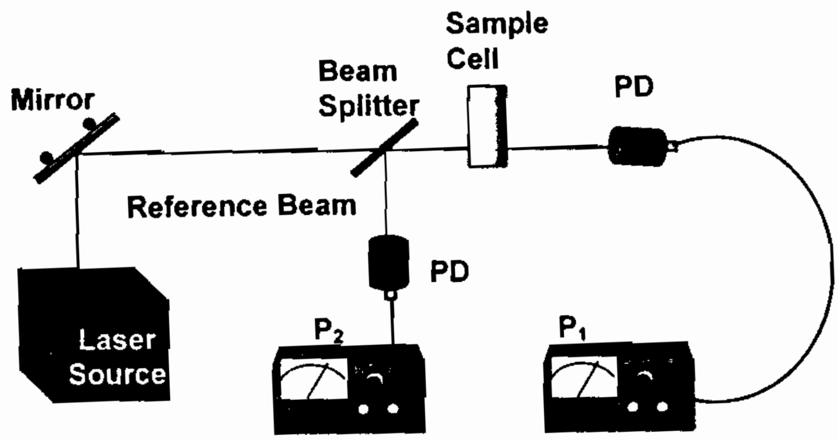

Fig 1: The experimental setup of measuring incident and transmitted intensities, P_1 and P_2 are the power meters, PD is photo detector.

Methods:

1. Oven drying technique:

Passing 1 L of irrigation water, containing suspended materials, thought a filter paper ,drying and get the mass of suspended particulate in mg/L (ppm). As mentioned in Nakayama and Bucks 1986.

2. Column specification:

Filters used in this study were manufactured at the irrigation market from PVC pipes (1-meter length, 90-mm outer diameter). The pipe is open from the top and the bottom is coupled to a small filter at the end cap.

Theoretical aspects:

The relation between the transmitted and incident laser light intensities can be expressed in the form of Beer-Lambert law.

$$I_t = I_0 \; e^{-\alpha x} \qquad \rightarrow (2)$$

The absorbance is equal to the logarithms of the ratio between the incident and transmitted laser light intensities given by:

$$A = Log \frac{I_0}{I_t} = a\ c\ x \rightarrow (3)$$

$$C_{Inflow} = \frac{\left(Log \frac{I_0}{I_{Inflow}} \right)}{a\ x} \rightarrow (4)$$

$$C_{Outflow} = \frac{\left(Log \frac{I_0}{I_{Outflow}} \right)}{a\ x} \rightarrow (5)$$

Where:

I_t = Transmitted intensity
I_0 = Incident intensity
α = Absorption coefficient
x = Optical path length
A = Absorbance
a = Molar absorbitivity
c = Concentration
C_{Inflow} = Inlet concentration of suspended soil particles.
I_{Inflow} = Transmitted intensity for inflow.
$C_{Outflow}$ = Outlet concentration of suspended soil particles.
$I_{Outflow}$ = Transmitted intensity for outflow.
The definition of filter efficiency (expressed as removal efficiency) is given by the following.
Since the removal efficiency is given by equation 1:
Substituting $S_{Outflow}$ & S_{Inflow} by $C_{Outflow}$ & C_{Inflow} from equations 3 and 4:

$$Er = \left(1 - \frac{C_{Outflow}}{C_{Inflow}} \right) * 100$$

Therefore, to calculate the removal efficiency, we need only to know the values of the light intensities such that:

The schematic diagram of the laser transmission experiment is shown in Fig. 2.

$$Er = \left(1 - \frac{Log \left(\frac{I_0}{I_{Outflow}} \right)}{Log \left(\frac{I_0}{I_{Inflow}} \right)} \right) * 100$$

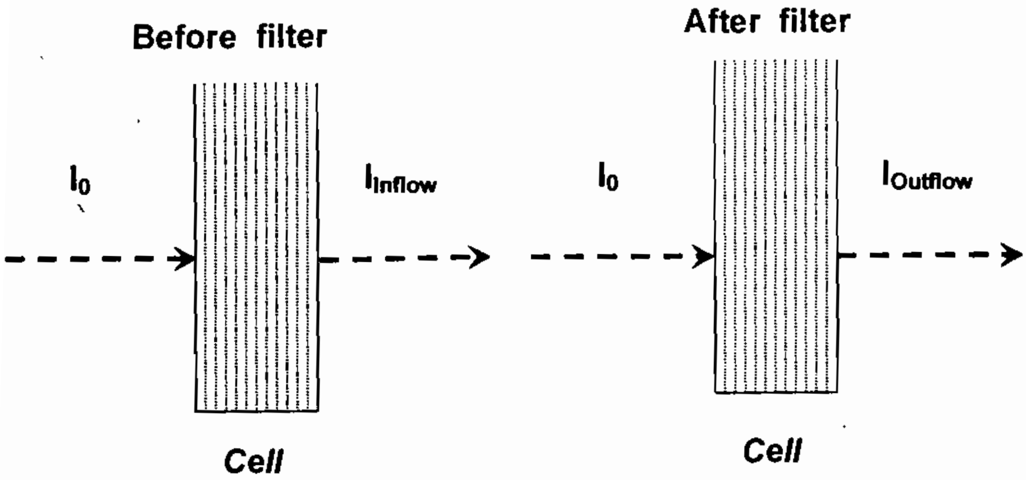

Fig. 2: The schematic diagram of the laser transmission experiment.

RESULTS AND DISCUSSION

1. **The effect of different combinations Cb of gravel G, depth L and particulates concentration W, on the removal efficiency (Er) as determined by the laser technique:**

Table 2 shows such effect for gravel G_1, depths L_1 and L_2 and particulates concentrations $W_1 - W_4$.

Table 2 : **Effect of different combinations (G, L and W) for gravel (1) on the removal efficiency (Er) as determined by oven drying method.**

Combinations of Gravel (1)	S_{InFlow} ppm	$S_{OutFlow}$ ppm	Er % Oven drying	$Log\frac{I_o}{I_{Inflow}}$	$Log\frac{I_o}{I_{outflow}}$	Er % Laser
$Cb_1 = G_1L_1W_1$	100	80	20	0.15	0.11	23.35
$Cb_2 = G_1L_1W_2$	200	157.50	21.25	0.30	0.24	20.09
$Cb_3 = G_1L_1W_3$	300	228.75	23.75	0.43	0.33	23.78
$Cb_4 = G_1L_1W_4$	400	295	26.25	0.60	0.43	28.15
$Cb_5 = G_1L_2W_1$	100	70	30	0.15	0.10	33.17
$Cb_6 = G_1L_2W_2$	200	130	35	0.30	0.19	35.58
$Cb_7 = G_1L_2W_3$	300	180	40	0.43	0.27	37.95
$Cb_8 = G_1L_2W_4$	400	215	46.25	0.60	0.32	47.63

The results show that the removal efficiency values are 23.35 and 33.17 for the combinations Cb_1 and Cb_5 for the same concentration (W_1) and the two different depths. While Cb_4 has the value of 28.15 compared with 37.95 for the combinations of Cb_8 for different depths and same highest concentration.

Increasing the concentration of suspended particulates in water increases the removal efficiency. However, the removal efficiency values in the second used gravel depth (50 cm) show a some what higher values than the values obtained using the shorter depth (30 cm).

The data in Tables 3 to 7 show that the same relation exists between the concentration and the removal efficiency for G_2 to G_6 as in the above case of G_1. However, the removal efficiency values in second gravel depth show also a slight increase higher than the removal efficiency values of the first depth.

The fluctuations in the removal efficiency values are clear in combinations G_1 and G_2, while for G_3 to G_6 the Er values tend to be more reasonable and much less fluctuating. This effect is mainly due to the fact that in combinations of G_3 to G_6 the grain size of the gravels is much less and consequently their distributions in the filter are more homogeneous contrary to the combinations of G_1 and G_2 where the grain size is much higher.

In general, and as mentioned before the results show that the removal efficiency Er increases as the concentration of suspended particulates increases in water. In addition, the value of removal efficiency Er at the second depth of (50 cm) is higher than Er values at the first depth of (30 cm).

2. The effect of different combinations Cb of gravel G, depth L and particulates concentration W, on the removal efficiency (Er) as determined by oven drying method:

The study depends upon the determination of the inlet and outlet concentration of suspended particulates before and after water passes through the gravel media filter $S_{Outflow}$ & S_{Inflow} exploiting the dry oven method. The values obtained are then substituted in equation 1 of removal efficiency.

Table 3 : Effect of different combinations (G, L and W) for gravel (2) on the removal efficiency (Er) as determined by oven drying method.

Combinations of Gravel (2)	S_{InFlow} ppm	$S_{OutFlow}$ ppm	Er % Oven drying	$Log \frac{I_o}{I_{inflow}}$	$Log \frac{I_o}{I_{outflow}}$	Er % Laser
$Cb_9 = G_2L_1W_1$	100	77.50	22.50	0.15	0.11	27.07
$Cb_{10} = G_2L_1W_2$	200	150	25	0.30	0.22	25.31
$Cb_{11} = G_2L_1W_3$	300	213.75	28.75	0.43	0.32	27.18
$Cb_{12} = G_2L_1W_4$	400	270	32.50	0.60	0.39	34.48
$Cb_{13} = G_2L_2W_1$	100	62.50	37.50	0.15	0.08	47.32
$Cb_{14} = G_2L_2W_2$	200	112.50	43.75	0.30	0.17	42.75
$Cb_{15} = G_2L_2W_3$	300	150	50	0.43	0.22	49.03
$Cb_{16} = G_2L_2W_4$	400	175	56.25	0.60	0.26	57.04

Table 4: Effect of different combinations (G,L and W) for gravel(3)on the removal efficiency(Er)as determined by oven drying method.

Combinations of Gravel (3)	S_{InFlow} ppm	$S_{OutFlow}$ ppm	Er % Oven drying	$Log \frac{I_o}{I_{Inflow}}$	$Log \frac{I_o}{I_{outflow}}$	Er % Laser
$Cb_{17} = G_3L_1W_1$	100	72.50	27.50	0.15	0.10	29.52
$Cb_{18} = G_3L_1W_2$	200	137.50	31.25	0.30	0.20	31.86
$Cb_{19} = G_3L_1W_3$	300	191.25	36.25	0.43	0.28	35.21
$Cb_{20} = G_3L_1W_4$	400	235	41.25	0.60	0.35	42.66
$Cb_{21} = G_3L_2W_1$	100	52.50	47.50	0.15	0.07	53.03
$Cb_{22} = G_3L_2W_2$	200	92.50	53.75	0.30	0.13	56.13
$Cb_{23} = G_3L_2W_3$	300	120	60	0.43	0.18	59.49
$Cb_{24} = G_3L_2W_4$	400	140	65	0.60	0.21	65.63

Table 5 : Effect of different combinations (G, L and W) for gravel (4) on the removal efficiency (Er) as determined by oven drying method.

Combinations of Gravel (4)	S_{InFlow} ppm	$S_{OutFlow}$ ppm	Er % Oven drying	$Log \frac{I_o}{I_{Inflow}}$	$Log \frac{I_o}{I_{outflow}}$	Er % Laser
$Cb_{25} = G_4L_1W_1$	100	66.25	33.75	0.15	0.09	35.58
$Cb_{26} = G_4L_1W_2$	200	122.50	38.75	0.30	0.18	39.21
$Cb_{27} = G_4L_1W_3$	300	165	45	0.43	0.24	44.06
$Cb_{28} = G_4L_1W_4$	400	195	51.25	0.60	0.29	52.29
$Cb_{29} = G_4L_2W_1$	100	42.50	57.50	0.15	0.06	61.93
$Cb_{30} = G_4L_2W_2$	200	75	62.50	0.30	0.10	64.96
$Cb_{31} = G_4L_2W_3$	300	97.50	67.50	0.43	0.14	67.41
$Cb_{32} = G_4L_2W_4$	400	115	71.25	0.60	0.17	71.91

Table 6 : Effect of different combinations (G, L and W) for gravel (5) on the removal efficiency (Er) as determined by oven drying method.

Combinations of Gravel (5)	S_{InFlow} ppm	$S_{OutFlow}$ ppm	Er % Oven drying	$Log \frac{I_o}{I_{Inflow}}$	$Log \frac{I_o}{I_{outflow}}$	Er % Laser
$Cb_{33} = G_5L_1W_1$	100	57.50	42.50	0.15	0.07	50.76
$Cb_{34} = G_5L_1W_2$	200	102.50	48.75	0.30	0.15	49.59
$Cb_{35} = G_5L_1W_3$	300	135	55	0.43	0.20	53.50
$Cb_{36} = G_5L_1W_4$	400	155	61.25	0.60	0.23	61.78
$Cb_{37} = G_5L_2W_1$	100	33.75	66.25	0.15	0.05	66.83
$Cb_{38} = G_5L_2W_2$	200	60	70	0.30	0.08	73.01
$Cb_{39} = G_5L_2W_3$	300	78.75	73.75	0.43	0.11	75.16
$Cb_{40} = G_5L_2W_4$	400	95	76.25	0.60	0.14	76.88

Table 7 : Effect of different combinations (G, L and W) for gravel (6) on the removal efficiency (Er) as determined by oven drying method.

Combinations of Gravel (6)	S_{InFlow} ppm	$S_{OutFlow}$ ppm	Er % Oven drying	$Log\frac{I_o}{I_{Inflow}}$	$Log\frac{I_o}{I_{outflow}}$	Er % Laser
$Cb_{41} = G_6L_1W_1$	100	47.50	52.50	0.15	0.06	60.83
$Cb_{42} = G_6L_1W_2$	200	82.50	58.75	0.30	0.12	60.84
$Cb_{43} = G_6L_1W_3$	300	108.75	63.75	0.43	0.16	63.29
$Cb_{44} = G_6L_1W_4$	400	125	68.75	0.60	0.18	69.37
$Cb_{45} = G_6L_2W_1$	100	27.50	72.50	0.15	0.04	69.52
$Cb_{46} = G_6L_2W_2$	200	50	75	0.30	0.06	78.60
$Cb_{47} = G_6L_2W_3$	300	67.50	77.50	0.43	0.09	79.62
$Cb_{48} = G_6L_2W_4$	400	85	78.75	0.60	0.12	80.02

Table 2 shows such effect for gravel G_1, depths L_1 and L_2 and particulates concentrations W_1 – W_4.The results show that the removal efficiency values are 20 and 30 for the combinations Cb_1 and Cb_5 for the same concentration (W_1) and the two different depths respectively. While Cb_4 has the value of 26.25 compared with 46.25 for the combinations of Cb_8 for different depths and same concentration.

Due to increasing the concentration of suspended particulates in water , The removal efficiency increases. However, the removal efficiency values in the second used gravel depth (50 cm) show a some what higher values than the values obtained using the first depth (30 cm).

The data in Tables 3 to 7 show that the same relation exists between the concentration and the removal efficiency for G_2 to G_6 as in the above case of G_1. The removal efficiency behavior with respect to the gravel depth is also the same as in case of G_1.

Concerning the first depth (L_1: 30) , result in Table 7 show that increasing the concentration of suspended particulates in water, increases removal efficiency. Lower Er value of (52.50) was found on using W_1, while the higher Er value of (68.75) was associated with W_4. Data also show the same trend for the second depth.

However, the Er values in second depth are slightly higher than the Er values of first depth. The Er values ranged from 52.50 to 72.50 for Cb_{41} and Cb_{45} respectively and 68.75 to 78.75 for Cb_{44} and Cb_{48} respectively.

In general, in case of using oven-drying technique, as in the laser transmission experiments, the removal efficiency (Er) increases when the concentration of suspended particulate increases in water. The value of removal efficiency (Er) at the second depth of 50 cm is higher than (Er) values at the first depth of 30 cm.

3. **Comparison between the oven drying method and laser technique by using (He-Ne) laser.**

The comparison depends on the calculation of the removal efficiency (Er) on the gravel media filter at different gravel media types by the oven drying method and laser technique using (He-Ne) laser.

3 - 1 Removal efficiency (Er) for different gravels types:

Table 2 lists the percentage values of the removal efficiency Er determined by oven drying method and laser technique for different combinations for gravel (1).

Date presented in Tables from 3 to 7 show that, the values of the removal efficiencies (Er) by laser transmission technique was found to be closed to the oven drying method and can use the laser technique (He-Ne) in the field application. Another way to analyze a population parameter, such as mean or standard deviation, is to compare that parameter to the corresponding parameter in a second population.

Condition

Sample data should be in paired from each of the two populations whose parameters are being compared. The condition that needs to be satisfied is:

The samples must be independently taken: that is, the sampling technique used for collecting sample data from the first population in no way affects the collection of the sample data from the second population.

T-Test values of mean difference = 0 (vs not = 0) for the different combinations using two different techniques are shown in Table 8

Table 8:Values of means,Standndr deviation and T-Test for different combinations of Gravel

COBINATION	MEAN1	MEAN2	STD1	STD2	T-TEST @
Gravel (1)	30.3125	31.2125	9.3958	9.1650	1.32
Gravel (2)	37.0313	38.7725	12.1180	11.9451	1.29
Gravel (3)	45.3125	46.6913	4.8051	4.8452	1.91
Gravel (4)	53.4375	54.6688	13.5908	13.8347	2.09
Gravel (5)	61.7188	63.4388	12.1180	11.1818	1.67
Gravel (6)	68.4375	70.2613	9.3958	8.2808	1.57

@) T-Test of mean difference = 0 (vs not = 0): T-Value calculated at 0.05 level and N=8 where ,T-Table =2.365

Non- significant difference found between means of the two procedures

Acceptance Criteria

H_0: Mean1 _ Mean2 $_{=0}$

Mean1:means of Removal Efficiency measured by oven dry method

Mean2: means of Removal Efficiency measured by LASER technique

In conclusion, using of He-Ne laser technique in the measurements of the removal efficiency is more convenient than the conventional method. This technique is fast, accurate, easy to use and from the economic point of view is lower in cost in comparison with the conventional oven drying method.

The relationship between the removal efficiency (Er) for the conventional method and laser transmission technique is shown in Fig 3.

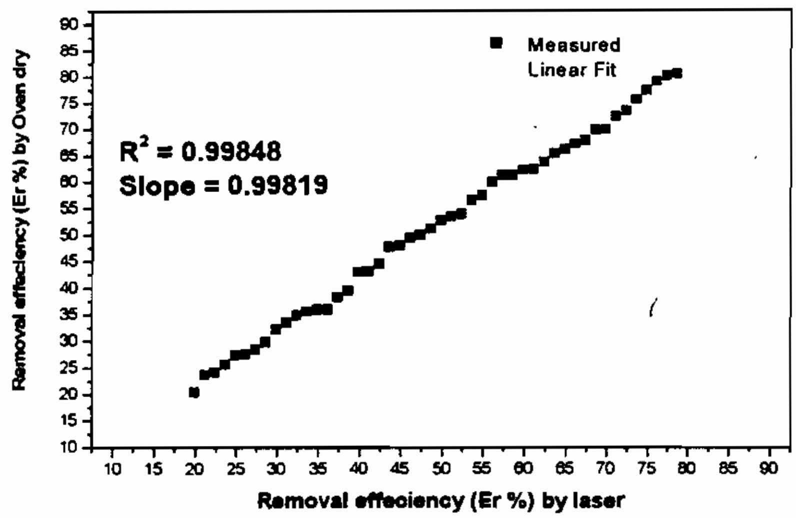

Fig. 3:The relationship between the removal efficiency (Er) for the conventional method and laser transmission technique.

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تقدير الكفاءة الفلترية للحصى فى نظم الرى بالتنقيط باستخدام تقنية شعاع الليزر والتجفيف بالفرن

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أجرى هذا البحث بغرض تقييم الكفاءة الفلترية لتوليفات مكونة من ٦ أنواع مــن الحصــى مختلفة الأحجام و ٤ تركيزات من المواد المعلقة فى مياه الري بــالتنقيط وهــى ١٠٠& ٢٠٠& ٣٠٠& ٤٠٠ جزء فى المليون وعمقين مختلفين من الحصى بالفلتر وهما ٣٠& ٥٠ سم . وذلك باستخدام طريقتين مختلفتين الأولى وهى طريقة التجفيف بالفرن والثانية هي تقنية استخدام نفاذيــة شعاع الليزر بنوع (هليوم – نيون) طول موجي ٦٣٢,٨ نانو ميتر وشدة ٦ ملى وات . أظهرت النتائج المتحصل عليها لقيمة الكفاءة الفلترية (Er) بوجود علاقة معنوية بين نتائج الطــريقتين المستخدمتين حيث كان معامل التقدير R^2 يساوى ٠,٩٩٨٤٨ مما يدل على صــلاحية طريقــة نفاذية شعاع الليزر فى تقدير الكفاءة الفلترية .