Performance of Biological Filter with Bio Fillings for the Treatment of Municipal Waste Water

Salam J. Bash Al-Maliky

Environmental Engineering/ AlMustansiriya University- Iraq

Faculty and Leader in Residence/ Ohio University-USA

Zainab Qahtan ElKhayat

Environmental Engineering/ AlMustansiriya University- Iraq

Abstract

Biological treatment of municipal waste water was tested via biological filter model of three different filling media; Wild Thorn, Arum Plant, and Date Palm Bark, separately. This was the first documented attempt, on the international level, of using these plants as fillings for biological filters. Tests were made for three different superficial flow rates (15, 30 and 45 $m^3/m^2.d$) for about four months, in order to consider the variations in ambient temperature.

Good BOD_5 removal efficiencies were achieved by the use of these filling Medias. With a superficial flow rate of (15 $m^3/m^2.d$), efficiencies of about (76%, 71% and 62%) for Wild thorns, Arum Plant and Date Palm Bark, respectively, were attained under ambient temperatures of about 36-40 ℃, and (73%, 69% and 61%), in the same sequence, under 23-25 ℃. Also the constants (n and K) affecting the performance of biological filter, were determined. A problem of filter clog was indicated with the use of Date Palm Bark under high superficial flow rates (+ 30$m^3/m^2.d$). Also, high abundance of flies around the model was noticed with the use of all tested filling media.

Keywords: Bio-Filling, Biological filter, Filter constant, Operational problems, Plant media Removal efficiency

1. Introduction

One of the major approaches for the biological treatment of municipal and industrial wastewater was the biological filter system. The differences between alternative versions of this system were principally in the material used as the packing to provide the solid support for the film of microbial slime, and in the rate and manner in which the wastewater load was applied to the bed (El Nadi, 2005). Plastic media began to replace rock media when the demand for good rock media exceeded the supply. Poor quality rock media breaks down more rapidly and allow the microbial growths to clog the biological filter media. Overall economics soon favored plastic media over rock media (UNEP, 2002). The plastic media has allowed the use of tall filters and higher loading rates with about 50-80%, final efficiencies for the treatment of municipal and industrial wastewaters (Ross, 2004). Efficiencies of about 78%- 82%, were achieved in the treatment of industrial wastewaters adopting cheap, randomly distributed plastic fill media (Al-Maliky, 2002). These facts had paved the way to search for other possible replacements for the plastic media that are cheaper, more durable and available locally.

New filling materials that may replace plastic should share almost all the properties that made plastic preferable for biological filters, such as, light weight, high specific surface area (surface area/ volume), high void ratio, cheap cost, chemical resistance, and mechanical durability(Smith, 2003).

Many empirical models have been developed for the design of biological filters, as illustrated in Table 1. The removal of soluble BOD in biological filters with all media types can be expressed using Schultz formula:

$$\frac{S_e}{S_0} = e^{-\mathrm{KD}/Q^n} \tag{1}$$

Where,

S_0, S_e: filtered influent and effluent, BOD concentration (mg/l).

A: the average geometric specific surface area of the particles (m^2/m^3).

D: Depth of filter (m).

K: replacement for the term (k A_B).

k: reaction rate constant. ($d^{-(1-n)}m^{-n}$).

n: Constants related to specific surface and configuration of Packing.

Q: Hydraulic loading ($m^3/m^2.d$).

Eq.1 can be applied to a specific, non reactive kind of packing, which is supporting a continuous biological layer and receiving a uniformly distributed hydraulic load. The effective specific surface area of the bed and the fractional void ratio of the bed (e) can often characterize the general structure of a bed of particles. The logical procedure to follow is to determine experimentally the exponent (n) and the reaction rate constant (K) in a pilot apparatus of the process geometry and to use these data for design purposes. This removes the necessity for separate determinations of (k) and (A_B) and this is exactly the advantage of using Schultz formula (Jorgensen, 2000). It is of course to be expected that (K) will vary in complex manner with flow rate due to changes in the effective specific surface area (Coulson and Richardson, 2003).

Equation (1) may be rewritten as:

$$\log(S_e / S_0) = -KD / 2.3Q^n$$

Hence the following steps would lead to the determination of (n and K) values for each type of filling materials:

1. Plot the logarithm of (S_e/S_0) term versus the depth (D) in filter packing. The slope of each line drawn for a specific hydraulic loading is defined as:

$$\text{Slope} = -KQ^{-n}/2.3$$

2. By taking the logarithm of both sides after multiplying both sides by (-1);

$$\log(\text{Slope}) = \log(K/2.3) - n\log Q$$

3. Plot log (Slope) versus log (Q). The slope of the straight line drawn would represent the value of (n).
4. The constant (K) may be determined by plotting log (S_e/S_0) versus (D/Q^n). The slope of the line drawn would equal (-K/2.3).

This paper was dedicated to examine the performance of bio-trickling filter that adopt each of three randomly distributed plant originated media; namely Wild Thorn (Prosopis Stephaniana), Arum Plant, and Date Palm Bark, which were widely existed in almost all Iraqi (and for some extent, around the world) regions without being economically used, hence their adoption as filling materials would serve twofold role; supply of cheap biological control media for waste water and reduce the amounts of agricultural wastes.

2. Experimental setup

The distribution of wastewater was achieved by a fixed screen of about 2 mm mesh covering the top section of 1.5 m column made up of three 0.5 m length and 0.4 m diameter plastic barrels with a natural aeration gap of 0.2 m between each other (Fig.1). Each single barrel has about 100 base-holes, so as to serve as distribution means for the following part of the biological filter, each hole was about 1 cm diameter.

Three types of filling media are to be tested in the biological filter model for their effects on overall performance and filter constant. Filling media whom their properties were experimentally determined and summarized in Table 2, were submerged in concentrated waste water for a period of time (18-24 hours) so as to ensure well colonization for the bio mass on their surfaces.

Municipal waste water to be treated which was characterized by a BOD_5 of about 177-200 mg/l was first settled and then screened using 1 cm mesh in order to discard the large non dissolved solids. The tests were carried over a period of four months; hence a broad range of operation parameter variations, such as flow rate, biological loads and ambient temperature, were covered. During that period, three different superficial flow-rates 15, 30 and 45 m^3/m^2 d were applied. The wastewater samples were settled for 30 min and filtered through Whatman (No.42) filter paper prior to BOD_5 analysis that was determined according to the standard methods (APHA, 2010).

3. Results and Discussions

Different operational circumstance for the biological filter model; filling materials, hydraulic loadings, biological loadings and ambient temperatures were tested and the results were summarized in Fig.2-4, in. Also, final removal efficiencies were summarized in Table 3.

All tested filling media have proved good removal efficiencies for BOD_5 (noting that these results were gained for the first stage only; i.e. no recycle) in addition to simplicity in handling and installation. Bio-filter`s BOD_5 removal efficiencies were about 73%, 69% and 61%, for Wild thorns, Arum Plant and Date Palm Bark, respectively under superficial flow rate of 15 $m^3/m^2.d$, and ambient temperatures of about 23-25 ℃. These figures were slightly increased to be 76%, 71% and 62% under lower ambient temperatures of 36-40 ℃ for the same flow rate. The removal efficiency has increased as the ambient temperature did for all filling media under all hydraulic flow rates, which might be attributed to the high activity of microorganisms held on the surfaces of filter media at high temperatures. Also, Wild Thorn was the most efficient filling media; Arum plant was the second and then came the Date Palm Bark and this may be justified due to the differences in superficial surface area and void ratio. Date Palm Bark has shown failure under high flow rates due its lower void ratio that made it vulnerable to clogging under heavy loads although it showed an acceptable efficiency under low hydraulic loads, especially when treating low contaminations.

The above good performances were accompanied with the drawback that significantly high abundance of some kinds of flies was noticed around the model for all types of filling media.

Filter's constants for each filling media (except the Date Palm Bark due to the insufficient data) were determined according to the previously mentioned procedure for the solution of equation 1 (Fig.5 & 6) and were summarized in Table 4.

4. Conclusions

This paper was the first documented attempt for the use of cheap and widely abundant plants; Wild thorn, Arum and Date palm bark, as filling media for bio-filters that were used for the treatment of municipal wastewater. With the good performance of these natural resources it was proved that Mother Nature was full of resources that need to be tested so as to replace the artificially made needs for different uses. Date Palm Bark should not be used as a filling media for biological filters under heavy (hydraulic and/or organic) loads. High ambient temperatures were found preferable for Wild Thorn, Arum and Date Palm Bark as biological filter's filling media. Finally, experiences from field work have proved that such bio-filter systems should be installed away from public locations, due to the nuisance that may be caused as a result of concentrated abundance of flies,.

Acknowledgement

Authors would like to acknowledge the support of International Institute of Education IIE, Scholars Rescue Fund SRF and Russ College of Engineering, Ohio University.

References

Al-Maliky Salam J. (Sept. 2002). Performance of trickling filter with scrap (PVC) fills in a Vegetable Oils Industry Factory. *Proceeding of Jordanian Chemical Engineering Conference IV, Vol.2.*

APHA. (2010). Standard Methods for the Examination of Water and Wastewater, Edited by Lenore S. Clesceri, Arnold E. Greenberg and Andrew D. Eaton. *20th Edition.*

Celenza G. (2000). Industrial Waste Treatment Process Engineering. *Biological Processes VII. Technomic Publishing Company Inc*.

Coulson J. and Richardson J. (2003). Chemical Engineering, V6, 3rd edition. *Butterworth- Heinemann publications*.

El Nadi M. El Hosseiny. (2005). Wastewater Treatment Design Report, *Task # 4:* Environmental Services for Improving Water Quality Management. Report No.8. *International Resources Group in association with EPIQ II Consortium.*

Jorgensen Sven Erik. (Sept.2000). Principles of Pollution Abatement. *Elsevier Publishing Company*.

Ross E. McKinney. (2004). Environmental Pollution Control Microbiology. *Marcel Dekker, Inc.*

Smith Matt. (2003). Trickling Filters. *L. S. Enterprises*,

UNEP. (2002). Environmentally sound Technologies for Waste water and Storm Water Management. *UNEP publications*.

Table 1. Various models for the operation of biological filter systems (Celenza, 2000)

Model name	Media				Loading	Rc	comments
	Type	D	V	A	Organic Hydraulics		
Velz	All	√					1st. order kinetics
Schultz	All	√			√		Residence time defined for Velz model
Germain	P	√			√		Schultz model plastic media
Eckenfelder	All	√		√	√	√	Follow first kinetics with an area term
Gottas	S	√			√	√	Based on data analysis
Kincannon and Stover	All			√	√		Based on Monod kinetics

Table 2. Properties of the different filling media

Filling material	Density Kg/m^3	Void ratio %
Wild Thorn	998	> 98
Arum Plant (Fiber)	290	95
Date Palm Bark	75	86

Table 3. Efficiencies of biological filter model with the different filling materials under different operational circumstances

Q $m^3/m^2.d$	Efficiency %			Temperature °C
	Plant of Wild Thorn	Arum Plant (Fiber)	Date Palm Bark	
15	72.97	69.19	61.08	23
15	72.78	69.44	61.67	25
15	75.79	71.58	62.11	36
15	76.22	70.27	62.16	40
30	71.28	65.96	52.13	23
30	71.19	66.67	53.11	25
30	73.33	66.15	59.49	36
30	74.19	67.74	60.22	40
45	65.76	58.15	Fail due to clogging	23
45	65.96	59.57		25
45	68.39	60.10		36
45	69.00	60.50		40

S: Stone media; All: All media; P: Plastic media; D: Depth; V: Volume; A: Area; Org: Organic loading; Hyd: Hydraulic loading rate; Rc: Recycle.

Table 4. Filter constants for Wild Thorn and Arum as filling media in the biological filter model

Filling material	n		K	
	Temperature 24-26°C	Temperature 36-42 °C	Temperature 24-26°C	Temperature 36-42 °C
Wild Thorn	0.1906	0.149	1.1477	1.8595
Arum Plant (Fiber)	0.1324	0.0975	0.9056	1.425

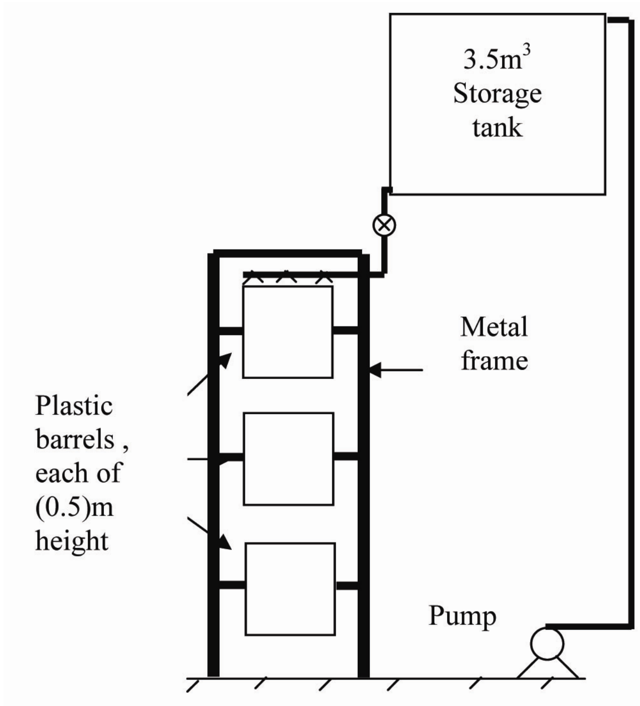

Figure 1. Schematic for the biological filter model

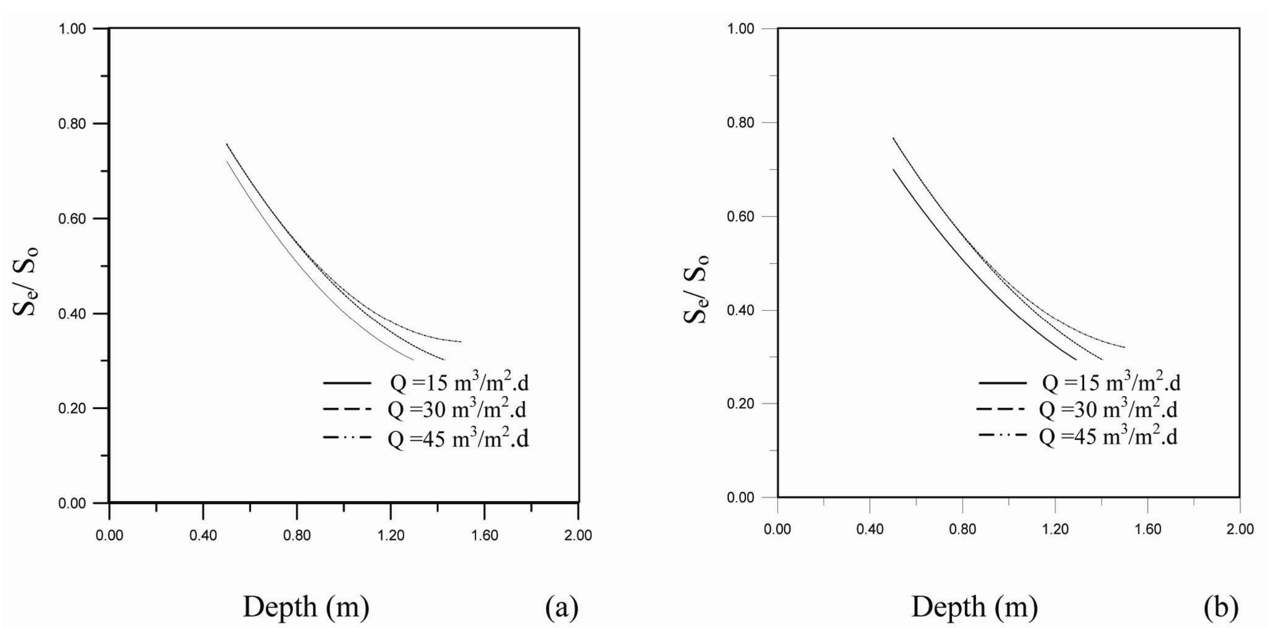

Figure 2. Variation of effluent's BOD_5 with the depth of the biological filter model using Wild Thorn as filling media.
a. Ambient Temperature (24-26 C). b. Ambient Temperature (36-40 C).

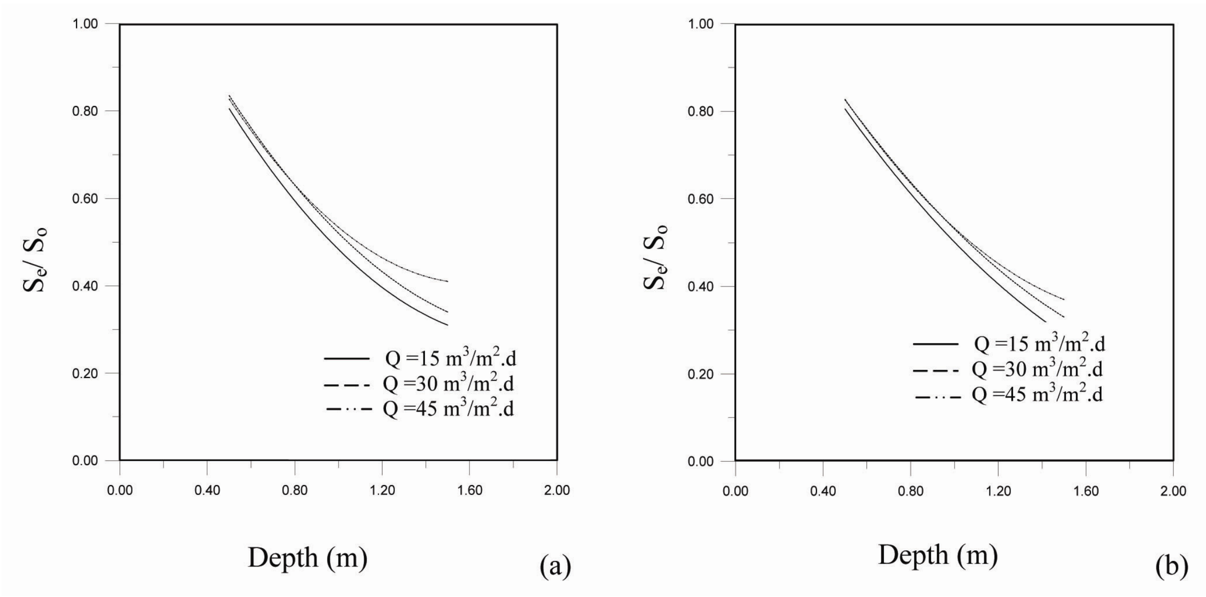

Figure 3. Variation of effluent's BOD_5 with the depth of the biological filter model using Arum as filling media.

a. Ambient Temperature (24-26 C). b. Ambient Temperature (36-40 C).

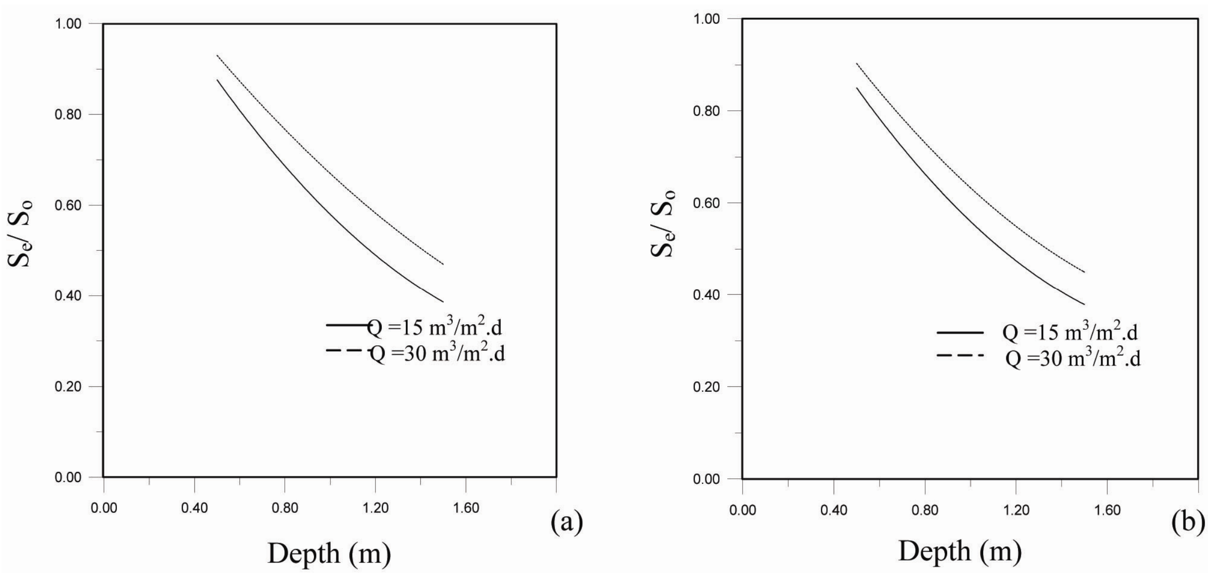

Figure 4. Variation of effluent's BOD_5 with the depth of the biological filter model using Date Palm Bark as filling media.

a. Ambient Temperature (24-26 C). b. Ambient Temperature (36-40 C).

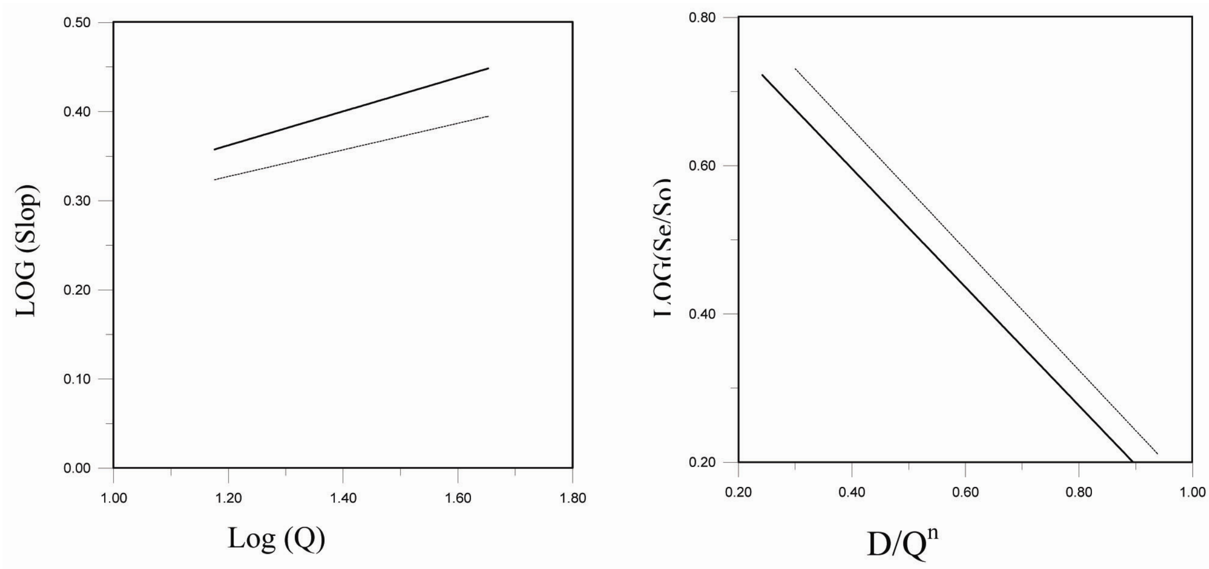

Figure 5. Determination of biological filter's constants using Wild Thorn as a filling media

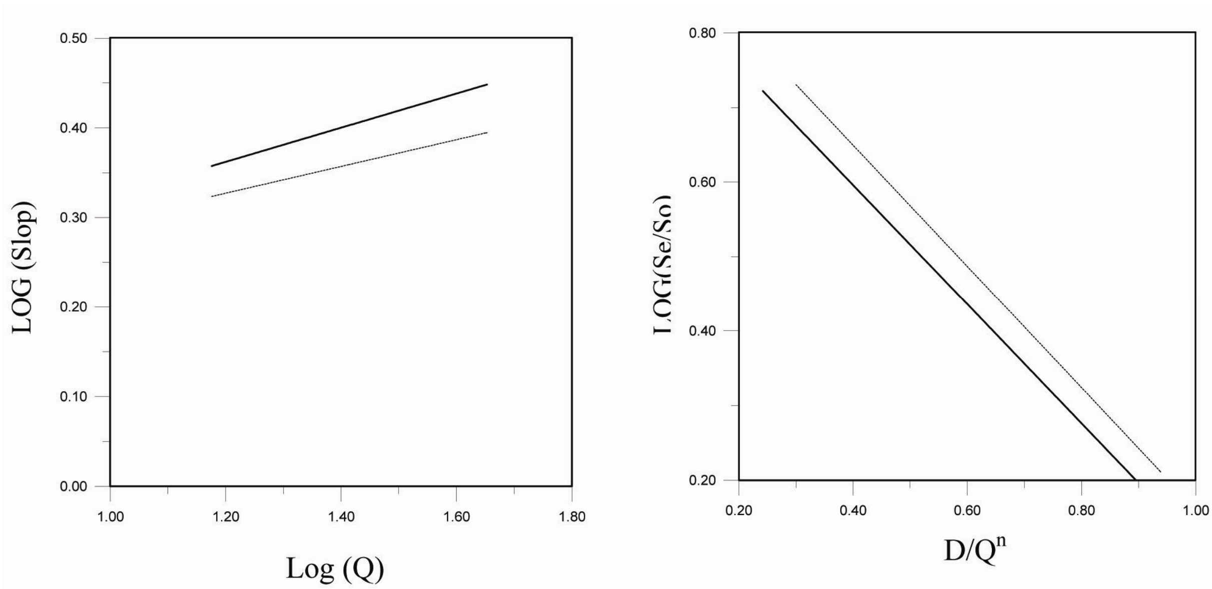

Figure 6. Determination of biological filter's constants using Arum as a filling media