Length-Diameter Relations in Hollow Fiber Membrane Reactors

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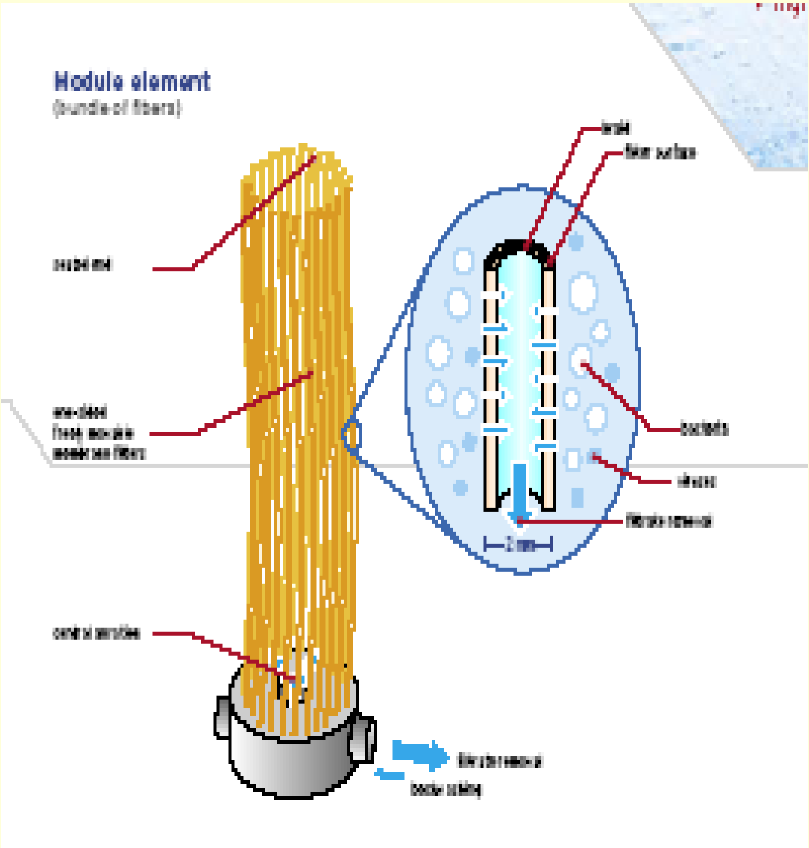
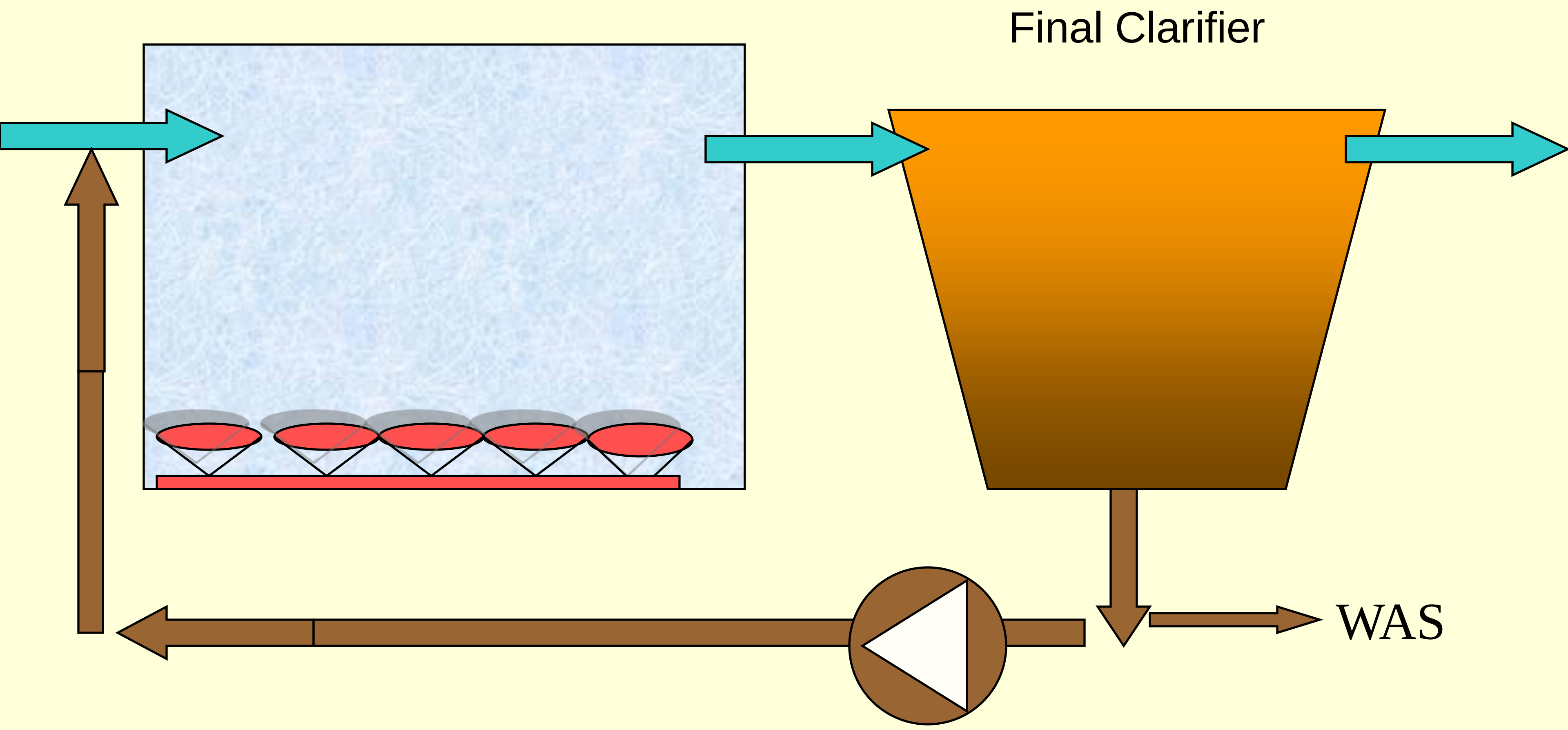
Module Element



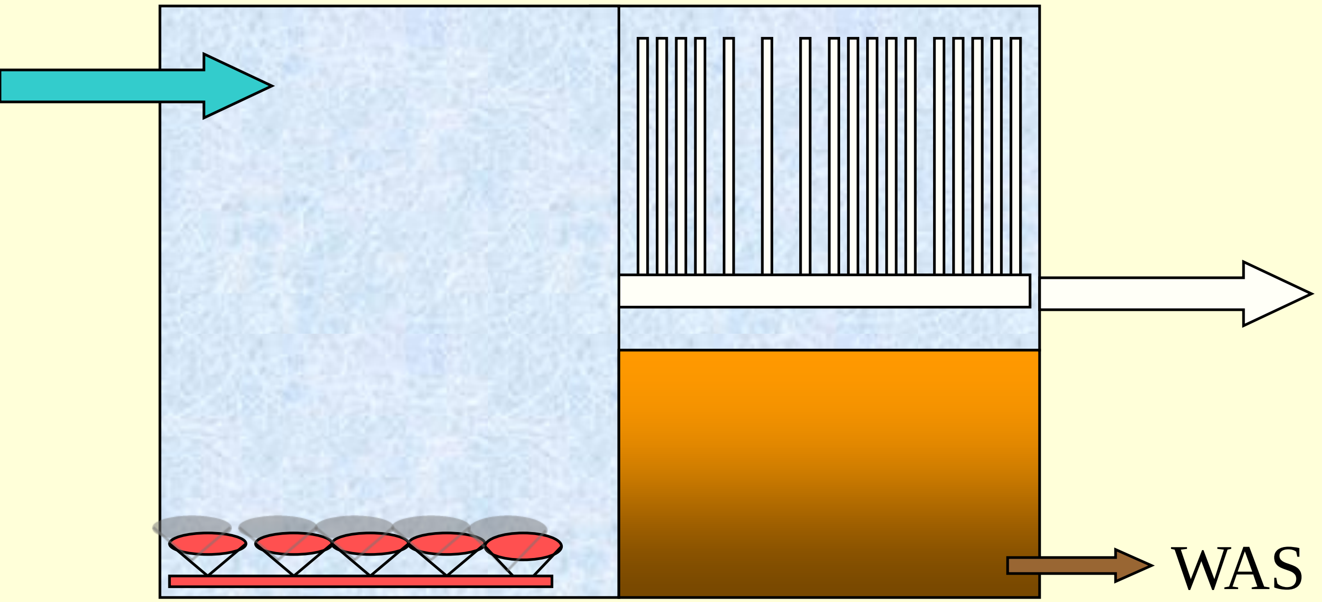
Module Row

Whole Module

A Conventional Activated Sludge Plant



AERATION TANK with immersed MBR (L= 2.5 m)



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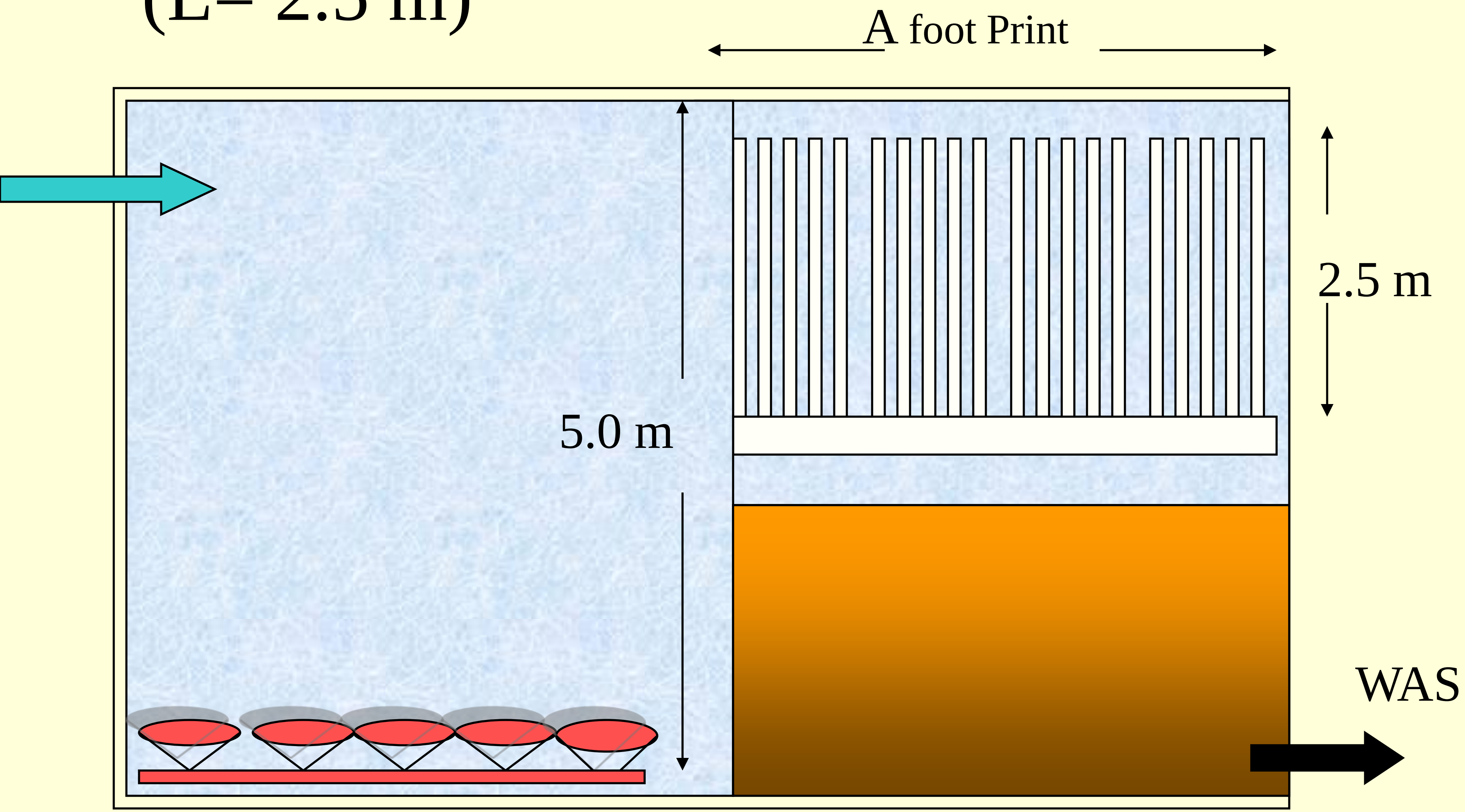
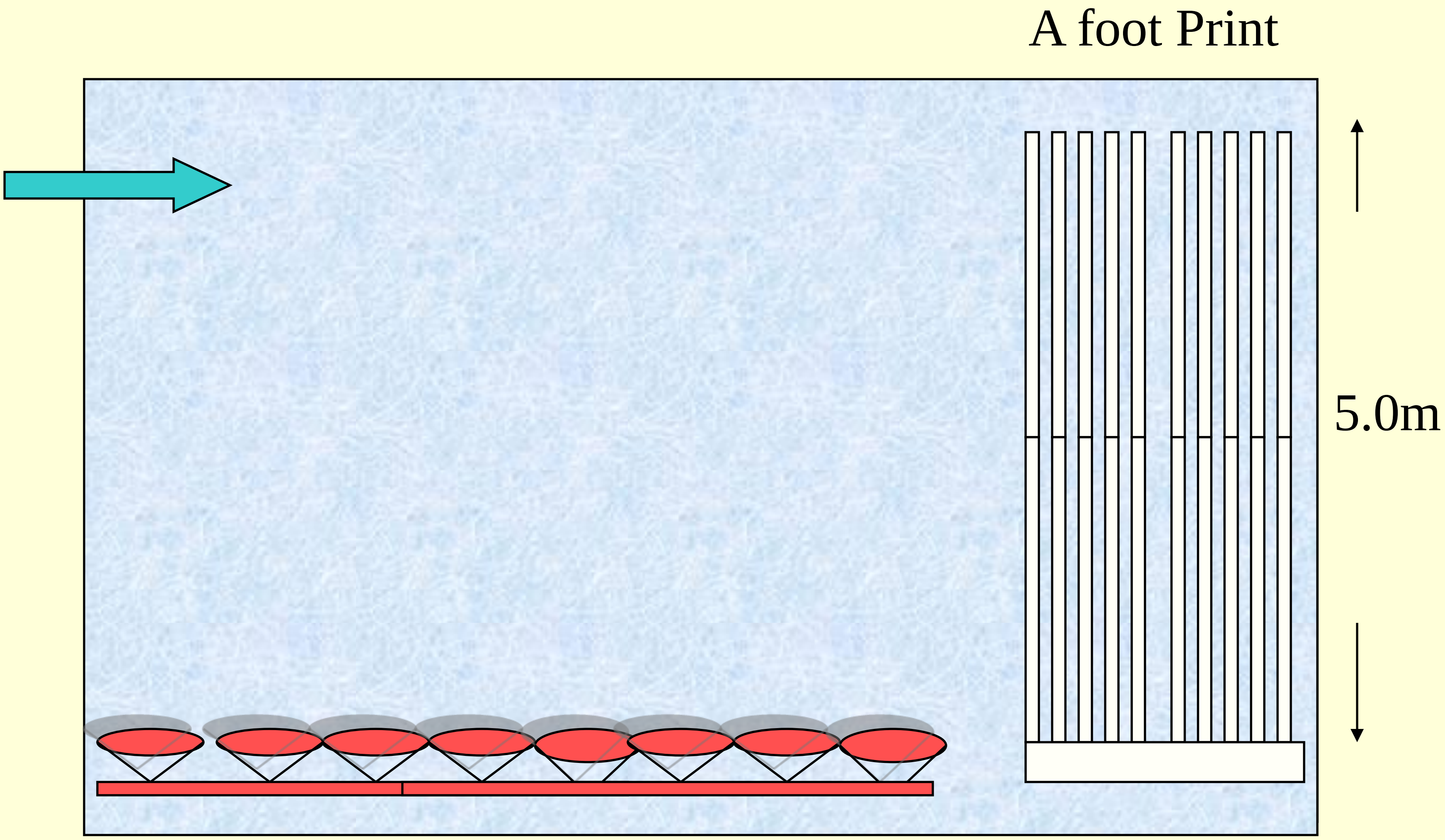


AERATION TANK with immersed MBR (L= 5 m)



MBR
Membranlı Biyolojik Reaktörler

- 0.5-1.0 mm ince ızgara montajı (Askıdaki BOI5 giderimi)
- Membran ömrü 6-8 yıl (Almanya da çoğu 3 yılda değişmiş)
- Almanya da en büyük tesis 80 000 eşdeğer (16 000 m3/g @ 200LCD)
- Yağ vb maddelerin tıkaması (En fazla verilen akı 25 L/h/m2)
- Yüksek bakteri konsantrasyonu difüzör verimini aşırı düşürür (düşük α değerleri).
- Bakteri konsantrasyonu 3-4 misli arttırılabilir ve havalandırma hacmı 3-4 misli daha az olabilir.
- Son çökeltme tankına lüzum kalmaz
- Çok iyi AKM tutulması. (Bakteri ve bazı virüsler dahi tutulur).
- Yüksek çamur yaşı elde edilebileceği için, daha az çamur üretilebilir.

Membran Maliyeti

Debi = 100 000 m3/g

Seçilen değer 20 L/h/m2 (Emniyetli boyutlandırma 10 L/h/m2 üzerinden yapılıyor)

Gerekli Alan = 100 000 m3/g * 1000 L/m3/ (24 * 20 L/h/m2) = 208 333 ~ 200 000 m2

Her modül 500 m2 (Modül plan alanı = 0.84 m * 2.10 m = 1.764 m2)

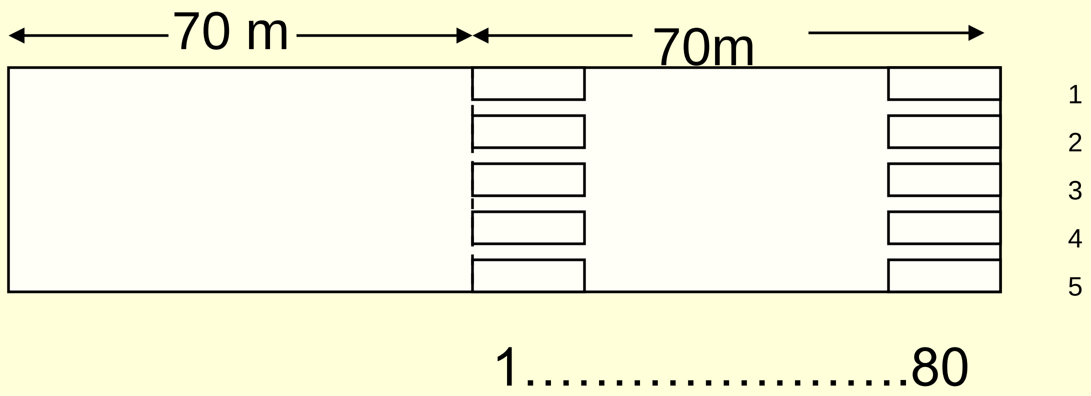
Modül sayısı= 200 000 m2 /500 m2 = 400 modül

1 m2 Membran maliyeti = 100 Euro

Membran Maliyeti = 200 000 m2 * 100 Euro = 20 Milyon Euro

Gerekli Membran Alanı

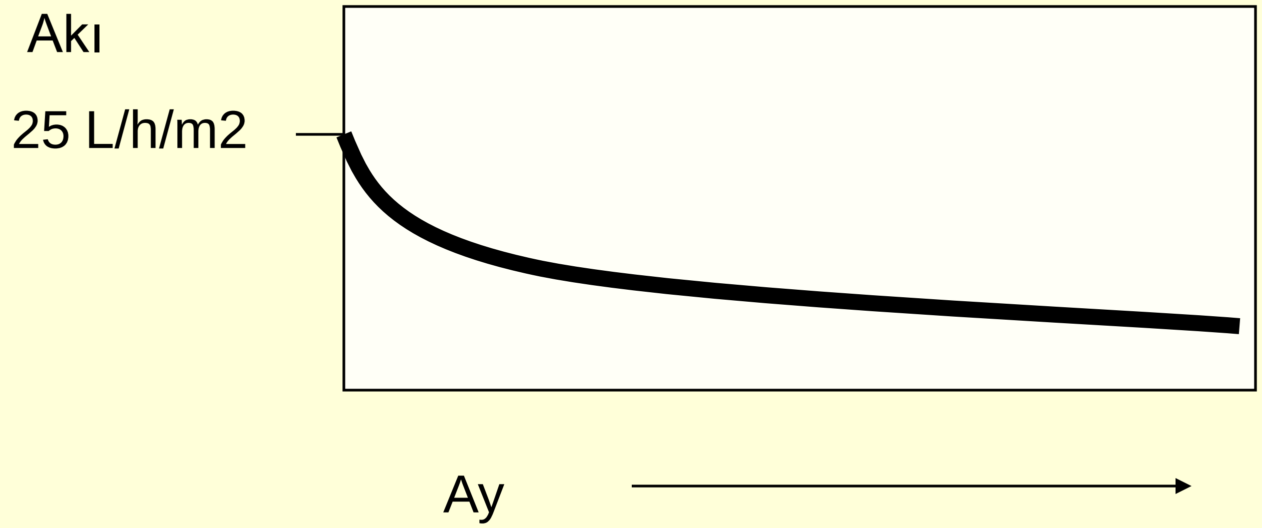
400 modülün son çökeltme tankına yerleştirilmesi



Boyutlandırma Akı Değeri

Akı = 15- 30 L/h/m2. Pilot tesis deneyleriyle akının zamanla nasıl azalacağı ölçülmelidir.

Bazı firmalar emniyetli boyutlandırma için 10-15 L/h/m2 değerini kullanmaktadır.

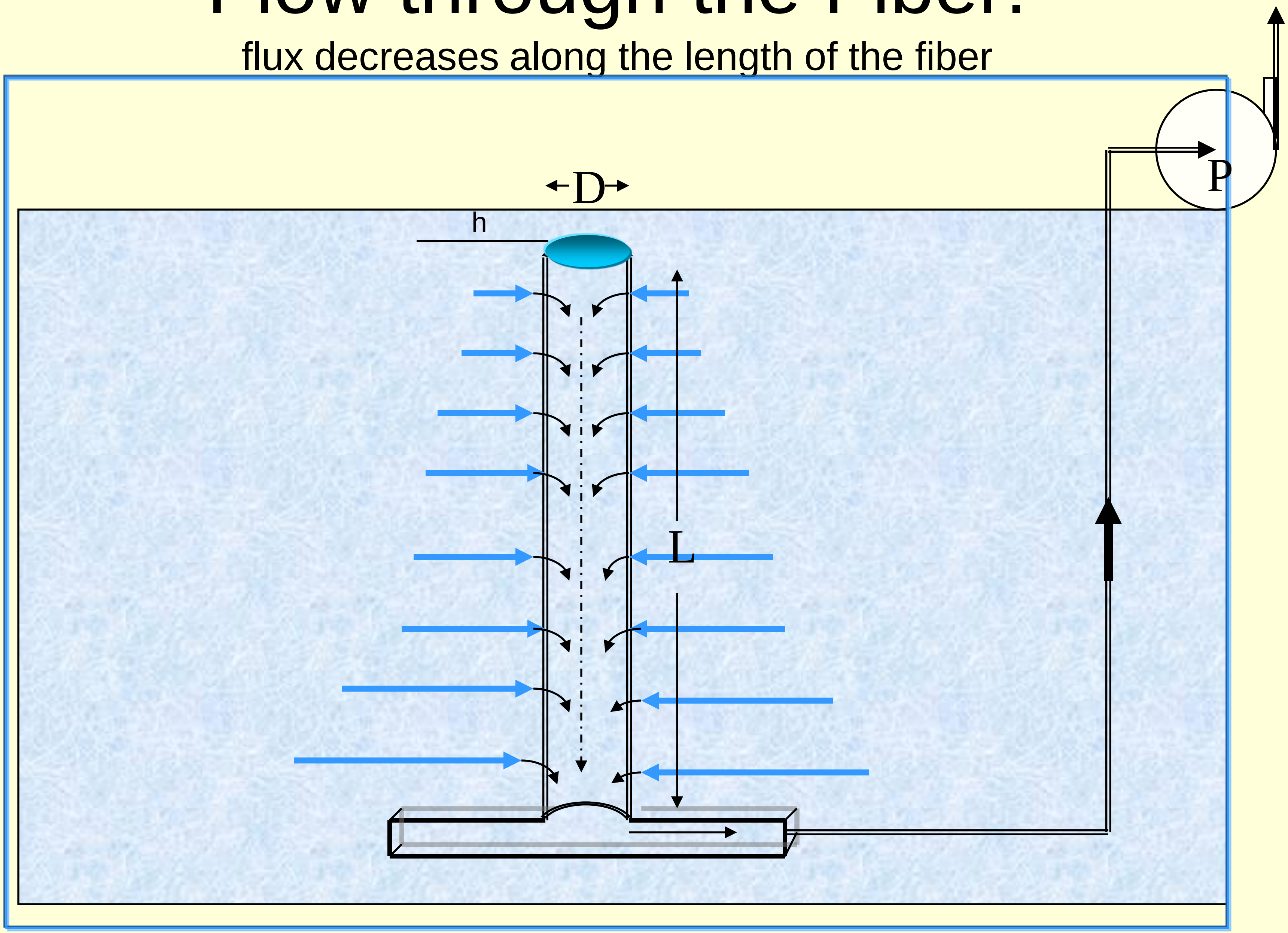


Theoretical Approach to Hallow Fibre Membranes

Dr. A. Saatci

Flow through the Fiber:

flux decreases along the length of the fiber



THEORY

$$Q = \frac{(\pi DL)K\Delta P}{(\alpha L)\coth(\alpha L)} = \frac{\pi D^4 \alpha \Delta P}{128\mu \coth(\alpha L)}$$

$$\alpha = 8\sqrt{2\mu K}\,D^{-3/2}$$

Flux Equation

$$\Phi = \frac{Q}{\pi DL} = \frac{K\,\Delta P}{\lambda\coth(\lambda)} = \frac{K\,\Delta P}{\lambda\left(\dfrac{e^{\lambda}+e^{-\lambda}}{e^{\lambda}-e^{-\lambda}}\right)} = K'\Delta P$$

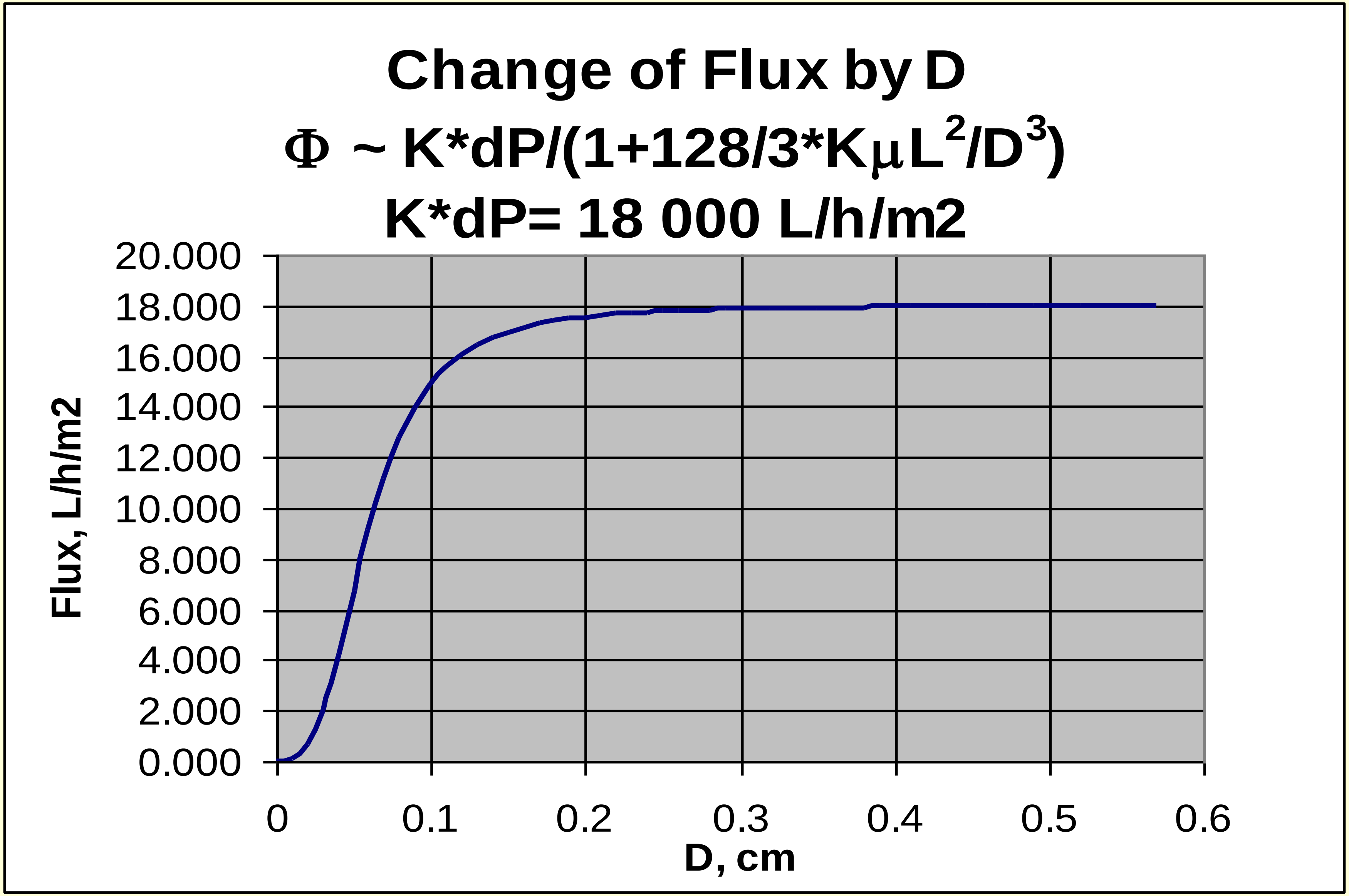
$$\lambda = \alpha L$$

$$\lambda \coth \lambda \cong 1 + \frac{\lambda^3}{3}$$

$$\boldsymbol{\Phi} = \frac{\boldsymbol{K}}{\left(1 + \frac{\lambda^3}{3}\right)} \Delta \boldsymbol{P}$$

Logistic Curve

$$\Phi = \frac{Q}{\pi D L} = \frac{K.\Delta P}{1 + \frac{128}{3}\mu K \frac{L^2}{D^3}}$$



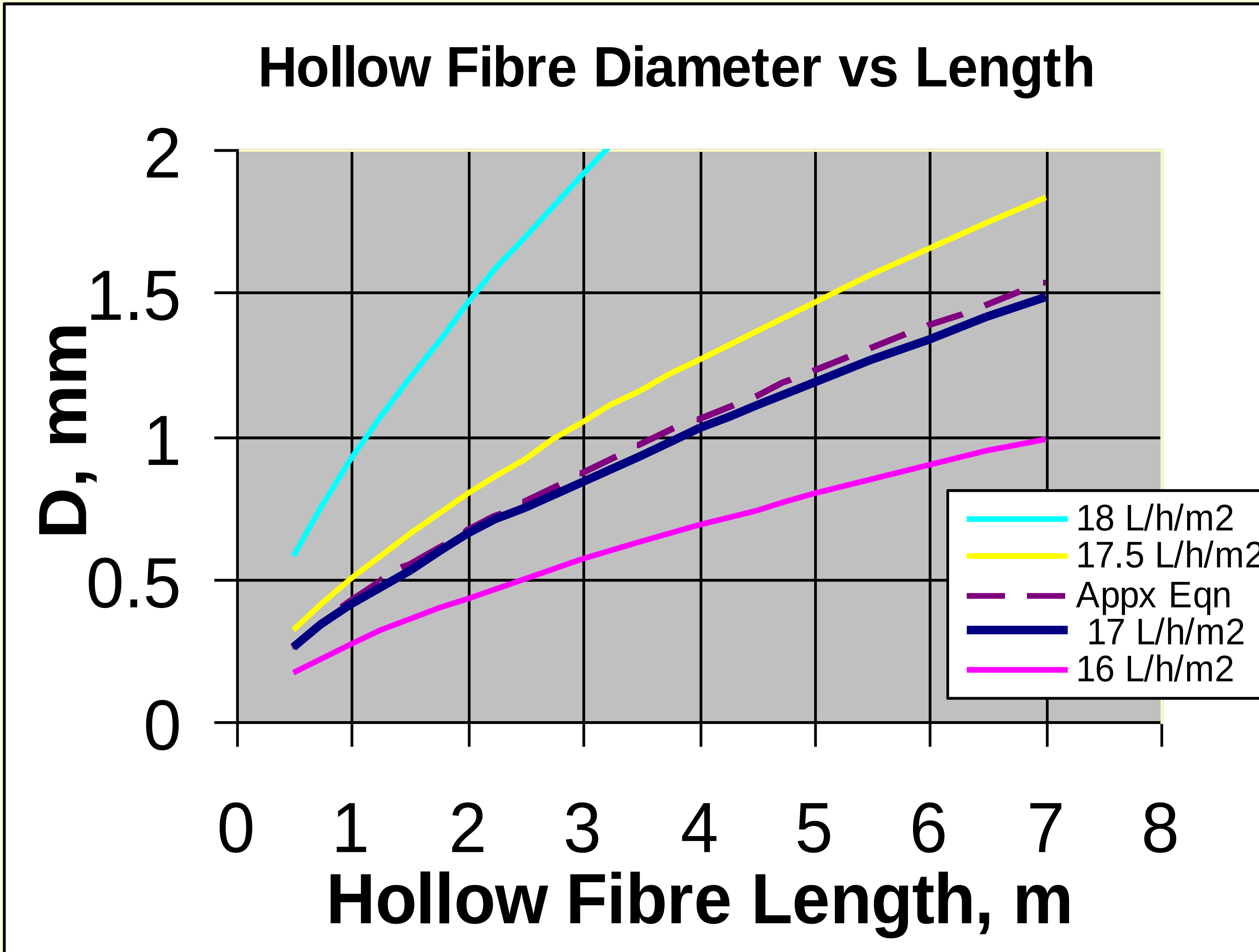
Change of Flux by D
Φ ~ K*dP/(1+128/3*KμL2/D3)
K*dP= 18 000 L/h/m2
Flux, L/h/m2
20.000
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
0
0.1
0.2
0.3
0.4
0.5
0.6
D, cm

Parameter Values Used

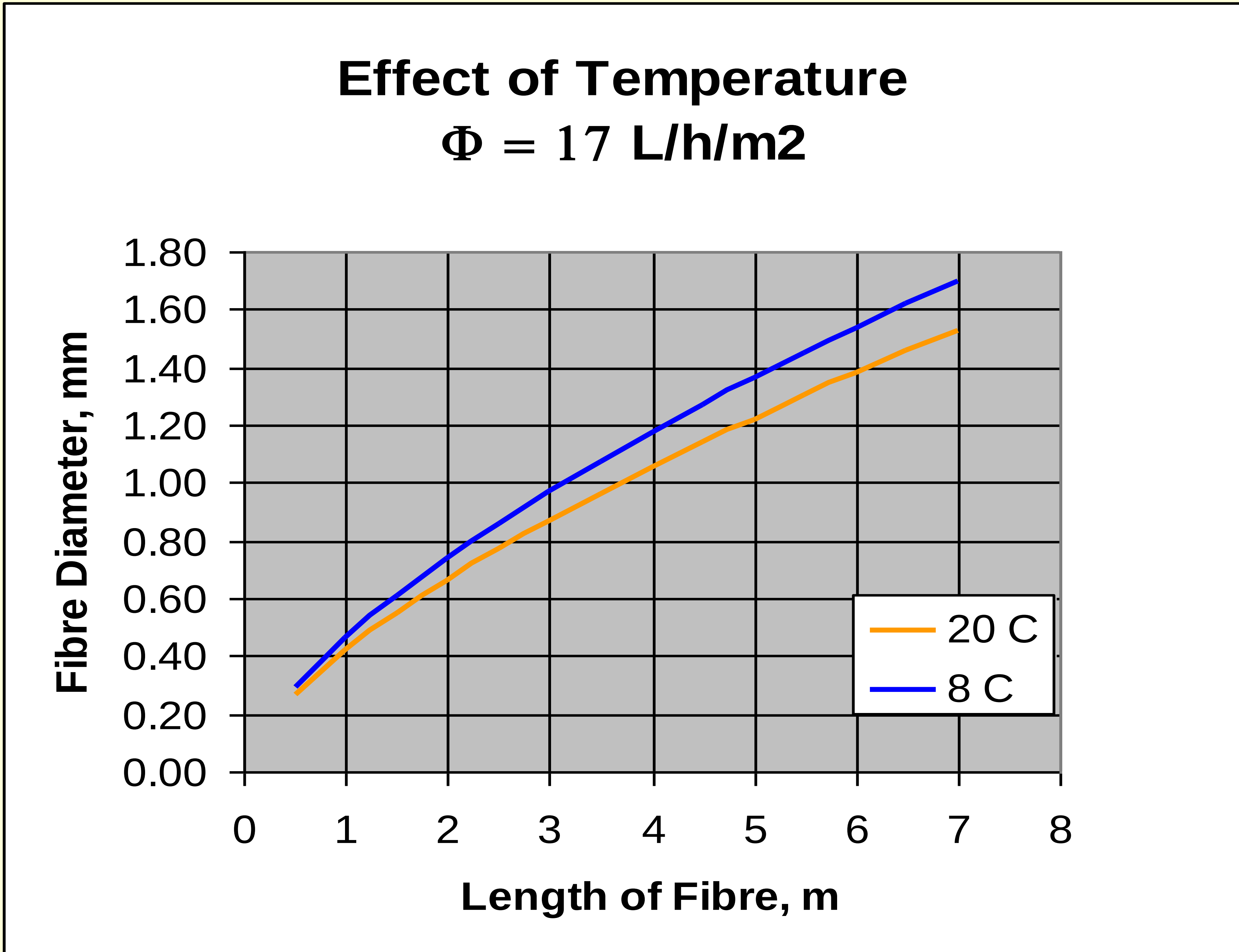
Description	Parameter	Value	Units
Membrane Permeability	K	10^{-9}	$cm^2.s/g$
Flow Rate	Q	.05	cm^3/s
Pressure Difference	dP	$5 * 10^5$	$Dynes/cm^2$
Viscosity	μ	1.004E-02	g/cm.s

D and L Relationship

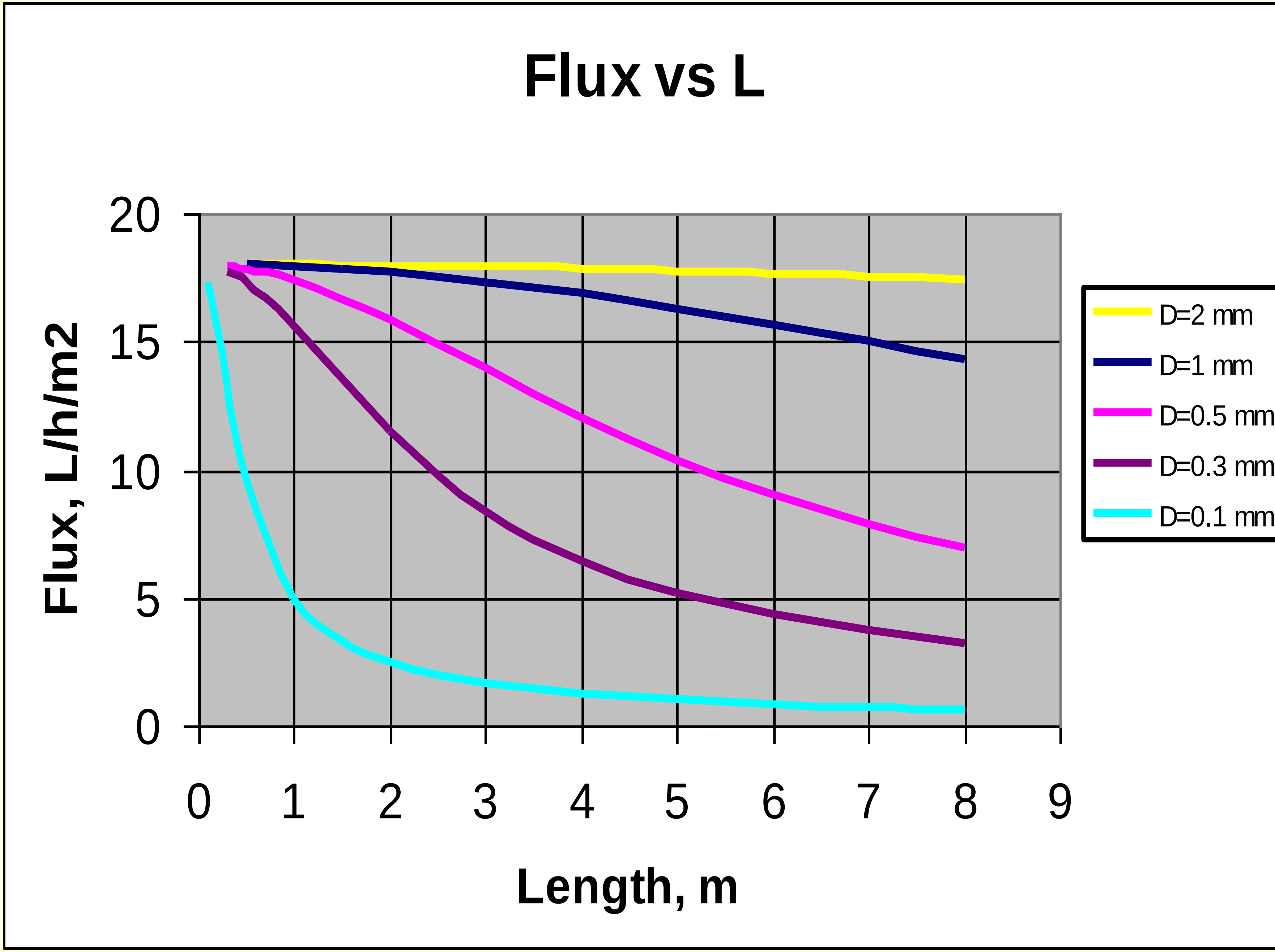
$$D \cong \left[\frac{\frac{128}{3} K\mu}{\frac{K.\Delta P}{\Phi} - 1} \right]^{1/3} L^{2/3}$$



Hollow Fibre Diameter vs Length
D, mm
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
8
Hollow Fibre Length, m
18 L/h/m2
17.5 L/h/m2
Appx Eqn
17 L/h/m2
16 L/h/m2

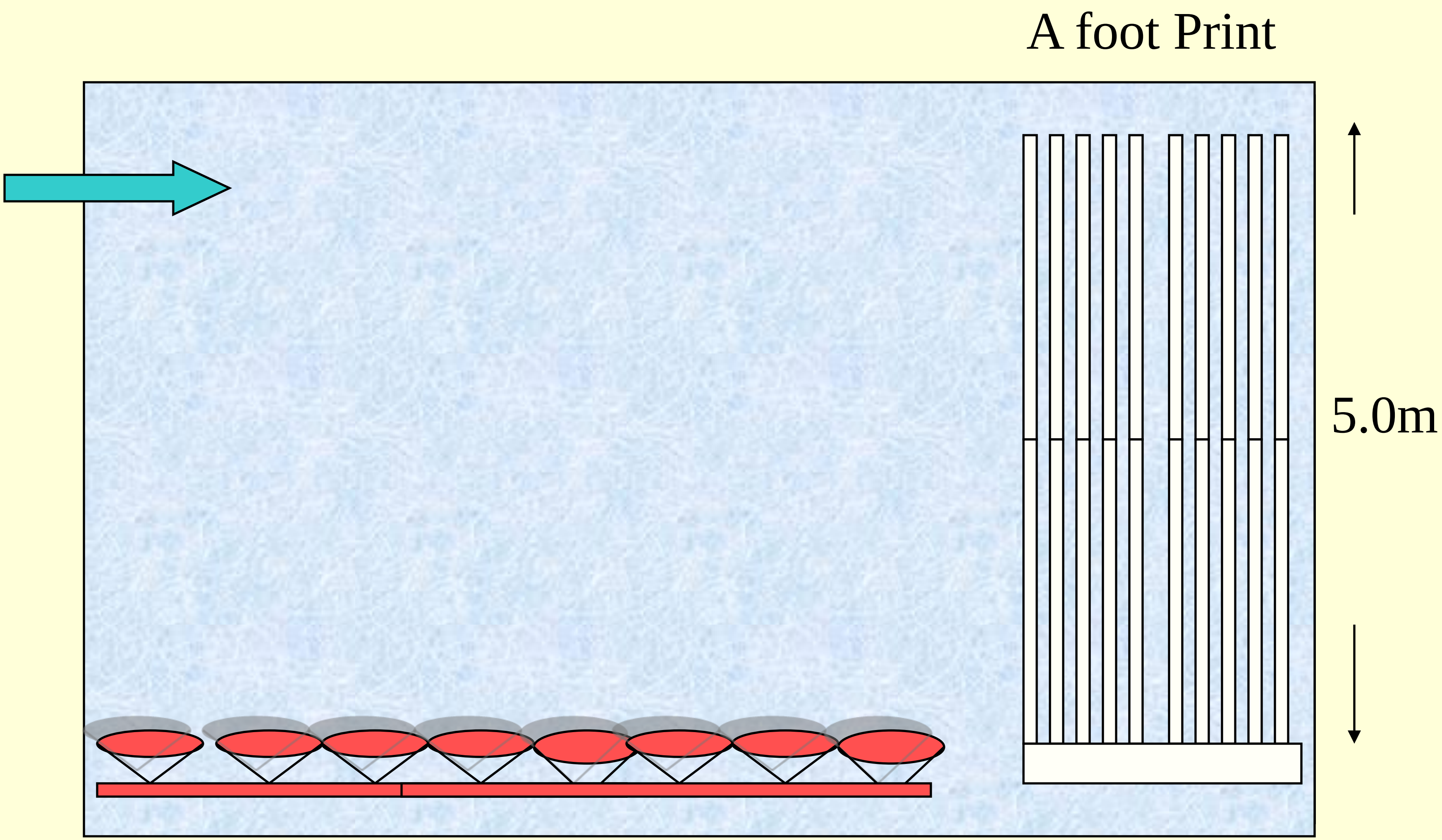


Effect of Temperature
Φ = 17 L/h/m2
Fibre Diameter, mm
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1
2
3
4
5
6
7
8
Length of Fibre, m
20 C
8 C



Flux vs L
Flux, L/h/m2
Length, m
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
D=2 mm
D=1 mm
D=0.5 mm
D=0.3 mm
D=0.1 mm

AERATION TANK with immersed MBR (L= 5 m)



$$L = \frac{1}{\alpha} \coth^{-1}\left(\frac{\pi D K \Delta P}{\alpha Q} \right)$$

$$u = \frac{\pi D K \Delta P}{\alpha Q}$$

$$\coth^{-1}(u) = \frac{1}{2} \ln\left(\frac{u+1}{u-1} \right)$$

$$\lambda = \frac{1}{2}\ln\left(\frac{u+1}{u-1}\right)$$

$$\lambda = \frac{1}{u} + \frac{1}{3u^3} + \frac{1}{5u^5} + \ldots$$

$$u = \frac{\pi D K \Delta P}{\alpha Q} = \frac{\pi}{8\sqrt{2}} \sqrt{\frac{K}{\mu}\left(\frac{\Delta P}{Q}\right)} D^{5/2}$$

$$L = \frac{1}{2\alpha} \ln\left(\frac{\alpha Q + \pi K \Delta P . D}{\pi K \Delta P D - \alpha Q}\right)$$

Required Minimum Pressure

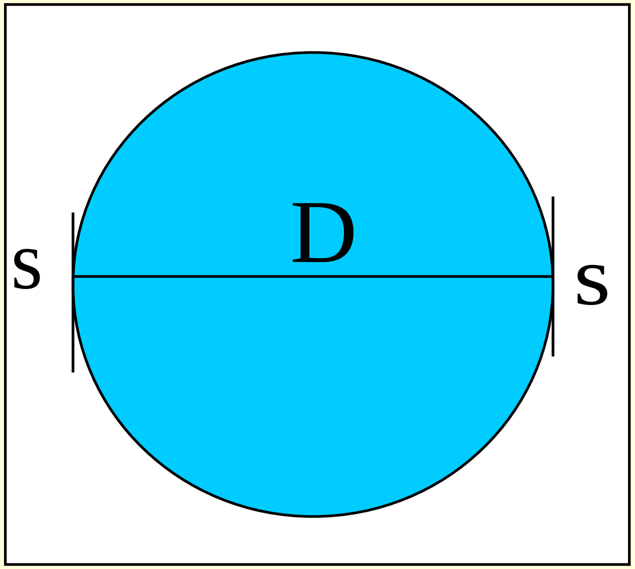
To achieve a flow through the hollow fibre: u> 1

$$\Delta P_{\min} > \frac{8\sqrt{2}}{\pi}\sqrt{\frac{\mu}{K}}\,QD^{-5/2}$$

Module Footprint Area

$$\text{foot print} = (\text{D} + 2\text{s})^2$$

$$f(D) = C_A(\pi DL) + C_{FP}\, A_{FP}$$



Cost Function f(D)

$$f(D) = C_A\left(\frac{Q}{K\,\Delta P}\right) + \frac{128\mu K}{3\pi}\left(\frac{Q}{K\,\Delta P}\right)^3 .D^4 + C_{FP}(D+2s)^2$$

$$f''(D) = 20\frac{C_A}{3}(128)\frac{\mu K}{\pi}\left(\frac{Q}{K\,\Delta P}\right)^3 D^{-6} + 2C_{FP} > 0$$

$$D_{optimum} \cong \left(\frac{256}{3}\frac{C_A}{C_F}\frac{\mu K}{\pi}\right)^{1/6}\sqrt{\frac{Q}{K\,\Delta P}}$$

Cost as a function of tube diameter (*CA/CFP = 0.1*)