Water and wastewater treatment – Homework 7

1. Analysis of particle size

The table below shows information on particle size distribution in a raw water and a flocculated/filtered water

Diameter (mm)	Cumulative number of particles in raw water (#/mL)	Cumulative number in flocculated/filtered water (#/mL)
< 5	55889	365
< 7.5	89943	544
< 15	109321	689
< 30	111581	723
< 50	111756	728
< 70	111777	729

a) Plot the particle distribution (log particle size distribution function vs log particle diameter). Hint: Make a table with the critical parameters d_p, particle number, Δd_p, ΔN, $\log(\Delta N/\Delta d_p)$ and $\log(d_p)$ of the raw water and the filtered water.

Raw water

d_p μm	Δd_p	ΔN	$\log(\Delta N/\Delta d_p)$	$\log(d_p)$*
5				
7.5				
15				
30				
50				
70				

*example mean d_p (5-7.5 μm) = $\sqrt{5 \times 7.5}$ (geometric mean)

Filtered water

d_p μm	Δdp	ΔN	$\log(\Delta N/\Delta dp)$	$\log(d_p')$*
5				
7.5				
15				
30				
50				
70				

*example: d_p' (5-7.5 μm) = $\sqrt{5 \times 7.5}$ (geometric mean)

b) Determine the parameters A and β. How do you interpret these values?

2. Sedimentation

a) Calculate the terminal settling velocity for a particle in water at 20ºC, using Stoke's law. The particle has a diameter of 25 μm and a density of 2000 kg/m^3. The density of water is 1000 kg/m^3 and at 20ºC, μ is 1.002 x 10^{-3} Ns/m^2.

b) Is the assumption of the Stoke's law correct (laminar conditions)?

c) What are the consequences for the terminal settling velocity if the temperature changes from 20ºC to 5ºC? Assumptions: Density of water remains constant, μ at 5ºC is 1.52 x 10^{-3} Ns/m^2.

d) Calculate the same parameters for a particle diameter of 250 μm at 20°C. Check again if the assumptions for the Stoke's law are fulfilled.

e) What is the minimum length (depth 4 m, width 10m) of a settling tank for the removal of the 25 μm particles at 20ºC and 5ºC? Flow rate of water 500 m^3/h.

f) Calculate the particle removal in the sedimentation basin from e) (depth 4 m, width 10 m, length 40 m, water flow rate 500 m^3/h, T= 20ºC). The particle concentration and size is given in the Table below. The particle density is 2000 kg/m^3.

Diameter μm	Number of particles 1/L
10	1×10^6
20	3×10^6
25	2×10^6
30	4×10^6
50	2×10^5
100	1×10^6

i) Calculate the critical settling velocity

ii) Calculate the settling velocities of the particles and the fraction of the particles removed. What is the number of remaining particles after the sedimentation tank?

iii) Plot the number of particles as a function of the particle diameter before and after the sedimentation tank.

iv) What is the overall particle removal in percent?

3. Filtration

A deep bed rapid filter consists of 1 m sand with an average diameter of the sand grains of 0.5 mm. The filtration rate is 10m/h.

a) Calculate the clean-bed head loss for a temperature of 5ºC. Use average values for κ_v, κ_I and ε and value for the dynamic viscosity from the lecture notes.

b) Plot the headloss as a function of porosity (using the parameters above). For the headloss to be 30% higher than in question a), how much would the porosity have to decrease (assuming that all other parameters remain constant)?

c) Calculate the head loss for a non-homogeneous deposition of particles (the filter influent water contains $5x10^5$ particles/L with a diameter of 50 μm and a density of 2000 kg/m^3). The table below shows the relative removal in each layer of the filter after 2h. Use the calculated cumulative amount of material to estimate the incremental head loss from the figure below.

Filtration depth cm	C_x/C_o
0	1
5	0.85
10	0.78
15	0.72
20	0.68
30	0.65
40	0.62
60	0.62
80	0.62
100	0.62

Estimate the head loss in each zone from the graph below

Filtration zone cm	Head loss m
0 -5	
5-10	
10-15	
15-20	
20-30	
30-40	
40-60	
60-80	
80-100	
Total head loss 0-100