Analysis of Type II Settlement in Water (Flocculent Particles)

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Abstract

The analysis and study involving fine sediments (colloids) transportation in H_2O is however complex and complicated as it comprises several separate processes which includes flocculation if the sediments are cohesive, mixing and settling, deposition and resuspension etc. Generally, chemical precipitate are formed in coagulations with respect to destabilization processes which tends to agglomerate during settling resulting from interparticle collisions as a result, changes exist continually in shapes, sizes and the specific gravity due to entrapment of H_2O in interstitial spaces of the flocs, following rigorous setting column tube analysis. In lieu of this 75% removal efficiency of the dilute suspension to form sludge is determined with hydraulic loading rate of 34.3m/day, from sedimentation tank size capacity of 13.623m.

Keywords: Flocculent; Coagulations; Settling Column tube; Isoremoval; Removal efficiency.

1. Introduction

Majority of natural water source contained in it are dissolved and suspended particles (Tzoupanos and Zouboulis 2008). However, such suspended particulates (materials) are usually as a results of erosion from lands, dissolutions of minerals as well as decay of agricultural vegetation’s and from numerous sources of both domestics and industrial waste discharge. Similarly, such existing materials may constitute suspended particles, both dissolved organics and inorganics constituents (matter), and including considerable biological organisms (bacterial, algae, and or viruses). Therefore, these minerals should be removed completely, because it’s a sources to water quality deterioration (reduces water clarity) such as turbidity/colour, ultimately a sources for pathogenic organisms and or toxic (harmful) compounds (Safe drinking water, 2007; Tzoupanos and Zouboulis 2008). Coagulation is an analytical process of neutralizing charges to form gelatinous flocs to be trapped in water (mass of fine particles capable of settling and to be trapped by filter) due to the presence of flocculent particles. While flocculation is a consistent slow stirring of solution to facilitate the agglomeration of flocs particle larger enough for settling/filtered (Tripathy T. and De B. R., 2006 and Gregory, 2006). In furtherance, coagulation and flocculation processes are used for separating the dissolved and suspended particles that exist in water. However, both coagulation and flocculation are relatively simpler in their relative nature as well as cost-effective with the availability of chemicals in line with appropriated dosage for the required water composition. Coagulation and flocculation is generally employed at pre-treatment (rapid sand-filtrations) or at post-treatment stage (at the completion of sedimentation), regardless of the water treatment nature. Majority of suspended solids in water possesses negative (-ve) charges which repel each other (Gregory, 2006), causing repulsion that prevents the finer particles from agglomerating, apparently allowing them to exist freely in suspension. Coagulation and flocculation occurs successively with the aim to subdue the

forces providing stability for the suspended particles, which apparently allows particles collision as well the growth of flocs, which subsequently allows settling, and are removed by sedimentation process or filtration process. (Safe drinking water, 2007; Gregory, 2006; Tzoupanos and Zouboulis 2008). Settling is also referred to as sedimentation, and is a procedure for removing solids particle in suspension through settling influenced by gravity as a result of their weights. Generally, particles found in water usually are fine colloids capable of forming flocs with smaller density and hence it depends on the flocs size which takes longer periods before settling occurs (Gregory, 2006), and as a result they need to be enhanced by chemical processes called coagulations and flocculation (Tzoupanos and Zouboulis 2008).
Furthermore, this experiment will aimed at observing settling from column tube *figure 1 and 2a*, for a dilute flocculent particles in suspension, which depends on the variation of setting velocity and the length of the column as well as the period. And a plot of samples concentration in curves represents isoremoval line. *Figure 2b*, which represents the instantaneous velocities. Similarly, there are basically four types of settling in relation to water and wastewater analysis namely, type I (discrete particle settling); type II (flocculent particles); type III (hindered/zone setting); and type IV (compression). However, this research work will evaluate the systematic nature of type II setting in column tube.

2. Laboratory procedure for type 2 column test analysis and Column requirements:

Column height should be equal to the height of proposed tank (2m); Column diameter (15 - 20cm); sampling pots; and sampling pots intervals (25/45cm) apart.

3. Method and hypothesis

- Mix suspension thoroughly for uniformly distributions of particles and pour into sample column
- Allow settling time for suspensions
- Collect samples from individual pots periodically (time interval)
- Determine Total Suspended Solids (TSS) concentration, at variable depth and time interval, by analyzing fractions remaining in suspensions
- Calculate the required percentage removed for individual sample, which is given by the below expression

  $\mathbf{X_{ij} = (1-C_i/C_o)*100}$…………………….……………………………………….. **(1)**

  - ✓ $\mathbf{X_{ij}}$ = fractional mass removal
  - ✓ $\mathbf{i^{th}}$ = depth (meters)
  - ✓ $\mathbf{j^{th}}$ = time interval
  - ✓ $\mathbf{C_o}$ = initial solid concentrations (mg/l)
  - ✓ $\mathbf{C_i}$ = initial sampling time interval (minuets)
- Plot isoremoval line graph (percentage (%) removal), with column depth on the vertical axis and time interval on the horizontal axis
- Interpolate between plots of points for curves which is equivalent percentage removal that indicates 40%, 50%, 60%, 70%, 80%, 90% and 100% as in *figure 2b*
- Determine $\mathbf{t_o}$ (retention time or intercept from horizontal axis) in minutes from graph which is drawn vertically upward from the horizontal line (time $_{min}$) axis. However this line bisects the isoremoval curve lines that provides interval between two bisection = $\Delta \mathbf{h_1}$, $\Delta \mathbf{h_2}$, ……………………….$\Delta \mathbf{h_{n\ miters}}$

4. Characteristics of the flocculent particles

The movement of the flocculating particles within the water sample is from top to bottom of the setting column tube (vertically down ward) but horizontally towards the sampling pots and the water should maintain constant temperature throughout the analytical process. However the residual settlement of the flocculent particles (flocs) are referred to as sludge (Tripathy T. and De B. R., 2006).

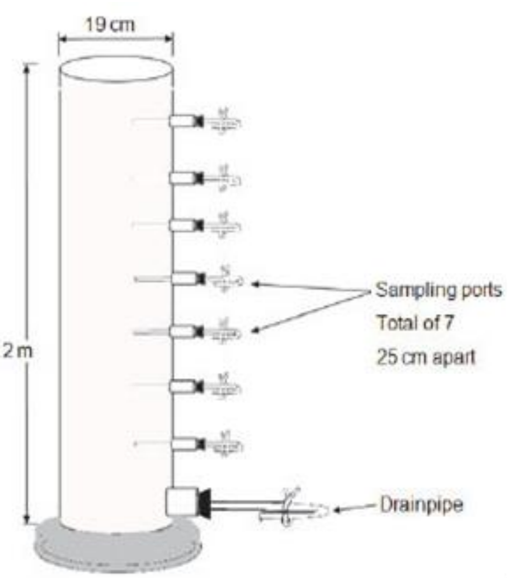

Figure 1: Settling column test

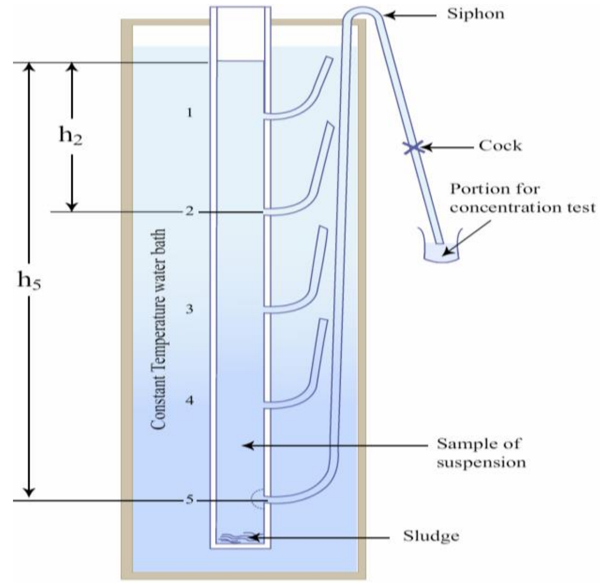

Figure 2a: section trough sampling column

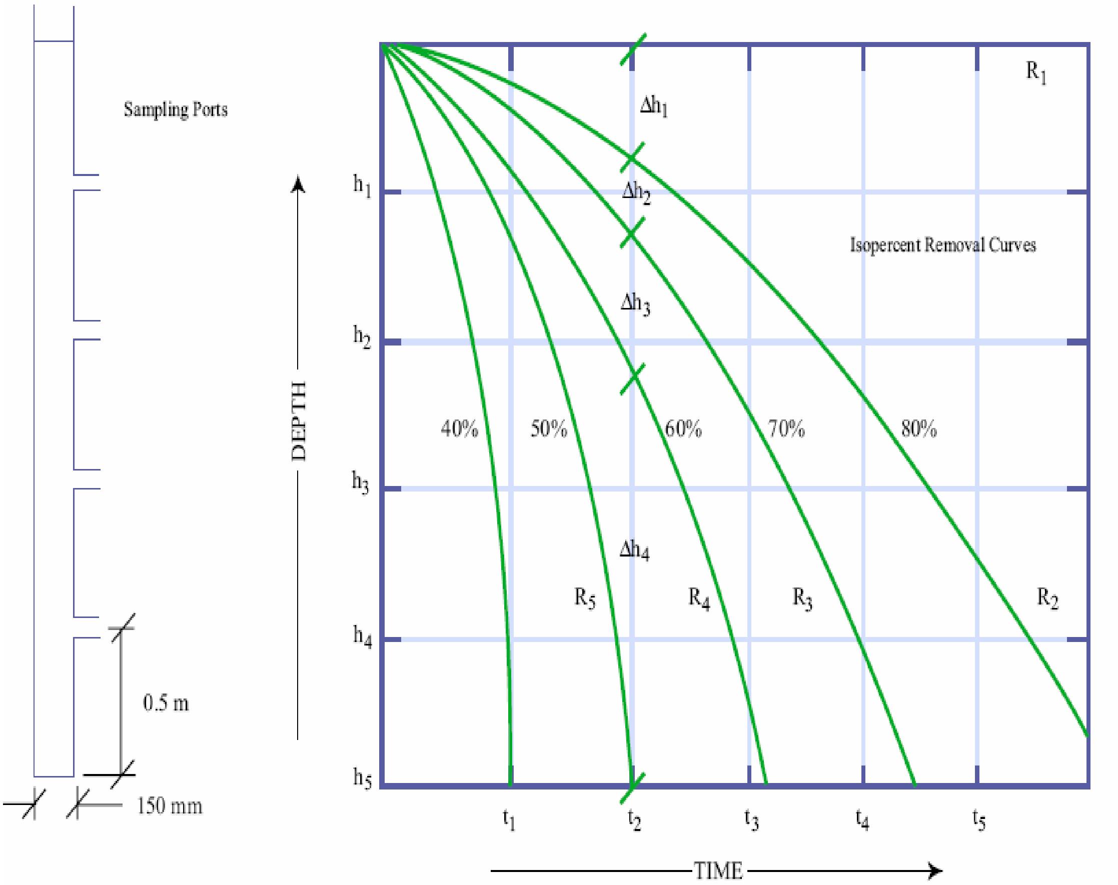

Figure 2b: isoremoval (%) plot, depth (m) Vs time (min) in respect to $\Delta h_1 .... \Delta h_n$

However, to determine the percent of particles having average setting velocities lower than the required designed velocity, which is removable by ratios of the average setting velocity of a specific depth reached within a required detentions period (time) in minutes. Hence, average depths reached at desired time is evaluated from the intersections (points) along the given experimental depths drawn at median between the drawn isoconcentration plots of curves.

5. Solid removal efficiency

$$\mathbf{R = r_o + \frac{1}{D(m)} \sum(\Delta R * Z_i) \ldots\ldots\ldots\ldots (2)}$$

- R = solids removal efficiency (%)
- r_o = **%** removal at retention time or intercept from horizontal axis (min)
- D = column depth or height of column (m)
- $\sum$ = summation of $\Delta R * Z_i$
- ΔR = interval between isoremoval percentage curve $[\frac{d}{100}]$

  d = individual interval between isoremoval curves from Horizontal axis
- Zi = average value reading for the points of bisection of $\mathbf{t_o}$ with any Isoremoval curve line denoted as intervals $\mathbf{\Delta h_1}$, $\mathbf{\Delta h_2}$ …………$\mathbf{\Delta h_n}$

6. Aims of this Experimental research (Analysis of type II settlement)

An experiment was conducted for a type II settlement in a column tube of depth equal 2.4 meters, with an initial completely mixed solid concentration of 200mg/l and the distribution concentration period (time) of the particles at variable depths in the column tube is given in *table 1a* below. However, to prove the above hypothesis and other required contents in relation to design procedures for circular tanks, the followings will be determined from the obtained results as the main aim of this research work, namely:

I. The overall removal efficiency in percentage (%) given the retention time to be 80minuets;
II. Most suitable hydraulic loading rate in meter per day (m/day) for a desired condition to achieving the removal efficiency for 75% in the column tube; and
III. If the design flow is 5000cm^3/day for a sized circular tanks base on the loading rate determined to be determined in (II) above, relevant hydraulic and other characteristics are checked to ensure acceptability of the design.

7. Laboratory Objective for settling column test

This analysis will provide for modeling the general behaviors for flocculent settings; evaluate setting tank and also to provide for developmental data for the expansions of plants. However, this process is not visible for designing of a new treatment works, because it's not easy in estimating concentrations of particles that emanates from coagulations/flocculation unit.

7.1 Purpose of setting in water and waste water

To eliminate coarsely dispersed phase in water; to provide for the removal of coagulated and flocculated as well as precipitated impurities thereafter chemical treatment, and to allow the settling of sludge (biomass) at the end of activated sludge/trickling filter processes.

7.2 Results and Discussions

7.2 Experimental time of Solid Concentrations of type II settlement

Table 1a: concentrated solid measured (mg/l) for a type II settlement column test

Sampling periods in minuets (min.)						
Depths (m)	**20min.**	**40min.**	**60min.**	**80min.**	**100min.**	**120min.**
0.40	110.90	68.90	41.87	31.99	24.88	18.96
0.80	149.96	104.02	78.04	54.08	45.98	35.98
1.20	169.98	124.87	97.69	77.96	58.04	48.02
1.60	178.05	139.90	113.04	91.89	74.90	57.99
2.00	182.89	149.95	120.97	102.89	86.05	67.03
2.40	188.02	156.88	128.95	111.02	94.06	78.90

7.3 Calculated values for normalized concentrations

Table 1b: Normalized concentration % (sampling time in minuets)

Sampling periods in minuets (min.)						
Depth (m)	**20min.**	**40min.**	**60min.**	**80min.**	**100**	**120**
0.40	**45**	66	79	84	88	91
0.80	**25**	48	61	73	77	82
1.20	16	38	51	61	71	76

1.60	11	30	44	54	63	71
2.00	9	25	40	49	57	67
2.40	6	22	36	45	53	61

7.4 Calculation for normalized concentration (%)

The values in *table 1b* above are obtained by the following procedure equation (1) above, from the given initial sampling time interval (minuets) = **111 min**. the given question as follows.

X_{ij} = (1-111/200)*100 = **44.5 = 45**………………………………. (i)

X_{ij} = (1-150/200)*100 = **25**…………………………………….. (ii)

$X_{ij\ (th)} = (1-C_{i(th)}/C_{o(th)})*100$……………………………………..($n_{th}$)

8. Required percentage for partial removal fractions

- 45% to 50%, the fractional difference = 5% and depth reached = 2.15m this implies $\frac{2.15}{2.4} \times 5\%$ = 4.479%, with same procedure, this implies:
- 50% to 60% = 10%, depth = 1.55m this implies $\frac{1.55}{2.4} \times 10\%$ = 6.468%
- 60% to 70% = 10%, depth = 1.05m this implies $\frac{1.05}{2.4} \times 10\%$ = 4.375%
- 70% to 80% = 10%, depth = 0.70m this implies $\frac{0.70}{2.4} \times 10\%$ = 2.916%
- 80% to 90% = 10%, depth = 0.40m this implies $\frac{0.40}{2.4} \times 10\%$ = 1.600%
- 90% to 100% = 10%, depth = 0.15m this implies $\frac{0.15}{2.4} \times 10\%$ = 0.625%

⤇ 4.479+6.468+4.375+2.916+1.600+0.625 = **20.463%**

Therefore, % removal efficiency at 80minuets is equal to complete % removed plus partially % removal. This implies **45% + 20.463% = 65.453%**

Table 2a: evaluated value for ΔR, Z_i and ΔR*Z_i at: 1hr 20min. (80min)

Elements	ΔR	Z_i	ΔR*Z_i
r_1	0.05	**2.2**	**0.11**
r_2	0,1	**1.6**	**0.16**
r_3	0.1	1.1	0.11
r_4	0.1	0.675	0.0675
r_5	0.1	0.275	0.0275
r_6	0.1	0.138	0.0138
∑			**0.4888**

9. Calculation for ∑ΔR*Z_i at variable ΔR, Z_i at: t_o = 1hr 20min (80min)

Δ**h** is obtainable from isoremoval graph as intervals of mean values of Z_1…...............Z_n

$Z_i = \frac{\Delta r1+\Delta h2}{2} = \frac{2.4+1.9}{2}$ = **2.15 = 2.2**

$Z_i = \frac{\Delta r2+\Delta h3}{2} = \frac{1.9+1.3}{2}$ = **1.6**

$Z_i(n^{th}) = \frac{\Delta r(nth) + \Delta h(nth)}{2} = n^{th}$

ΔH*Z_i = 0.05*2.2 = 0.11………………………………….. (i)

ΔH*Z_i = 0.1*1.6 = 0.16…………………………………..... (ii)

$\Delta H*Z_i$ (n^{th}) = Δ**h(n^{th})** * Z_i**(n^{th})** = n^{th} ……………………….(n^{th})

10. Calculation for Solid removal efficiency

From **equation (2)** above the percent solid removal efficiency is:

- r_o = % removal at retention time or intercept from horizontal axis (min) = **45% (t_o = $\frac{45}{100}$) = 0.45**
- D = column depth or height of column (m) = **2.4m**
- $\sum$ = summation of $\Delta R*Z_i$ = **0.4888**

R = $\mathbf{0.45 + \frac{1}{2.4m} \times 0.4888 = 0.6536}$

R = $\mathbf{0.6536 \times 100 = 65.4\%}$

11. The percentage efficiency removal of suspended solids at t_o = 1hr 20min.

From the graph in appendix (figure 3), the percentage efficiency of removed suspended solids at retention time (**t_o**) = 1hour 20 minutes (80minuets) = **45%**

Hence, the Solid removal efficiency is 65.4%, this is less than 70% as the minimum design requirement. Hence increase detention time to improve SS removal efficiency to 70%, 75%, 80% up to 99.9% as 100% removal efficiency is not possible. However, using the same procedure as in the calculation from *table 2a* above with t_o = 85minuets from the isoremoval graph *(figure 3)* with the expression:

$Z_i = \frac{\Delta r1+\Delta H2}{2}$ which produces *table 2b* below as follows.

Table 2b: evaluated value for ΔR, Z_i and $\Delta R*Z_i$ at: 1hr 25min (85min)

Elements	**ΔR**	**Z_i**	**$\Delta R*Z_i$**
r_1	0.07	2.285	0.15995
r_2	0.1	0.1785	0.1785
r_3	0.1	0.12	0.12
r_4	0.1	0.079	0.079
r_5	0.1	0.037	0.037
r_6	0.1	0.008	0.008
$\sum$			**0.53675**

R = $0.45 + \frac{1}{2.4m} \times 0.53675 = 0.69614583$

R = $0.69614583 \times 100 = 69.615\% = 70\%$

Hence, Solid removal efficiency is 70%, this is equal to the minimum design requirement. However the requirement is for hydraulic loading in meter per day at 75% removal efficiency. Therefore, increase detention time to improve SS removal efficiency to 75%. As third trial is required.

12. Required percentage for partial removal fractions

- 58% to 60%, the fractional difference = 2% and depth reached = 2.25m this implies $\frac{2.25}{2.4} \times 2\% = 1.875\%$, with same procedure, this implies:

- 60% to 6=70% = 10%, depth = 1.81m this implies $\frac{1.81}{2.4} \times 10\% = 7.542\%$
- 70% to 80% = 10%, depth = 1.16m this implies $\frac{1.16}{2.4} \times 10\% = 4.830\%$
- 80% to 90% = 10%, depth = 0.58m this implies $\frac{0.58}{2.4} \times 10\% = 2.416\%$
- 90% to 100% = 10%, depth = 0.18m this implies $\frac{0.18}{2.4} \times 10\% = 0.750\%$

⇨ 1.875+7.542+4.830+2.416+0.750+ = **17.413%**

Therefore, % removal efficiency at 112minuets is equal to complete percentage removed plus partially percentage removal. This then implies: **58% +17.413% = 75.413%**

Table 2c: evaluated value for ΔR, Z_i and ΔR*Z_i at: 1hr 52min (112min)

Elements	**ΔR**	**Z_i**	**ΔR*Z_i**
r_1	0.02	2.25	0.045
r_2	0.1	1.81	0.181
r_3	0.1	1.16	0.116
r_4	0.1	0.58	0.058
r_5	0.1	0.18	0.018
r_6	0.1	0.00	0.00
∑			**0.418**

$$R = \mathbf{0.58} + \frac{\mathbf{1}}{\mathbf{2.4m}} \times \mathbf{0.418} = \mathbf{0.75416}$$

$$R = \mathbf{0.75416 \times 100 = 75.416\% = 75\%}$$

However, this is the 75% removal efficiency of SS required from the setting column in order to determine its hydraulic loading rate in meters per day.

13. Hydraulic loding rate (V_o) at removal efficiency of 75%

$$V_o = \frac{Q*t}{A*t} = \frac{\text{volume}}{A*t} = \frac{\text{column depth(m)}}{\text{detention time(min)}} = \frac{d(m)}{t(min)}$$

$$= \frac{2.4m}{[\frac{112min}{(60\times24)}]} = \frac{2.4m}{(\frac{112min}{1440})} = \frac{2.4m}{0.07day} = 34.285714 = 34.3m/day$$

34.3m/day is the reccommended hydraulic loading rate required to achive the desired 75% removal efficiency of suspended solids.

14. Sedimentation tank size based on hydraulic loading of 34.3m/day

The design flow (Q) = 5000m^3/day

Therefore, $V_o = \frac{\text{design flow (Q)}}{\text{area(A)}} = \frac{5000(m3/day)}{34.3(m/day)} = 145.773m^2$

However Area (A) = $\boldsymbol{\pi}D^2/4$, D = tank diameter and $\boldsymbol{\pi}$ = 22/7

D = [4×A/(22/7)] = $[4\times145.773/(22/7)]^{0.5}$ = 13.6227 = **13.623m**

15. To check for weirs overflow rate (q_w) as design requirement

$$\Rightarrow (q_w) = \frac{\text{design flow (Q)}}{\text{weir length(l)}} = \frac{Q}{\pi D} = \frac{5000(m3/day)}{[\frac{22}{7}\times(13.623m)]} = 116.8123m^3/m.day$$

However, by conversion (m.day) into (hr), this then implies:

$$\frac{116.8123m3/m.day}{\pi D}$$

πD Is same as circular tanks circumference. Then the expression is identically equal to:

$\frac{116.8123m3/m.day}{24\ m*day}$ = **4.8672m²/hr**

⇰ 4.8672 m^2/hr is less than 6, the maximum design weir overflow rate. Therefore, this is satisfactory accepted value for the design requirement.

16. Conclusions

The outcome of this research work outlined type II setting, which describes dilute suspension of particles in water that can flocculate to form sludge. It can be concluded that colloidal particles are generally complex to be separated from water because they do not have settling weights and they lacks settling by gravity, similarly they are so minute that they can easily escapes through the pores of any filtration membrane. Hence in order to remove these colloids from water, individually they must aggregate and increase in size so as to settle faster. And the experimental analysis revels that, the partial percentage removal of flocculent particles at t_o = 80 minutes is equal to 48.9% and its overall removal efficiency is equal to 45%, similarly at t_o = 85 minutes is equal to 53.7% and its overall removal efficiency is equal to 65%, which both results are inadequate for the design requirement. However, at t_o = 112 minutes is equal to 41.8% partial removal, while its overall removal efficiency is equal to 75%. Hence, this is adequate as the design requirement. Finally the hydraulic loading rate V_o is equal to 34.3m/day, while the sedimentation tank size based on this value is equal to 13.623m, but provision should be made for more than one tank, should one break down. And the weir overflow rate (q_w) of this analysis is less than the maximum allowable design requirement, this means it's adequate. Finally, the analysis of flocculent particles can be applicable in the fields of Civil engineering; Earth science; Surface chemistry; Physical chemistry and Biology respectively.

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Appendix

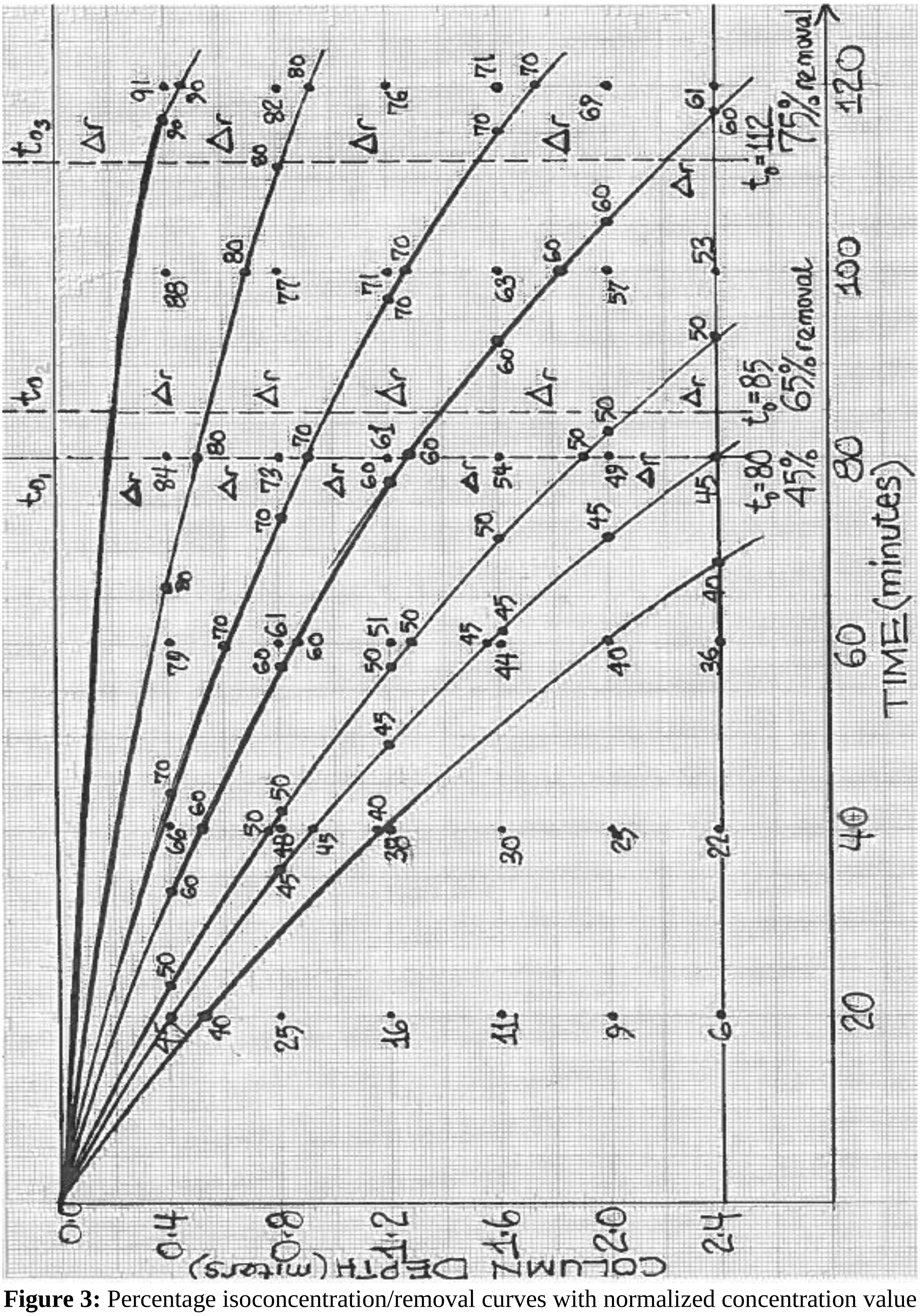

Figure 3: Percentage isoconcentration/removal curves with normalized concentration value

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