FRACTAL DIMENSIONS AND SETTLING PROPERTIES OF CHEMICAL COAGULATION FLOCS

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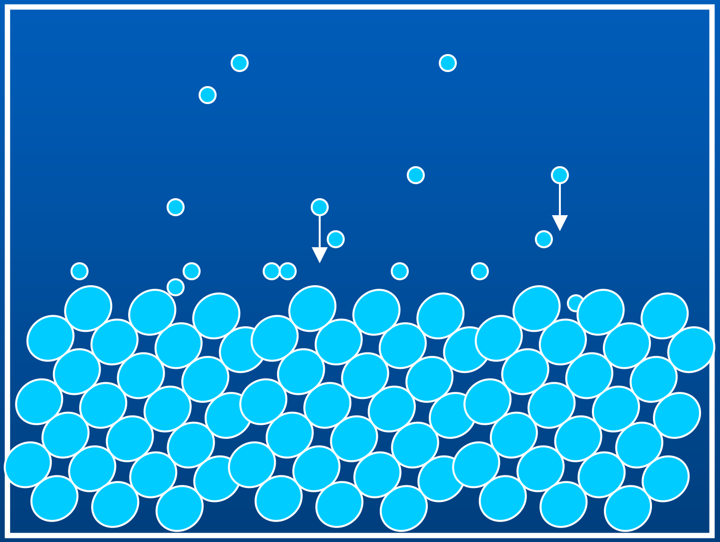
Gravity Settling



Individual flocs

Floc blanket – solid/liquid interface zone settling

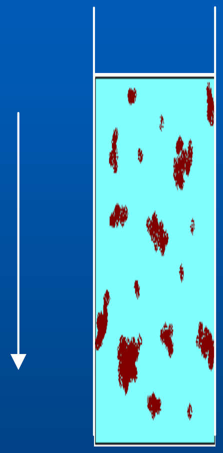
Settling of Individual Flocs
Stokes' Law

$$V_t^2 = \frac{4g(\rho_F - \rho_w)d}{3\,\Omega\,C_D\,\rho_w}$$

Density

Size

Drag



Inaccurate Floc Settling Velocity Predictions

Settling of Floc Blanket

$$V_{zs} = k \exp(-nC)$$

C – sludge concentration

K,n, - empirical coefficients specific for each sludge

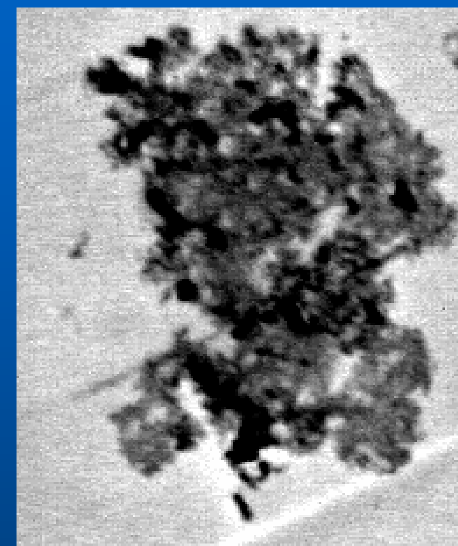
Parameter	Alum Coagulation Sludge	Activated Sludge
k_1 (m/h)	2.57 (Zheng and Bagley, 1999)	13 (Ekama et al., 1997)
v_t (m/h)	2.52	13.68
k_2 (kg/m^4/h)	$3.61 * 10^5$ (Zheng and Bagley, 1999)	$3.62 * 10^4$ (Zheng and Bagley, 1999)
$(\rho_f - \rho_w)\, u / k$ (kg/m^4/h)	$2.25 * 10^5$	$9.95 * 10^4$
n_2 (m^3/kg)	0.5 (Zheng and Bagley, 1999)	0.64 (Zheng and Bagley, 1999)
ρ_s^{-1} (m^3/kg)	0.4 (Gorczyca, 1991)	0.71 (Li and Ganczarczyk, 1987)

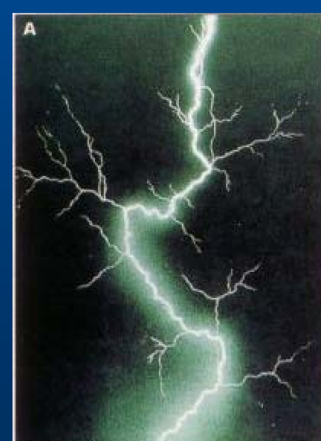
Objectives of this study

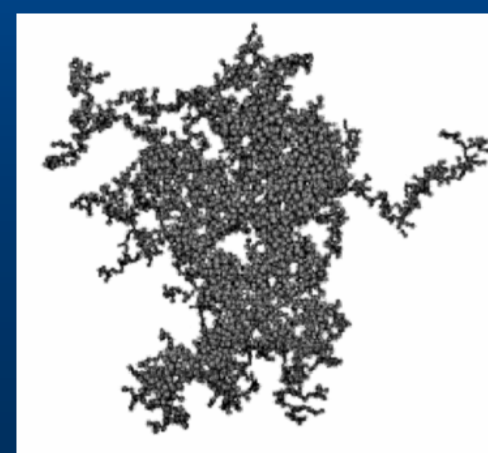
Analyze Properties of Flocs

Model Settling of Flocs

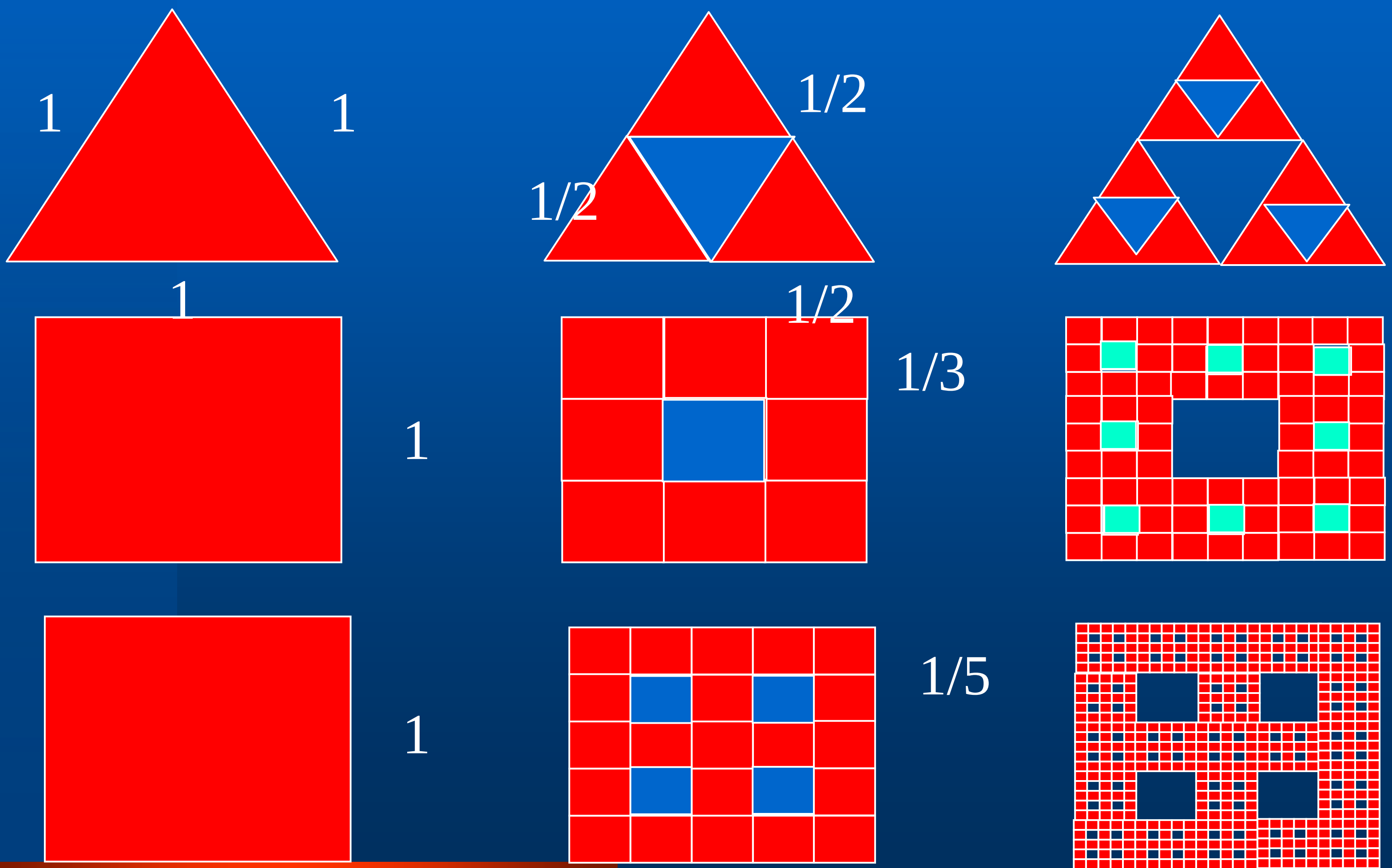
Flocs are Fractals





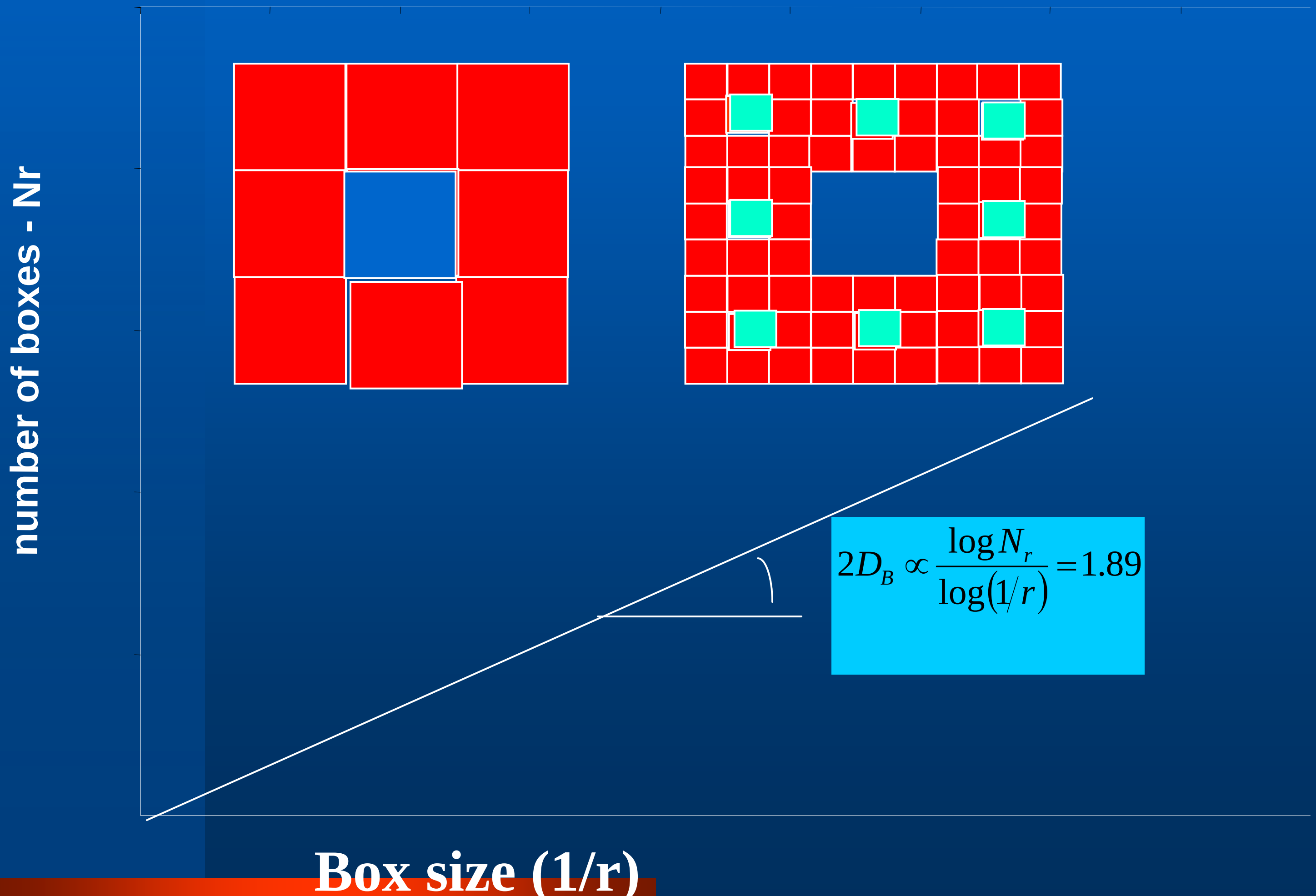


Mathematical Fractals



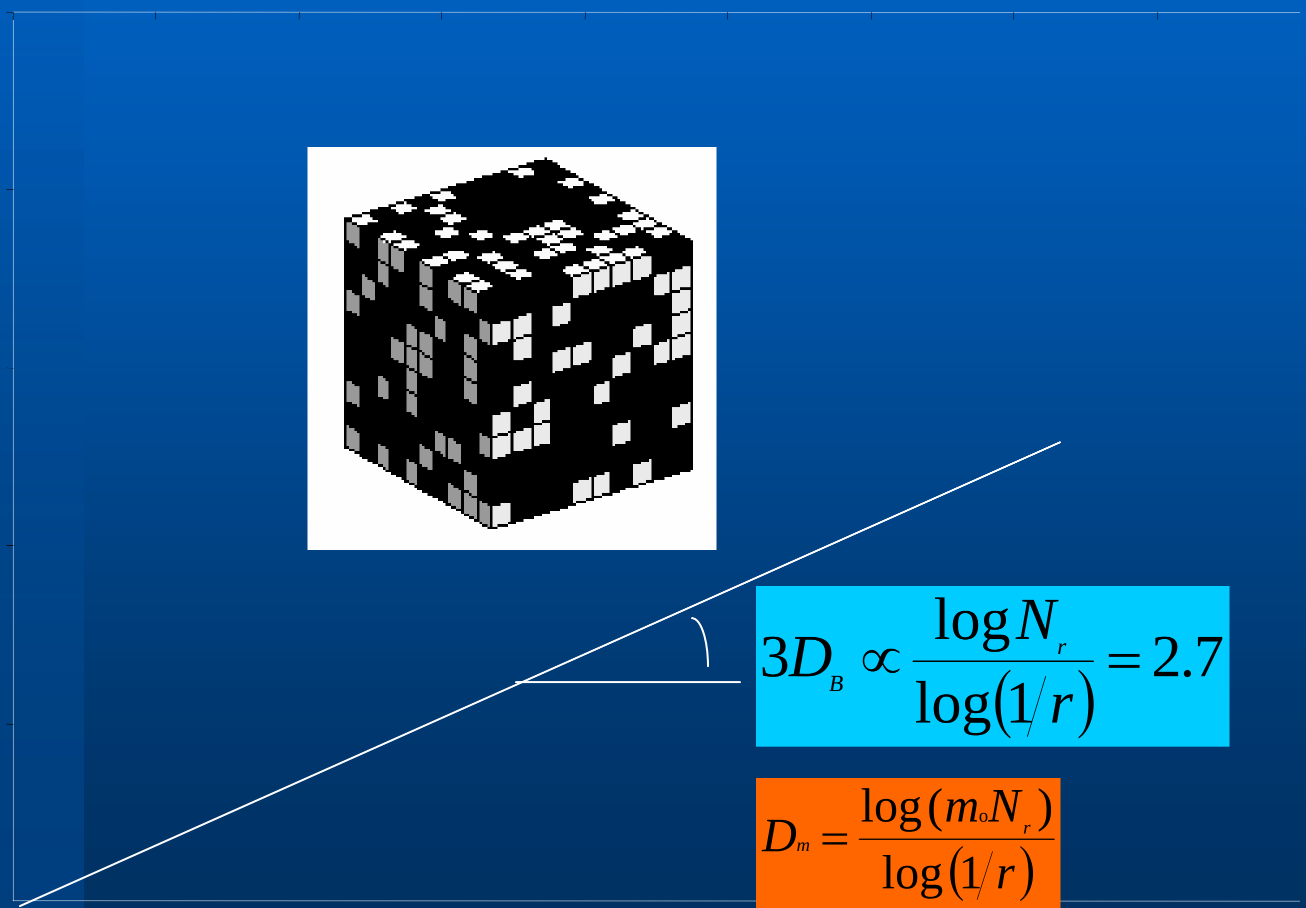
Fractal Dimension in 2D

Box counting method



$$2D_B \propto \frac{\log N_r}{\log(1/r)} = 1.89$$

Fractal Dimension in 3 D



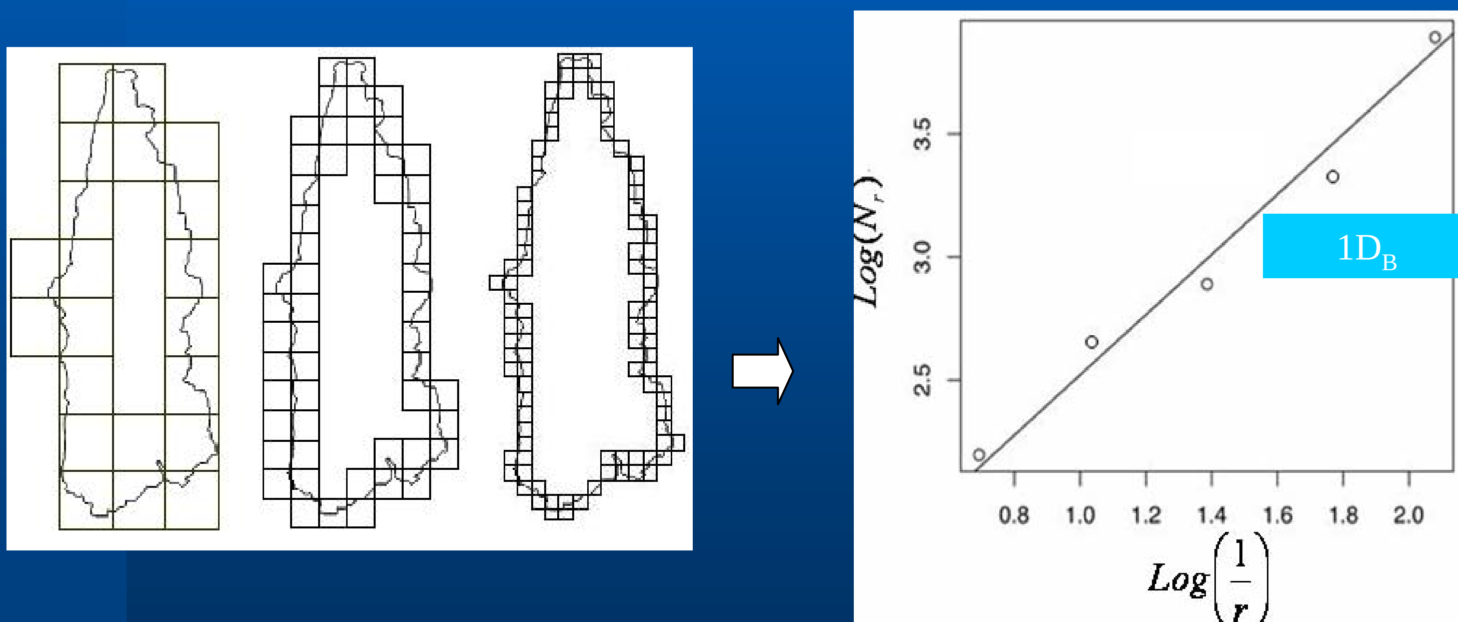
number of 3D boxes - Nr

Box size (1/r)

$$3D_B \propto \frac{\log N_r}{\log(1/r)} = 2.7$$

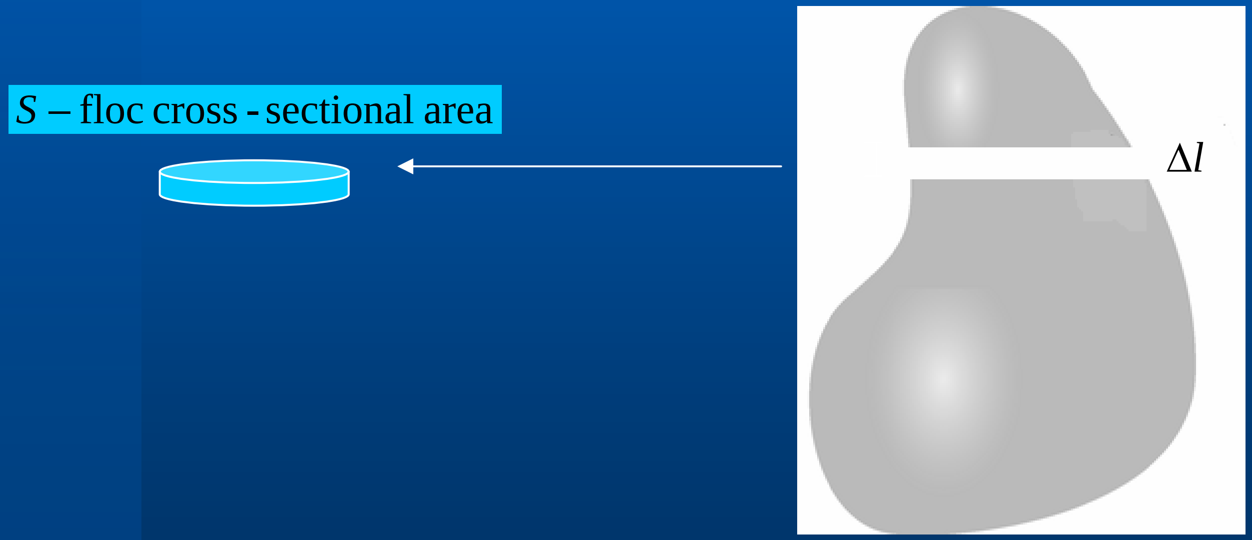
$$D_m = \frac{\log(m_o N_r)}{\log(1/r)}$$

Direct Measurements of Fractal Dimensions on Floc Section Image



Fractal Dimension in 3D

Reconstruction of a Floc in 3 D



Indirect Determination of Mass Fractal Dimension (D_m)

$$M = m_o N_r = r^{-Dm}$$

$$D_m \propto \frac{\log(m_o N_r)}{\log(1/r)}$$

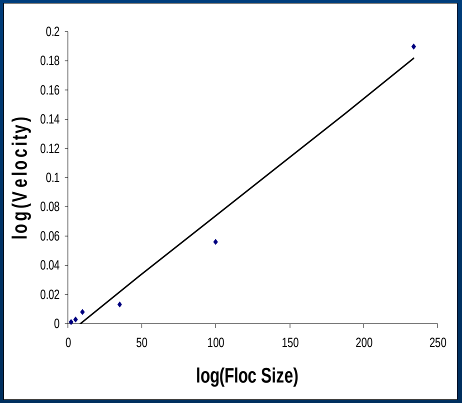
$$M = V\rho \sim r^3 \rho$$

Flocs are perfect spheres

$$\rho \ \alpha \ (velocity)/r^2$$

Flocs are non-permeable

$$-D_m = C + 1$$

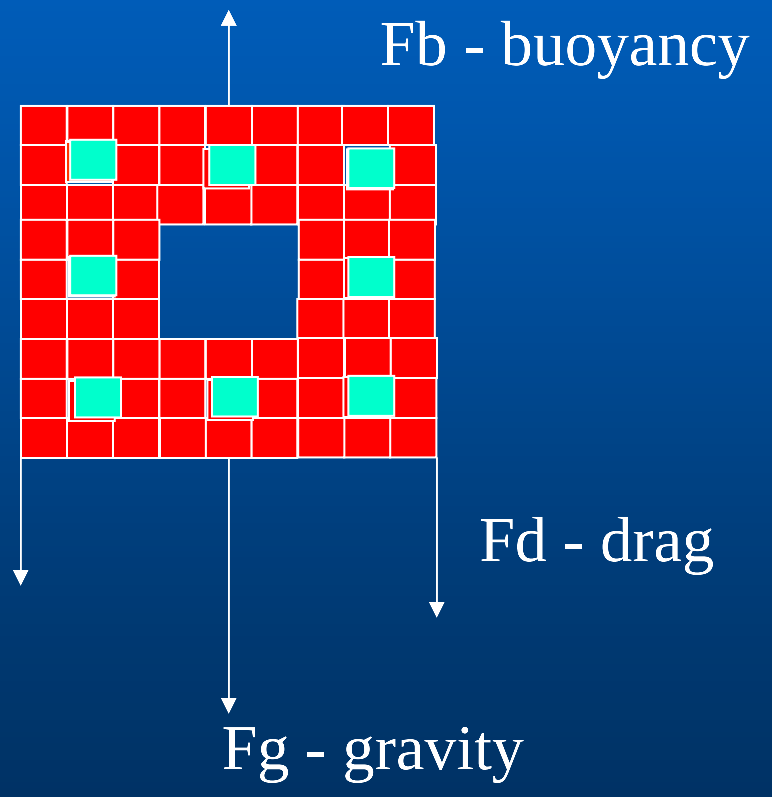


Fractal Dimensions of Chemical Coagulation Flocs

	FRACTAL DIMENSIONS			
	($1D_B$)	($2D_B$)	($3D_B$)	(D_m)
Lime softening flocs (Vahedi & Gorczyca 2008)	1.09	1.91 (1.89)	2.71 (2.70*)	1.82
Alum coagulation flocs (Gorczyca 1991,Gorczyca & Ganczarczyk 1996, 1999)	1.13-1.25	1.91-1.99	N.A	1.37-1.79
Ferric coagulation flocs (Bahrami & Gorczyca 2008)	1.11- 1.16	1.94-1.99	N.A.	N.A.

* Sierpinski Carpet (1/3)

Settling of Chemical Coagulation Flocs

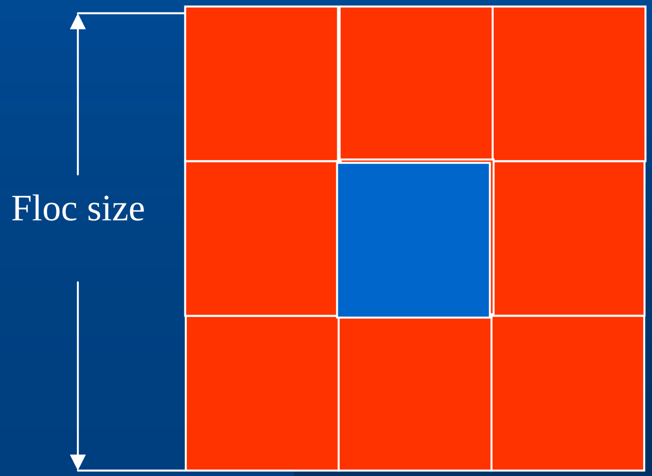


Fractal Permeability Model

(Adler, 1986)

Carman - Kozeny equation for Sierpinski carpet

$$k^* = 1/3.51((b^2-l^2-b)/4l)^2((b^2- l^2)/b^4)^N$$



k^* – dimensionless permeability $k^* = k/d_a^2$

b^2 – number of sub squares in the carpet , b=3

l^2 – number of sub squares removed in the carpet, l=1

N – the construction stage , N=1

Summary

- Direct microscopic reconstructions of lime softening flocs indicate that Sierpinski Carpet model with constriction ratio of 1/3 can be used to model structure of these flocs

- Modelling of settling of these flocs may be possible with the Stokes' law once it is re-written for this particular Sierpinski carpet

- Work on other types of flocs (biological flocs) is needed.

Acknowledgements

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