CHAPTER VII

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Appendix

NOTATION

VARIABLE	DESCRIPTION	CHAPTER
	A	
a	Reactive surface area (precipitation/dissolution).	II-VII
a_m	Effective specific surface of the matrix.	VII
a_M	Specific surface of water-biofilm phase boundary.	VII
a_1	Dimensionless coefficient in Hurni's equation.	VI
a_2	Coefficient in Hurni's equation.	VI
a_3	Exponent of pressure-dependent term in the equation of cake filtration with compression.	VII
a_4	Constant that relates τ_w and q (Govindaraju and Reddi).	VII
a_5	Constant that relates τ_w and q (Govindaraju and Reddi).	VII
a_s	Coefficient in the equation of Rajagopalan and Chu.	VII
A	Hamaker constant.	II
A_i	Screen area of a recharge well.	V-VI
A_m	Membrane area.	V-VII
A_P	Coefficient of Philip's equation	I-V-VI
A_S	Factor that accounts for the neighboring media grains in the Rajagopalan and Tien model.	VII
A_1	Coefficient of Kostiakov's equation.	VI
A_2	Exponent of Kostiakov's equation.	VI
	B	
b	Height of the clogging layer.	VII
b_S	Specific shear loss coefficient.	VII
b'_S	Analogous to b_S, though related to biological detachment.	VII
B	Coefficient of Hazen's equation.	V
B_P	Thickness of a filtration filling (in meters).	VI
B_T	Dimensionless empirical coefficient of Tare's model.	VII
B (N_{LO})	Function of the London-van der Waals number, N_{LO}. It is given here by the equation: $B(N_{LO}) = N_{LO}^{-0.22} + 0.05\ N_{LO}^{2.7}$	VII
BOC	Biochemical oxygen demand.	VI
	C	
c	Empirical parameter in Bianchi's equation.	VI
c_b	Concentration of ferrous iron in the liquid.	VII
c_{in}	Influent concentration of ferrous iron.	VII
c_m	Coefficient of kinetic absorption in membranes.	V
c_p	Concentration of ferrous iron in the matrix (support medium).	VII
c_t	Actual mineral concentration.	VII
c_w	Concentration of ferrous iron in the stagnant liquid film.	VII
c_{cake}	Concentration of retained particles in the clogging layer.	VII
$c_{s,sat}$	Concentration at saturation.	VII
c_0	Initial concentration.	VII
c_1	Coefficient. It is defined by: $c_1 = \eta \alpha_a q^2 d_g^2 \pi / 4$	VII
c_2	Linear coefficient of removal increase due to the existence of new retained particles.	VII
c_3	Linear coefficient of removal due to a diminution in the grain area.	VII
c_4	Quadratic coefficient of removal decrease due to the reduction in area of	VII

	retained particles.	
c_5	Constant that relates k_c and n^b (slope).	VII
c_6	Constant that relates k_c and n^b (slope).	VII
c_7	Constant relating the fluid shear stress to hydraulic magnitudes.	VII
C	Proportionality coefficient between K and d.	V
C_f	Microbiological clogging factor (square root of the acceleration factor).	V
$C_{f,\, max}$	Maximum value of the microbiological clogging factor.	V
CM	Factor that accounts for methyl orange alkalinity and calcium concentration in the Ryznar stability index.	V

D

d	Diameter of grains (generic).	VI-VII
d_g	Mean diameter of grains (aquifer or soil particles).	II-VII
d_m	A representative mean diameter.	V
d_p	Mean diameter of suspended particles (in water).	II-VII
d_T	Diameter of a tube if there is bioclogging (Okubo and Matsumoto).	VII
d_0	Diameter of a non-clogged tube (Okubo and Matsumoto)	VII
d_1	Diameter of type 1 (size 1) particles.	VII
d_2	Diameter of type 2 (size 2) particles.	VII
d_5	Grain size diameter at which 5% by weight of the particles is finer.	V
d_{10}	Grain size diameter at which 10% by weight of the particles is finer. It is termed effective grain size.	V
d_{16}	Grain size diameter at which 16% by weight of the particles is finer.	V
d_{84}	Grain size diameter at which 84% by weight of the particles is finer.	V
d_{95}	Grain size diameter at which 95% by weight of the particles is finer.	V
D	Coefficient of hydrodynamic dispersion (is a tensor if not 1D).	VII
D_{ij}	Components of the dispersion tensor.	VII
$D(\theta)$	Water diffusivity. It is defined by: $D(\theta) = K\frac{\partial \psi_m}{\partial \theta}$	I
D_o	Diffusion constant for oxygen across the diffusion layer.	VII
D_R	Groundwater depth on the right side of a trench.	VII
D_S	Diffusion constant for the substrate (across the diffusion layer).	VII
D_W	Depth of groundwater relative to the water height in a basin.	II
$D_{W\,80\%}$	Value of D_W at which infiltration rate is 80% of the initial value.	II

E

e	Electron charge.	II
[e]	Concentration of electrolyte.	II
E	Elasticity module.	VII
E_1	Coefficient of linear losses for a well.	V
E_2	Coefficient of non-linear losses for a well.	V

F

f	Infiltration capacity at a given time.	VI
f_b	Pore size distribution function if bioclogging exists.	VII
f_C	Infiltration capacity at the final time (asymptotic value).	VI
f_{en}	Coefficient of use of oxygen for energy (by bacteria).	VII
f_0	Infiltration capacity at t=0.	VI
f (r)	Pore size distribution function.	V-VII
f (φ)	Function introduced by Shektman and Sherwood.	VII
f (Ω)	Function of saturation ratio. It describes the precipitation/dissolution rate.	II-VII
f^0_{syn}	Coefficient of use of oxygen for synthesis (by bacteria).	VII
F	Filter capacity.	VII
F	Vector of external forces (applied tectonic stress).	VII

G

g	Gravity modulus.	II-V-VI
g_b	Maximum rate of substrate utilization in the biofilm.	VII
g_C	Clogging constant. It is the L_{ac} value at which C_f is half $C_{f,max}$	VI
g_o	Oxygen saturation constant.	VII
g_S	Half saturation constant in Monod-type equations for the substrate.	II-VII
g_1	Linear term coefficient at Taylor et al. empirical equation.	VI
g_2	Cuadratic term coefficient at Taylor et al. empirical equation.	VI
g_3	Permeability ratio if [BOC] > 0.4 mg/cm^3 at Taylor et al. empirical equation.	VI
ΔG^*	Activation energy for nucleation.	VII

H

h	Piezometric head.	II-VI-VII
h_b	Head build-up at the beginning of a recharge cycle (Olsthoorn).	VII
h_e	Head build-up at the end of a recharge cycle (Olsthoorn).	VII
h_s	Standard build-up for a recharge well (Olsthoorn).	VII
h_0	Initial water head.	VI
H	Screen thickness.	VI
H_{bi}	Bulk modulus of the porous medium.	VII
H_{cap}	Width of the capillary fringe.	II
H_W	Height of water in a surface system (depth of ponding).	II

I

i	Infiltration rate	I-II-V-VI-VII
i_0	Initial infiltration rate.	VI
i_∞	Final (asymptotic) value of infiltration rate, due to clogging.	VI
I	Cumulative infiltration: time integral of infiltration rate	I-V-VI-VII
I_B	Factor of blocking filtration.	VII
I_F	A measure of the membrane fouling potential of water (in MFI).	V-VII

J

j	Empirical coefficient for pressure build-up (Ives' equation).	VII
J	Mean velocity gradient.	VII

K

k	Intrinsic permeability.	II-V-VI-VII
k_b	Intrinsic permeability if there exists bioclogging.	VII
k_c	Probability of capture per unit depth (Herzig).	VII
k_d	Coefficient of pressure build-up (Ives' equation).	VII
k_{dec}	Coefficient of microbial decay.	VII
k_f	Microscopic coefficient of attachment (Rajagopalan and Chu).	VII
k_h	Coefficient of detachment rate for microorganisms.	VII
k_r	Detachment coefficient (Rajagopalan and Chu).	VII
k_s	Initial value of pressure in Boucher's equation.	VI
k_t	Rate constant for the pressure build-up in Boucher's equation.	VI
k_{OM1}	Bioclogging coefficient (Okubo and Matsumoto).	VII
k_{OM2}	Bioclogging coefficient (Okubo and Matsumoto).	VII
k_0	Initial permeability of a medium (column).	VI
k_1	Biclogging macroscopic model (Vigneswaran and Suazo): coefficient.	VII
k_2	Biclogging macroscopic model (Vigneswaran and Suazo): coefficient.	VII
k^s	Coefficient of the boundary condition equation.	VII
k'_c	Probability of capture of a particle per unit time.	VII
k'_r	Probability of decolmatage of a particle per unit time.	VII
$k(x,y)$	Rate of agglomeration of two clusters of masses x and y.	VII
$k(\sigma)$	Factor of physical clogging kinetic terms per unit depth (Herzig).	VII

$k'(\sigma)$	Analogous, but per unit time.	VII
K	Hydraulic conductivity. It depends on the water content (θ)	I-II-V-VI
$K(\varphi)_0$	Unsaturated hydraulic conductivity at time t=0.	V
$K(\varphi)_j$	Unsaturated hydraulic conductivity at a given time for layer j.	V
$K(\sigma)$	Generalised function for physical clogging -kinetic term-.	VII
K_{abio}	Abiotic rate of oxidation of ferrous iron.	II
K_{bio}	Biocatalysed rate of oxidation of ferrous iron.	II
K_B	Boltzmann's constant.	II-VII
K_C	Hydraulic conductivity of the clogging layer.	II-VI
K^*	Equivalent hydraulic conductivity (Olsthoorn).	VI
K_1	Accumulation coefficient.	VII
K_2	Detachment coefficient.	VII

L

L	Depth within the porous medium.	VII
L_{ac}	Acetate concentration, in gC/m^2d	VI
L_b	Biofilm thickness.	VII
L_C	Thickness of the clogging layer.	II
L_1	Coefficient of Loeffler's equation to describe the time evolution of i.	VI
L_2	Coefficient of Loeffler's equation to describe the time evolution of i.	VI

M

m	Packing factor for a porous medium.	V
m_c	Cell mass per colony.	VII
m_1	Adjustable exponent (empirical) of a precipitation/dissolution rate.	II
m_2	Another adjustable exponent (empirical) of a precipitation/dissolution rate.	II
m_3	Empirical coefficient for pressure build-up (Ives' equation).	VII
M	Number of terms of Philip's series.	VI
MFI	Modified (or membrane) fouling index.	V
M_V	Molecular volume.	VII

N

n	Number of clogged layers under the bottom of a basin.	V
n_i	Number concentration of particles (type i).	VII
n_j	Number concentration of particles (type j.	VII
n_o	Empirical coefficient of the precipitation equation.	VII
n_p	Number of blocked pores.	VII
$n(x,t)$	Concentration of clusters of mass x at time t.	VII
n_{LOSS}	Exponent of non-linear losses for a well.	V
n^b	Biomass concentration in the biofilm.	VII
n'_1	Number concentration of finer particles in the presence of coarser ones.	VII
N	Number of retained particles acting as collectors.	VII
N_A	Avogadro's number.	II
N_c	Colony density: number of colonies per aquifer volume.	VII
N_e	Number of elements.	VII
N_g	Number of filter grains.	VII
N_G	Gravity number.	VII
N_{ij}	Concentration number of new(agglomerated particles).	VII
N_{in}	Concentration of influent cells.	VII
N_{LO}	Coefficient of London-van der Waals attractive force.	VII
N_{ORR}	Exponent of the Orr generic formulae for particle deposition.	VII
N_p	Number of pores per unit area of filter.	VII
N_{pe}	Peclet number: ratio of advective to diffusive forces.	VII
N_r	Concentration of bacteria in the support medium.	VII
N_R	Interception number.	VII
N_s	Concentration of bacteria in the cylindrical reactor.	VII

N_σ	Number of retained particles.	VII
N_1	Number of particles of size 1 (type 1).	VII
N_2	Number of particles of size 2 (type 2).	VII

O

o_c	Oxygen concentration in the colony.	VII
o_w	Oxygen concentration in the water.	VII
O_a	Mass of adsorbed oxygen per unit area.	VII
$O(d_p)$	Function that depends on d_p	VII

P

p	Parameter of kinetic absorption in membranes.	V
p_{HO}	Adjustable parameter in Horton's equation.	VI
pH	Minus decimal logarithm of concentration of protons.	V
P or ΔP	Pressure or pressure build-up.	V-VI-VII

Q

q	Darcy's velocity	I-II-VII
Q	Flow.	V-VI-VII
Q_b	Flow at the beginning of a recharge cycle in a well.	V
Q_c	Total recharge form a recharge trench.	VII
Q_e	Flow at the end of a recharge cycle in a well.	V
Q_L	Recharge from the left side of a trench.	VII
Q_R	Recharge form the right side of a trench.	VII

R

r	Pore radius. Also, radial distance.	V-VII
r_{bact}	Rate of a bacterial-controlled reaction.	II
r_c	Radius of a microcolony.	VII
r_{clean}	Rate of particle removal.	VII
r_{coll}	Rate of change of collector particles.	VII
r_{min}	Rate of precipitation/dissolution of a mineral.	II-VII
r_o	Rate of oxygen utilisation by a microcolony.	VII
r_{nuc}	Velocity of nuclei formation.	VII
r_{pd}	Precipitation/dissolution rate.	VII
r_s	Rate of substrate utilisation by a colony.	VII
r_V	Radius of the clogging-affected volume.	VI
r_0	Minimum pore radius. Also, radius of a well (Olsthoorn).	V-VI-VII
r_{0b}	Minimum pore radius if there exists bioclogging.	VII
r^b_b	Rate of production of biomass in the biofilm phase.	VII
r^w_b	Rate of production of biomass in the water phase.	VII
r^w_s	Rate of consumption/production of substrate in the water phase.	VII
r^0_{nuc}	Factor in the equation of nuclei formation. It depends on numerous factors.	VII
R	Maximum pore radius. Also, radial distance for wells (Thiem's equation).	V-VI-VII
R_{ae}	Membrane resistance due to the preliminary absorption phase.	V
R_C	Time varying resistance of a membrane due to both kinetic absorption and cake filtration.	V
R_d	Rate of biomass deposition on the biofilm due to sedimentation, filtration and adsorption.	VII
R_H	Hydraulic radius in an open channel.	VII
R_{ij}	Radius of an agglomerated particle.	VII
R_s	Rate of biomass shear form the biofilm due to the action of mechanical forces.	VII
R_{sd}	Term of substrate-biomass interaction.	VII
R'_m	Resistance of a membrane, it is the sum of a clean resistance component	V

	and the preliminary absorption phase (R_m).	
$R(\varphi)_0$	Resistance at time t=0.	V-VII
$R(\varphi)_t$	Resistance at time t.	V
RI	Ryznar index.	V

S

s	Drawdown (or build-up) during a pumping (or recharge) test.	V
s_c	Substrate concentration in the colony.	VII
s_W	Concentration of a bacterial substrate (nutrient).	II-VII
s'	Empirical exponent of the blocking filtration equation.	VII
S	Saturation index.	VII
S_a	Mass of adsorbed substrate per unit area.	VII
S_b	Microscopic concentration of substrate in the biofilm.	VII
S_P	Absorptivity. It is defined by: $S_P = S(\theta_0, \theta_1) = -\int_{\theta_0}^{\theta_1} \eta \, d\theta$	I-V-VI
Sh	Sherwood number.	VII
Sh_r	Sherwood number if repulsive electric interactions exist.	VII
S(y)	Sink/source term of suspended particles.	VII

T

t	Time	I-II-V-VI-VII
t_0	Standard time of injection (wells): 1 year.	V
tBOD	Total biological oxygen demand: carbonaceous + nitrogenous BOD.	VI
T	Absolute temperature.	II-VII
T_c	Flow transport capacity.	VII
TD	Factor related to TDS in the Ryznar index determination.	V
TSS	Total concentration of suspended solids (in mg/l).	VI

U

u	Velocity of particles.	VII
u	Displacement of the porous medium.	VII
u_m	Real flow velocity (Darcy's velocity divided by the porosity).	VII
U	Injected volume of water (wells).	V
U*	Bed velocity, if relevant, for an open channel.	VII

V

v_S	Sedimentation velocity of a particle due to the gravitatory force.	II-VII
v_0	Standard reference infiltration velocity (wells): 1 m/h	V
v_1	Velocity of points that stay on the interface fluid-solid during its motion.	VII
V	Filtrated volume.	V-VII
V_A	van der Waals attractive potential between particles.	II
V_c	Colony volume.	VII
V_{max}	Maximum value of the interaction energy profile.	VII
V_R	Electric potential between particles.	II
V_σ	Volume of retained particles.	VI

W

w	Displacement perpendicular to the interface fluid-solid.	VII
w_o	Term of Olsthoorn's equation. $w = (2\,TSS\,\mu\,c_0^2) / (P\,k)$	VI
w_b	Width of a recharge basin.	II
w_1	Adjustable coefficient of Behnke's equation.	VI
w_2	Adjustable coefficient of Behnke's equation.	VI
w_3	Adjustable coefficient of Behnke's equation.	VI

X

x	Spatial coordinate.	II-VII

Y

y	Concentration of suspended particles in water.	VII
y_D	Concentration of suspended particles in number per unit volume.	VII
Y	Yield coefficient of microorganisms.	VII

Z

z	Depth	I-V-VII
z_D	Adimensional parameter in the equation of interaction potential.	II
Z	Adimensional charge of a particle.	II
$Z(\varphi)$	Hydraulic impedance of the clogging layer (cake).	VII

GREEK LETTERS

α_a	Attachment coefficient.	VII
α_{CF}	Specific resistance of the clogging deposit times the concentration of suspended particles (for cake filtration).	V
α_{GR}	Coefficient that relates T_c and τ_w (Govindaraju and Reddi).	VII
α_{oc}	Fraction of collisions leading to agglomeration of particles (orthokinetic coagulation).	VII
α_p	Attachment coefficient.	VII
α_{pc}	Fraction of collisions leading to agglomeration of particles (perikinetic coagulation equation).	VII
α_{p1}	Attachment coefficient for particles 1.	VII
α_{p2}	Id. for particles 2.	VII
α_1	Attachment coefficient for particles of type 1 (size 1).	VII
α_2	Attachment coefficient for particles of type 2 (size 2).	VII
$\alpha(j)$	Coefficients of Philip's power series for cumulative infiltration, I.	VI
$\alpha(y)$	Sticking probability for particle capture.	VII
β_B	Coefficient of clogging properties (Berend's equation).	VI
β_1	Coefficient of Kavanaugh's equation.	VII
β_2	Exponent of Kavanaugh's equation.	VII
β'	Factor in the model of Tare and Venkovachar.	VII
χ	Fraction of retained suspended solids.	VI
δ	Diffuse layer thickness (model of microcolonies for bacteria).	VII
δ_{ij}	Kronecker's delta.	VII
ε	Permitivity in water.	II
$\boldsymbol{\varepsilon}$	Strain tensor.	VII
ε_0	Permitivity in vacuum.	II
ϕ	Porosity of the medium.	V-VII
ϕ_b	Porosity affected by the biofilm (Taylor and Jaffé model).	VII
ϕ_w	Water potential per mass unit.	I
γ_{int}	Interfacial free energy.	II-VII
γ_{VA}	Factor in the model of Vigneswaran and Aim.	VII
η_p	Collision efficiency.	VII
η_{p1}	Collision efficiency of type-1 particles (analogous for subindex 2).	VII
η_r	Removal efficiency of a single collector.	VII
η_{r1}	Removal efficiency of finer particles in the presence of coarser ones.	VII
$\eta(y)$	Mass transfer (or removal) coefficient.	VII
φ	Impact angle at Mackley and Sherman's model.	VII
κ	Inverse of the double layer thickness.	II
κ_{MU}	Mualem's constant.	V-VII
λ_B	Factor that controls the water build-u in Boucher's law.	VI
λ_0	Filtration coefficient (introduced by Iwasaki).	VII

μ	Dynamic viscosity.	II-VII
μ_{max} or μ_m	Maximum rate of utilisation of a nutrient by bacteria.	II-VII
μ_0 or μ_{20}	Dynamic viscosity at the reference temperature (20 ºC)	V
μ_b	Dynamic viscosity at the beginning of a recharge run (wells).	V
μ_e	Dynamic viscosity at the end of a recharge run (wells).	V
θ	Volumetric humidity (water content).	I-V
ρ_c	Cell mass per colony volume.	VII
ρ_l	Liquid density.	II-VII
ρ_S	Density of suspended solids.	II
ρ^b	Biomass density.	VII
σ	Concentration of retained particles.	VII
$\boldsymbol{\sigma}$	Tensor of porous medium stress.	VII
σ_1	Inclusive standard deviation. It gives an idea of the spread of the gradation curve, defined by Masch and Denny.	V
τ	Fluid shear stress.	VII
τ_{cr}	Critical shear stress.	VII
τ_w	Actual shear stress.	VII
τ_0	Bed shear for open channels.	VII
υ	Cinematic viscosity: dynamic viscosity divided by water density.	VII
υ_{bi}	Poisson's ratio.	VII
ϖ	Sand shape factor of a porous medium (Fair-Hatch equation).	V
ξ	Detachability parameter.	VII
ψ	Matrix potential due to suction.	I-V
ψ_φ	Factor of Shekthman's model. It is the ratio of c_0 to (c_{cake}-c_0)	VII
Γ_r	Reach transmissivity in the absence of clogging.	VII
Γ_L	Local reach effective transmissivity.	VII
Γ_R	Reach effective transmissivity.	VII
Ω	Saturation ratio.	II-VII
%	Percentage of sand held between adjacent sieves (Fair-Hatch equation).	V