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Water Treatment Unit Processes

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Table of Symbols

a	Surface Area (particles & grains)
A	Area
A_c	Capture cross section around a single grain
A_h	Total capture cross section in a unit area of bed and depth h
A_p	Horizontally projected area of the grains in a bed per unit volume.
B	Width of a trough
C	Concentration (in units consistent with the other concentrations, normally volume fraction)
C^*	Equilibrium concentration
C_d	Coefficient of discharge
C_o	Initial concentration
δC	Incremental change in concentration
d	Floc or particle diameter, or smaller particle.
D	Grain diameter, or larger particle diameter, Impellor diameter, pipe diameter, Dispersivity.
D_m	Hydraulic diameter
D_p	Pore diameter
e	Bed Voidage
e_A	Air Voidage within the bed
e_i	Unexpanded bed voidage (before or after fluidisation)
e_o	Clean bed voidage
E	Bed expansion, energy/unit volume
f	Friction factor
F_D	Force due to drag
F_L	Filterability number
F_w	Force due to weight
g	Gravitational constant
G	Shear rate
h	Height or depth
H	Head (water column)
ΔH	Headloss (difference), (Suffixes described in the text)
J	No. of tanks in series.
K	Roughness factor
K_B	Boltzmann constant

K_D	Diffusion Coefficient
K_F	Floor Headloss Coefficient
K_L	Liquid phase mass transfer coefficient
l	Length
L	Length
L_T	Total length of wall in a set of filters
N	Number concentration
N_o	Initial number concentration
N_p	Power Number
N_Q	Flow Number
p	pressure
Δp	pressure difference
P	Power
Q	Volumetric flow
Q_L	Flow per unit length of launder
Q_w	Flow per unit width of weir
R	Ratio of decline
R'	Average shear stress on the surface of media
S	Specific surface area
S_c	Surface area of capillaries
t	time
T	Temperature (Absolute), tank diameter
u	Velocity
u_a	Air velocity
u_b	Backwash rate or velocity
u_c	Velocity of flow in a capillary
u_l	Velocity of flow in a lamella
u_{max}	The maximum value of the velocity in a manifold or trough in which the velocity varies along the length
u_s	Settling velocity
u_y	Velocity at distance y from a surface
u_w	Effective water velocity when air is present
V	Volume
w	Width of a lamella
W	Width of a filter or impeller blade
y	Distance from a surface

Re	Reynolds No.
Sc	Schmidt No.
Sh	Sherwood No.

α	Angle of friction
β	Partition coefficient
γ	Surface Tension
λ	Filtration coefficient (defined in Equation 3.7), or hydraulic gradient
λ_o	Filtration coefficient in clean media
μ	Viscosity
π	Ratio of circumference to diameter of a circle
ρ	Density, (subscripts S & L for solid & liquid)
σ	Standard deviation, σ^2 = variance
θ	Mixing time, residence time, blade angle

Glossary of Terms Used in Granular Media Filtration

Adhesion Stress
The shear stress that must be overcome to remove a particle from the surface of a grain, or the stress that will prevent deposition.

Aggressive Water
Water that is undersaturated with calcium carbonate and liable to cause corrosion of iron.

Air Blinding
Clogging of filter media with air, which prevents water passing.

Air Scour
The agitation of a bed of media by means of air distributed from below.

Angular Material
(Angularity)
Material with sharp edges produced by crushing massive material such as anthracite, glass, flint etc.

Anoxic
Devoid of dissolved oxygen

A.O.C.
Assimilable (biodegradable) organic carbon.

Aspect Ratio
(Sphericity)
The ratio of the largest to the smallest dimension of a given grain.

AWWA
American Water Works Association

Backwash
The procedure used to flush deposited solids out of the granular material filter at the end of the filtering run. This normally involves feeding clean water in at the base of the granular bed washing in an upwards direction.

Bed Volume
A volume of water corresponding to the overall bulk volume of the bed of media.

BOD
Biological Oxygen Demand.

Breakthrough
The point where suspended solids penetrate through the filter bed to an unacceptable extent.

Bulk Density
The weight of a unit volume of the material in a stated condition, eg tipped or backwashed.

Bulk Material
Loose, unpacked material.

Capture Cross Section
The projected area around the grains in a bed viewed in the direction of flow through which particles have to pass to be captured. (The term is used for a similar purpose in nuclear physics for neutron capture).

Charge
(n)   a) The granular material content of one filter.
        b) Electrical charge on particles which affects the inability to adhere to surfaces. (Zeta Potential)
(v)   To fill.

Ciliate (algae), flagellate
Algae having hair like tails.

Clarifier
This term is used in several industries and denotes different things. In the water industry it refers to the primary separation stage upstream of filters, usually sedimentation but sometimes applied to flotation.

Clogging Head
The headloss (measured in metres water gauge) caused by the dirt in a filter. It corresponds to the total headloss minus the clean bed headloss at the same flow rate.

Coagulant (Coagulation)
A chemical that will cause a stable colloidal suspension to start to agglomerate and adhere to surfaces.

Coagulant aid
A chemical, eg. ployelctrolyte, added to improve the action of the above.

Conductance
The inverse of resistance.

Crown (Pipe)
The top of the pipe.

Demand
The amount of a disinfectant consumed by reaction with impurities in the water before any residual is left.

Determinand
A parameter such as the concentration of an element or compound in water which is to be measured and recorded.

Destabilisation
Neutralisation of any electrical charge or other influence which prevents particles agglomerating. Equivalent to coagulation but without any subsequent processing.

Dirt
Loose removable material capable of dispersion (eg clay) which is of substantially smaller particle size than the grains of the filtering material.

Dump (Water)
The discharge of residual supernatant water from a filter (usually preceded by draining down) prior to commencing the wash procedure.

EBCT
Empty bed contact time, ie. bed volume/flow (The converse of bed volumes per hour).

Effective Size
A traditional but meaningless and non-preferred term used widely in the USA to describe the 10 percentile size (the sieve size that the 10% by weight of the material would penetrate).

Effective Specific Gravity
The resultant value of the specific gravity when a porous grain is saturated with water (relevant to its settling behaviour).

Epilimnion
The upper aerobic layer of a reservoir or lake.

Expansion
The ratio of the height of a fluidised bed to the settled height.

Filter
A device, which includes a barrier or medium, for separating solids from liquids.

Filter Medium (Media)
The term 'media' is in common use to describe granular filtering materials. It is grammatically plural and strictly speaking should apply to the bulk material to be installed in several filters. (A single filter has a filter medium). To avoid ambiguity the term 'material' used in the AWWA Specification is preferred for legal documents.

Floc
Coagulated and agglomerated particle in suspension.

Floc Blanket
A fluidised or settling bed of floc particles or a mass of such particles in hindered settlement.

Flocculation
The process of causing small particles in suspension to agglomerate into larger clusters which then separate more readily. The term is especially applied to the use of low speed paddles or energy dissipation in tanks, pipes or capillaries for this purpose. The term is sometimes used to describe coagulation.

Friable Material
Material such as anthracite (coal), granular activated carbon, pumice, etc., which tends to crumble if compressed.

Grain
A single unit indivisible particle of media

Gravel
This is a non-specific term signifying coarse material above about 3mm mean size, mainly silica normally but not exclusively, used in a passive role as a support material.

Gravity Filter
An open filter working at atmospheric pressure where the flow is created by a difference in head between the inlet and outlet.

Hazen
Degrees. A measure of natural colour in water (based on mg/l platinum as platinic chloride stabilised with cobalt).

Headloss, Head
Pressure loss expressed as a height or head of water (1m = 104 Pa).

High Lift Pump
Final high pressure pump delivering into supply.

Hydraulic Diameter
The diameter of an equivalent circular pipe which has the same hydraulic characteristics as a specific non-circular pipe, duct or channel. It is calculated as (4 × cross section ÷ wetted perimeter).

Hydraulic Size
The uniform grain size that would produce the same resistance to flow as the material under consideration (at the same voidage). (See Appendix to Chapter 30 for method of calculation). The term is also used by some to describe the size of spherical grain that settles at the same velocity as an arbitrary non-spherical grain.

Hypolimnion
The anaerobic lower layer of a reservoir or lake.

Invert
The bottom of a pipe or channel.

Jar Test
A term employed loosely describing laboratory (bench top) treatment tests.

Laminar Flow
Streamline flow where the pressure loss is linearly related to velocity.

Lateral
A term used in the water and engineering industries to denote a branch or one of a set of branch pipes or ducts connected to a single common manifold.

Launder
A collecting channel or trough usually set at high level to decant water from a tank (i.e. decanting trough).

Low Lift Pump
Usually describes the pump feeding the treatment plant.

Micron
A traditional term for $1\mu m$.

Mld
A unit of flow in common use in the United Kingdom. Megalitres/day=Thousands of cubic metres/day=tcmd (the latter is not used in this book!)

Negative Head
A condition in a filter bed where the hydrostatic pressure is below atmospheric pressure. This can lead to the nucleation of air bubbles.

Nozzle (Filter)
A unit component which is set into a filter floor to retain the media, allow the filtrate to pass through and also to regulate the flow of water and possibly air during backwashing.

NTU
Nephelometric Turbidity Unit, ie based on light scattering using a standard formazin suspension. Numerically the same as Formazine units (FTU) and Jackson units (JTU).

OA, PV, Oxygen Absorbed, Permanganate Value
A measure of the organic content of water capable of reacting with permanganate under standard test conditions.

Packing, Packing Layer
Coarse sand and gravel placed beneath the working layer of sand in a filter. See Support Material.

Plug Flow
Piston type flow where the fluid across the entire cross section moves at the same velocity.

Porosity
In the context of this book, the term is applied to the internal space within the grain (as with activated carbon). Some use the term to describe voidage, see below.
NOTE: Porosity may be 'open' and capable of filling with water or 'closed' and isolated from the surrounding fluid.

Pressure Filter
An enclosed filter which operates at a pressure above atmospheric.

Primary Treatment
Any process applied upstream of filtration (see Clarification).

Quartering
A procedure whereby a pile of material is divided in four by inserting a spade or divider blade across the diameter of the pile and then again at right angles.

Residual
The concentration of active disinfectant left after part of the dose has reacted (see demand).

Reynolds Number
A dimensionless number which characterises the flow regime in a pipe or round a particle.

Riffler
A device consisting of a set of alternating chutes to split a sample of granular material in two without segregation.

Rise Rate
The vertical velocity of fluid in a filter during backwash. Also applied to the flow in settlement tanks. (m^3/m^2-hr=m/hr or mm/s)

Sand
This is a non-specific term. Normally it refers to a silica based granular material smaller than about 3mm mean size of S.G. $2.65 \pm .05$. It is also used non-specifically to describe the material that plays the major role in the filtering action.

Schmutzdecke
German for dirt blanket. Used to describe the surface dirt layer in a slow sand filter.

Sharpness
See Angular Material

Size (Size Range)
Unless otherwise stated filter materials are defined in terms of an upper and lower sieve size based upon BS 410 (1986). The lower size will be the standard sieve mesh which retains 95% by weight or more of the material, and the larger size the standard mesh on which 5% or less is retained, regardless of the size range.

Sparge
Noun. A perforated pipe used to distribute a fluid.
Verb. To discharge a fluid, particularly air, through a sparge pipe.

Specific Gravity
The density of the grain or material divided by the density of water (only applicable to the grains not the material en masse).

Sphericity
See Aspect Ratio.

Strainer
The component of a nozzle which retains the media. A sieve-like component.

Streamline
The path taken by an element of fluid, eg. when passing round an obstacle.

Streamline Flow
Laminar flow, Viscous flow in which the velocity is proportional to the applied pressure.

Submerged Specific Gravity
The difference between the specific gravity of the grain and water.

Support Material/Gravel
A granular material coarser than the working material which is not intended to capture suspended solids and neither is it intended to move or be fluidised in filter washing. Its role is to prevent percolation of the finer material into under-drains or equivalent means of collection of the filtrate, and in some cases to protect the latter from abrasion and reduce the pressure loss of the collection system.

Surface Flush
A procedure whereby unfiltered water is caused to flow across the surface of a filter bed.

Surface Scour
A method of assisting the cleaning of the media involving high velocity water jets impinging on the surface of the bed.

THM
Trihalomethane. A class of chloroform-like chemicals that are produced as a by-product from the reaction of chlorine on natural organic matter.

TOC
Total organic carbon

Transitional Flow
Flow which has characteristics between streamline and turbulent.