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PROVISIONAL

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

APPLIED CHEMISTRY DIVISION

COMMISSION ON WATER QUALITY*

in conjunction with

INTERNATIONAL ASSOCIATION ON WATER POLLUTION RESEARCH AND CONTROL

RECOMMENDED NOTATION FOR USE IN THE DESCRIPTION OF BIOLOGICAL WASTEWATER TREATMENT PROCESSES

Prepared by the Working Group consisting of

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Comments on these recommendations are welcome and should be sent within 8 months from June 1983 to the Secretary of the Division:

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Comments from the viewpoint of languages other than English are especially encouraged. These may have special significance regarding the publication in various countries of translations of the nomenclature eventually approved by IUPAC.

*Membership of the Commission during the period in which these recommendations were prepared is as follows:

Chairman: P. SCHJØDTZ HANSEN (Denmark); *Secretary:* V. B. JENSEN (Denmark); *Titular Members:* J. GOLDSHMID (Israel); E. I. HAMILTON (UK); J. KOLLER (Czechoslovakia); *Associate Members:* W. W. ECKENFELDER, JR. (USA); S. FREYSCHUSS (Sweden); B. GÖRANSSON (Sweden); J. S. LEMLIN (UK); K. TROBISCH (FRG); *National Representatives:* D. J. LANE (Australia); L. J. OTTENDORFER (Austria); P. BENEDEK (Hungary); K. S. VENKATESWARLU (India); Y. KITANO (Japan); C. D. STEVENSON (New Zealand); J. E. SAMDAL (Norway); S. RUBEL (Poland); J. F. J. VAN RENSBURG† (Republic of South Africa).

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PROVISIONAL

RECOMMENDED NOTATION FOR USE IN THE DESCRIPTION OF BIOLOGICAL WASTEWATER TREATMENT PROCESSES

The Executive Committee of the International Association on Water Pollution Research and Control (IAWPRC) and the Commission on Water Quality of the International Union of Pure and Applied Chemistry (IUPAC), appointed a Working Group in 1980 to prepare a proposal for unifying notation used in the description of biological wastewater treatment processes. The task was motivated by the benefits that would result if a common notation was used for the dissemination of results in international publications.

In beginning the task of proposing a common notation it was recognized that unless the Working Group used established practice and common acceptance as a basis for symbol choice, it would be difficult to get authors to adopt the recommendations. Therefore, a number of journals and books within the English, French, German, and American literature were reviewed in order to establish the quantities most often symbolized and to determine the symbols most commonly used to denote the quantities. As a result the proposal consists of a limited number of quantities for which symbols have been chosen and the choice is based generally on common practice.

It is recommended that all contributors to IAWPRC and IUPAC publications conform to the proposed notation for a period of one year. After this period, a review of the original proposal will follow and a revised notation list agreed upon for compulsory use.

INTRODUCTION

The number of quantities for which symbols have been chosen is purposely limited to those commonly used in the description of biological wastewater treatment processes. The symbol chosen for each quantity is based on established practice where possible. The quantities have been tabulated under seven different headings, a symbol specified for each, and the dimension for the quantity stated. Dimensions have been denoted as follows:

length = L
mass = M
time = T
temperature = θ
mole = mol.

The author must state the specific units used for each quantity within the SI system. For example, pressure which has the dimensions $ML^{-1}T^{-2}$, can be expressed in units such as kilopascal, newton per m^2, etc. Definitions have not been stated for the quantities. It is expected that the author will provide a definition for a quantity when requested as per footnote 6.

Symbol	Quantity name or names	Dimension	Footnote
I. *Geometric dimensions, amounts, concentrations*			
H	Height or depth	L	
L	Length	L	
δ	Thickness	L	
d	Diameter	L	
A	Area	L^2	
a	Specific interfacial area	L^{-1} (from L^2L^{-3})	
V	Volume	L^3	

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Symbol	Quantity name or names	* Dimension	Footnote
ϵ	Intergranual porosity or void volume fraction	— (from L^3L^{-3})	
X	Particulate material concentration	M_iL^{-3}	1,2
S	Soluble material concentration	M_iL^{-3}	1,2
C	Total material concentration (particulate plus soluble)	M_iL^{-3}	1,2
	II. *Thermodynamic parameters*		
T	Temperature	θ	
p	Total pressure	$ML^{-1}T^{-2}$	
p_p	Partial pressure	$ML^{-1}T^{-2}$	3
R	Ideal gas constant	$ML^2T^{-2}\theta^{-1}$ mol^{-1}	
P	Power	ML^2T^{-3}	
	III. *Physical properties of matter*		
D	Diffusion coefficient, dispersion coefficient, or material diffusivity	L^2T^{-1}	
η	Dynamic viscosity	$ML^{-1}T^{-1}$	
ν	Kinematic viscosity	L^2T^{-1}	
σ	Surface tension	MT^{-2}	
ρ	Density	ML^{-3}	
	IV. *Time, velocities, and flow rates*		
t	Chronological or running time	T	
θ	Space time (volume of reaction phase divided by volumetric flow rate of phase entering the reactor)	T	4
$\bar{t}$	Mean hydraulic residence time	T	5
θ_X	Mean solids retention time	T	3,6
u	Velocity	LT^{-1}	
v	Superficial velocity	LT^{-1} (from $L^3L^{-2}T^{-1}$)	7
g	Gravitational acceleration	LT^{-2}	
G	Velocity gradient	T^{-1}	
Q	Liquid volumetric flow rate	L^3T^{-1}	
Q_G	Gas volumetric flow rate	L^3T^{-1}	3,4
D	Dilution rate	T^{-1} (from $L^3L^{-3}T^{-1}$)	6,8
R	Recycle ratio	—	8
	V. *Parameters for mass flow rate, mass loading rate, and heat and mass transfer*		
F	Mass flow rate	M_iT^{-1}	1
N_X	Solids loading rate per unit area or solids flux	$M_xL^{-2}T^{-1}$	1,3,6
B_A	Mass flow rate per unit area	$M_iL^{-2}T^{-1}$	1,3,6
B_V	Mass flow rate per unit volume or volumetric loading rate, Raumbelastung, etc.	$M_iL^{-3}T^{-1}$	1,3,6
B_X	Mass loading rate per unit mass, Schlammbelastung, etc.	$M_iM_x^{-1}T^{-1}$	1,3,6
k	Mass transfer coefficient	LT^{-1}	9
K	Overall mass transfer coefficient	LT^{-1}	9
α	Oxygen transfer ratio	—	6
β	Oxygen saturation ratio	—	6
	VI. *Reaction rates and stoichiometry*		
r_A	Reaction rate per unit area	$M_iL^{-2}T^{-1}$	1,3,10
r_v	Reaction rate per unit volume	$M_iL^{-3}T^{-1}$	1,3,10
r_X	Reaction rate per unit mass	$M_iM_x^{-1}T^{-1}$	1,3,10
μ	Specific biomass growth rate	T^{-1} (from $M_xM_x^{-1}T^{-1}$)	1
μ_{max}	Maximum specific biomass growth rate	T^{-1} (from $M_xM_x^{-1}T^{-1}$)	1,3

* Subscripts to dimension, though unusual, may be used in water research.

Symbol	Quantity name or names	Dimension	Footnote
μ_{obs}	Observed or net specific biomass growth rate	T^{-1} (from $M_x M_x^{-1} T^{-1}$)	1,3
b	Specific biomass loss rate	T^{-1} (from $M_x M_x^{-1} T^{-1}$)	1,11
Y	Biomass yield coefficient	$M_x M_i^{-1}$	1
Y_{obs}	Observed or net biomass yield coefficient	$M_x M_i^{-1}$	1,3
v	Stoichiometric coefficient	$M_i M_j^{-1}$	1
VII. *Parameters for reaction rates and conversions*			
n	Reaction order	—	
k	Reaction rate coefficient or constant	Dimension depends on kinetic model	8,10,12
K_S	Saturation constant, half-velocity coefficient, or Michaelis–Menten constant	$M_i L^{-3}$	1,3
K_I	Inhibition constant	Dimension depends on kinetic model	3
E	Temperature coefficient or activation energy	ML^2T^{-2} mol^{-1}	13
A_0	Pre-exponental factor or frequency factor	Dimension depends on kinetic model	14
κ	Temperature coefficient	θ^{-1}	15
E	Efficiency	—	8
f	Fraction (such as fraction of active organisms, etc.)	—	
η	Effectiveness factor (correction of reaction rate for diffusion)	—	8

FOOTNOTES

1. The subscripts i and j refer to the compounds or materials as defined by the author. Subscript X specifically refers to the nature of the solids as defined by the author (e.g. suspended solids, volatile suspended solids). See notes under "subscripts" for further explanation.

2. Particulate material concentration plus soluble material concentration equals the total material concentration ($C = X + S$). If material is known to be soluble (e.g. oxygen, nitrate, nitrite), the authors should use the symbol S.

3. The subscript used here is an inherent part of the symbol. For further explanation see notes under "subscripts", p. 1504.

4. For gases, temperature and pressure conditions must be stated.

5. The value of $\bar{t}$ must be calculated from residence time distribution function.

6. The authors must supply a definition preferably by equation.

7. This quantity and the representative symbol applies to hydraulic loading rate to biological reactors (trickling filters, rotating biological contactors, fluidized beds, etc.), overflow rates from clarifiers, etc. When specified for biological reactors it represents empty bed velocity.

8. Use this symbol provided no confusion is possible with same symbol being used for another quantity. If confusion is possible add subscript to symbol for representation of one of the quantities. Such a subscript becomes an inherent part of symbol. An example is the use of D for dilution rate and D_S for dispersion coefficient.

9. Appropriate subscripts must be used with k and K (e.g. k_G and k_L). The subscripts are an inherent part of the symbol.

10. The use of $\frac{dS}{dt}$, $\frac{dC}{dt}$, $\frac{dX}{dt}$ as a general definition of reaction rate (r) is valid for batch reactors only. The relationship is derived from a material balance around the reactor.

11. The symbol b may refer to mechanisms such as decay, endogenous metabolism, death, predation, etc. which may be distinguished by subscripts as defined by the author. Such subscripts become an inherent part of the symbol.

12. The type of reaction or order of reaction may be specified by a subscript if necessary.

13. Temperature coefficient as used in the equation:

$$k = A_0 e^{-E/RT}.$$

14. Pre-exponential factor as used in the equation:

$$k = A_0 e^{-E/RT}.$$

Dimension of A_0 dependent on dimension of reaction rate coefficient (k).

15. Temperature coefficient as used in the equation:

$$\frac{k_{T1}}{k_{T2}} = e^{\kappa(T1 - T2)}.$$

This equation is preferred over:

$$k_{T1} = k_{T2}\theta^{(T1 - T2)}$$

(θ being a temperature coefficient) which is dimensionally not homogeneous.

SUBSCRIPTS

The information contained in the subscripts is organized in the following manner and *order or sequence:*

1. Subscripts as an inherent part of the symbol as specified in symbol list (e.g. θ_X and μ_{max}). Such subscripts must always be used.

2. Alphabetical subscripts representing the type of compound or material. Such subscripts are only necessary if the author is symbolizing more than one type of compound or material.

The abbreviations used as subscripts should be defined by the author and may be based on the language in which the paper is written. Examples:

S_{BOD} = soluble BOD_5 concentration
S_{BSB} = in Lösung BSB_5 konzentration
$B_{V,TBOD}$ = total BOD_5 volumetric loading rate
$B_{V,TBSB}$ = Raumbelastung mit totalem BSB.

3. Numerical subscripts identifying the location to which the symbol applies. Such subscripts are only necessary if symbols are being used to represent compounds or materials at different locations in a flowsheet.

The location to which the symbol applies should be specified by positive non-zero integer numbers. The numbered locations must be defined by the author by means of a flow diagram or a list.

4. Subscripts specifying miscellaneous information such as temperature, statistical properties, etc. Examples;

k_{T1} = reaction rate at temperature $T1$
Y_M = mean biomass yield coefficient.

Note: The subscripts belonging to different groups (1–4) should be separated by a comma.

SPECIAL NOTATION

1. For dimensionless variables use the overscript ($\sim$). Example: $\tilde{\theta}$ = dimensionless space time.
2. Time should be indicated by use of brackets following the symbol and on the same line. Examples:

$C(t)$ = total material concentration at time t
$C(5)$ = total material concentration at time equal to 5 min (or h, etc.).

3. No superscripts (asterisks, primes, etc.) are allowed.

ILLUSTRATING THE USE OF STANDARD NOTATION

To illustrate the use of standard notation for biological wastewater treatment, two examples are presented of equations referenced from the literature and then translated into a form reflecting the use of the proposed standard symbols. In addition, a process flow sheet is presented to illustrate the use of standard symbols and subscripts.

TRANSLATION OF REFERENCED EQUATIONS

Referenced form	Acceptable translated form
$\mu = \frac{kYS}{K_s + S} - b$	$\mu_{obs} = \frac{r_{X,max} YS}{K_S + S} - b$

where:

μ = net specific biomass growth rate	$= \mu_{obs}$
Y = biomass yield coefficient	$= Y$
k = maximum specific rate of substrate utilization	$= r_{X,max}$
S = concentration of substrate	$= S$
b = microorganism decay rate	$= b$
K_s = half-velocity coefficient	$= K_S$

Lawrence A. W. & McCarty P. L. (1970) Unified basis for biological treatment design and operation. *J. sanit. Engng Div., Am. Soc. civ. Engrs* **96(SA 3)**, 757–778.

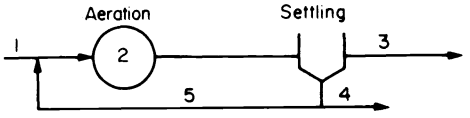
$$S = \frac{S_0 \cdot}{1 + k_a X_v t} \qquad S_2 = \frac{S_1}{1 + kX_V 0}$$

where:

S = effluent substrate concentration	$= S_2$
S_0 = influent substrate concentration	$= S_1$
k_a = substrate removal rate	$= k$
X_v = mixed liquor volatile suspended solids	$= X_V$
t = retention time in aeration basin	$= 0$

Eckenfelder W. W. Jr (1970) *Water Quality Engineering For Practicing Engineers*, 162 pp. Barnes & Noble, New York.

Process flow sheet



where.

Q_1	= influent flow rate
$C_{BOD,1}$	= influent total BOD_5 concentration
V_2	= aeration tank liquid volume
$X_{VSS,2}$	= aeration tank volatile suspended solids concentration
$S_{BOD,3}$	= effluent soluble BOD_5 concentration
Q_4	= waste sludge flow rate
Q_5	= return sludge flow rate.