Chap 5 Wastewater treatment & Disposal

Table 5-1 Important waste contaminants

contaminant	Environmental significance
superded solid	· sludge deposit · anerobic condition
Biodegradable organics	· biological degradation · DO감소
pathogens nutrients refractory organics (일반적으로 non-biogradoble organics heavy metal Dissolved inorganic solids	entrophication taste odor를 가질 수도 있다 toxic, carcinogenic

* pathogen

i) chlorination

$Cl_2 + H_2O \rightarrow HOCl + H^+$

ii) hypochlorination

$Ca(OCl)_2 \rightarrow Ca^{++} + 2OCl^-$

* Nitrogen

i) suspended-growth nitrification & denitrification

ii) Fixed-film

iii) Ammonia stripping

iv) Ion exchange

v) breakpoint chlorination

$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$ (monochloroamine)

$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$ (dichloroamine)

* Phosphorus

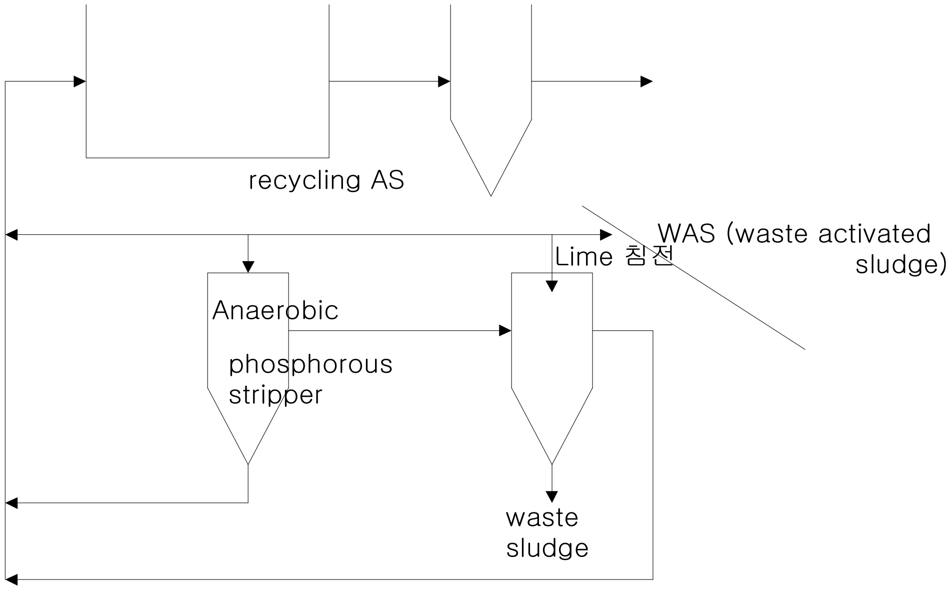
i) metal-salt addition

ii) Lime

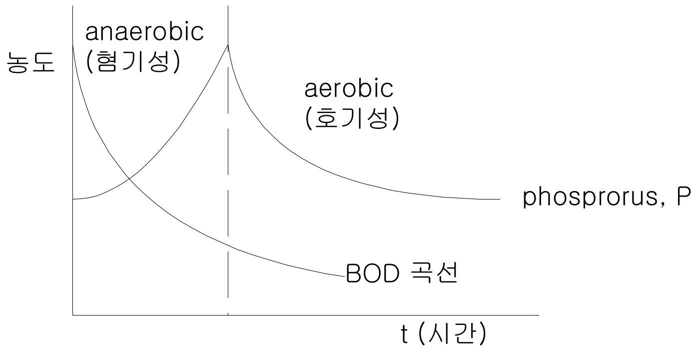
iii) biological-chemical phosphorus removal

P제거

① Biological-chemical phosphorus removal(phostrip process)



② Biological treatment



③ chemical treatment

ⅰ) $10Ca^{+2} + 6PO_4^{-3} + 2OH^{-} \rightarrow Ca_{10}(PO_4)_6(OH)_2$

ⅱ) $Al^{+3} + H_nPO_4^{3-n} \leftrightarrow AlPO_4 + nH^{+}$

ⅲ) $Fe^{+3} + H_nPO_4^{3-n} \leftrightarrow FePO_4 + nH^{+}$

plug-flow reactions

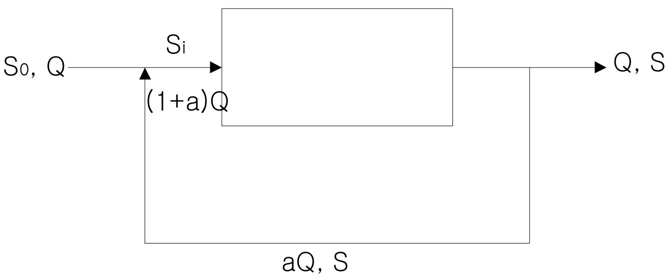
$$\chi = \frac{\Theta_c Y(S_0 - S)}{\Theta(1 + k_d \Theta_c)}$$

$$r_s = -\frac{k_0}{Y}\frac{S\chi}{k_s + S}$$

χ : average biomass 농도 “Lawrence & Macarity [5.29]″

$$\frac{1}{\Theta_c} = \frac{k_0(S_0 - S)}{(S_0 - S) + (1 - \alpha)(k_s \ln S_i / S)} - k_d$$

α=recycle ratio (=Θ_r/Θ)



material balance after mixing with recycled sludge

$QS_0 + \alpha QS = (1+\alpha)QS_i$

$$S_i = \frac{S_0 + \alpha S}{1 + \alpha}$$

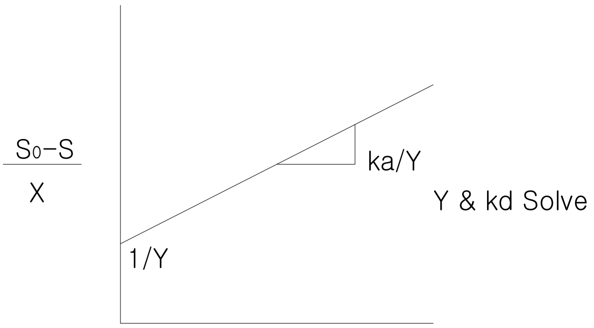
↑순환 sludge와 mixing 후 기질 농도

* $\Theta=\Theta_c$ (no recycle of activated sludge)

<problem>

$X=\frac{Y(S_0-S)}{1+k_d\Theta}$ 에서 kinetic parameter Y, k_d,μ_m, K_s을 experimental 구하시오.

i) $\frac{S_0-S}{X}=\frac{k_d}{Y}\Theta+\frac{1}{Y}$



ii) $\frac{dX}{dt}\cdot V=QX_0-QX+V(\frac{\mu_m\times S}{K_s+S}-k_dX)$

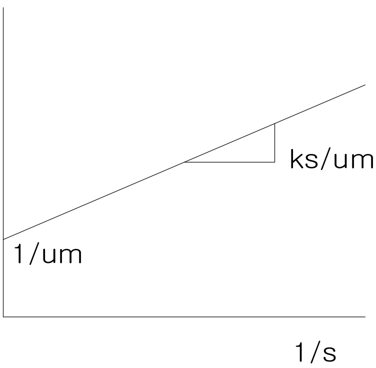
㉠ assumption X_0 = 0

㉡ steady-state

$$\frac{Q}{V}=\frac{1}{\Theta}=\frac{\mu_m S}{k_s+S}-k_d$$

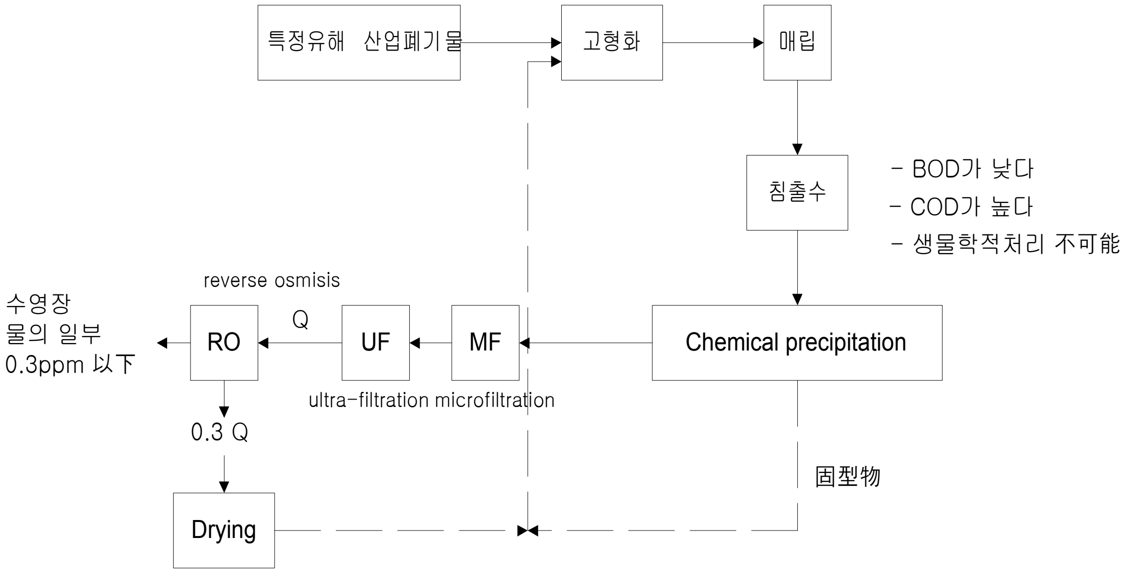
$$\frac{1+k_d\Theta}{\Theta}=\mu_m\frac{S}{K_s+S}$$

$$\frac{\Theta}{1+k_d\Theta}=\frac{K_s}{\mu_m}\cdot\frac{1}{S}+\frac{1}{\mu_m}$$



환경관리공단

'화성사업소'-연색 폐수 sludge



SVI (sudge volume index)…30min 정치후의 sludge 침강상태

$$SVI = \frac{SV(\%) \times 10^4}{MLSS} \qquad \left(SV = \frac{V_s}{V}\right) \quad [\text{㎖}/g]$$

MLSS → mixed liquor suspended solid

V_s : 30분후 침강된 sludge volume [㎖]

V : sample volume [㎖]

MLSS [㎎/ℓ]

ⅰ) SVI는 MLSS의 charactristics와 concentration에 따라 변한다

ⅱ) 다른 reporter volume과 비교 불가능

ex) 전혀 침강되지 않은 MLSS 1000㎎/ℓ → SVI = 1000

≠ 전혀 침강되지 않은 MLSS 10,000㎎/ℓ → SVI = 100

ⅲ) Unit

$$SVI = \frac{SV(-)}{MLSS}\left[\frac{1000\text{㎎}}{g}\right]\left[\frac{1000\text{㎖}}{\triangle}\right]$$

$$= [\text{㎖}/g]$$

* 일본 Kasumigaura 하수처리장
특징
i) N, P 고도처리
ii) sewage treated water가 식수원인 호수에 유입

operation conditions of kasumigaura kohoku sewage treatment plant

Sep. 1987

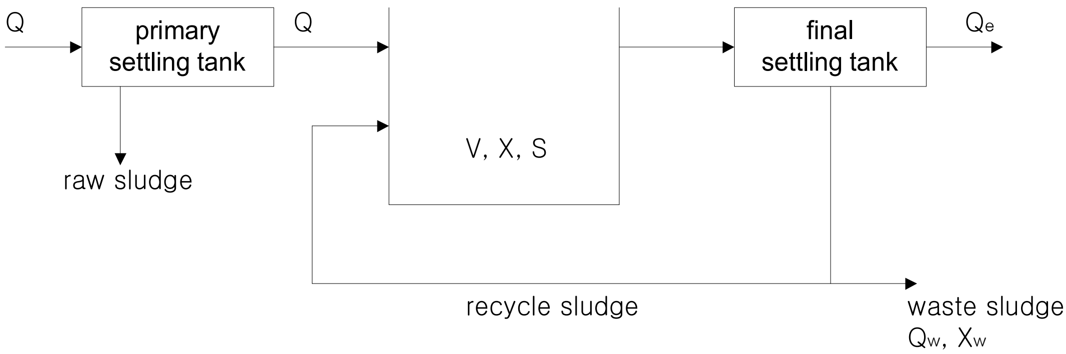
	reaction tank No. 1	reaction tank No. 2	reaction tank No. 3	Unit
Inf. flow	10380	10380	10380	㎥/day・tank
Temp	23.7	23.7	23.7	℃
KRT	9.2	9.2	9.2	h
MLSS	2470	2085	2480	㎎/ℓ
BOD-MLSS loading	0.054	0.064	0.054	㎏/㎏・day
SRT	19.5	13.7	22.8	day
	2.7	2.5	2.5	㎎/ℓ
SVI	118	208	142	㎖/g
VSS/SS	67.6	73.9	69.8	
Al	2.0	-	2.0	㎎/ℓ

W a t e r Q u a l i t y (Sep 1987)

unit : ㎎/ℓ (except pH)

	primary eff.	secondary eff. No. 1	secondary eff. No. 2	secondary eff. No. 3	final eff.
pH	7.2	6.9	7.1	7.0	7.0
BOD	52	< 1	1.1	2.9	< 1
COD_{Mn}	41	7.3	8.1	7.9	7.3
SS	32	1.0	1.2	2.7	< 1
Alkalinity	176	73	98	91	88
T-N	22.4	-	-	-	9.2
NH_3-N	14.9	0.6	0.4	0.5	0.6
NO_3^--N		11.6	6.8	6.1	8.2
T-P	2.72	-	-	-	0.10
PO_4^{3-}-P	1.35	0.40	0.03	0.03	0.15

＊ sewage treatment plant



V ： volume [㎥]

X ： biomass concentration [kg/㎥]

S ： soluble food concentration [kg/㎥]

ⅰ) HRT (hydraulic retention time) $= \frac{V}{Q} [hr]$

ⅱ) SRT (sludge retention time)

= MCRT (mean cell residence time)

= $\frac{VX}{Q_w X_w} [hr]$

ⅲ) MLSS (mixed liquor suspended solid) ≒ X

ⅳ) BOD loading rate = $\frac{QS_{BOD}}{V}$ [kg/㎥ · day]

ⅴ) BOD-MLSS loading rate $\frac{QS_{BOD}}{V \cdot X}$ [kg · BOD/kg · MLSS · day]

only assation tank 0.3 - 0.5 kg · BOD/kg · MLSS · day

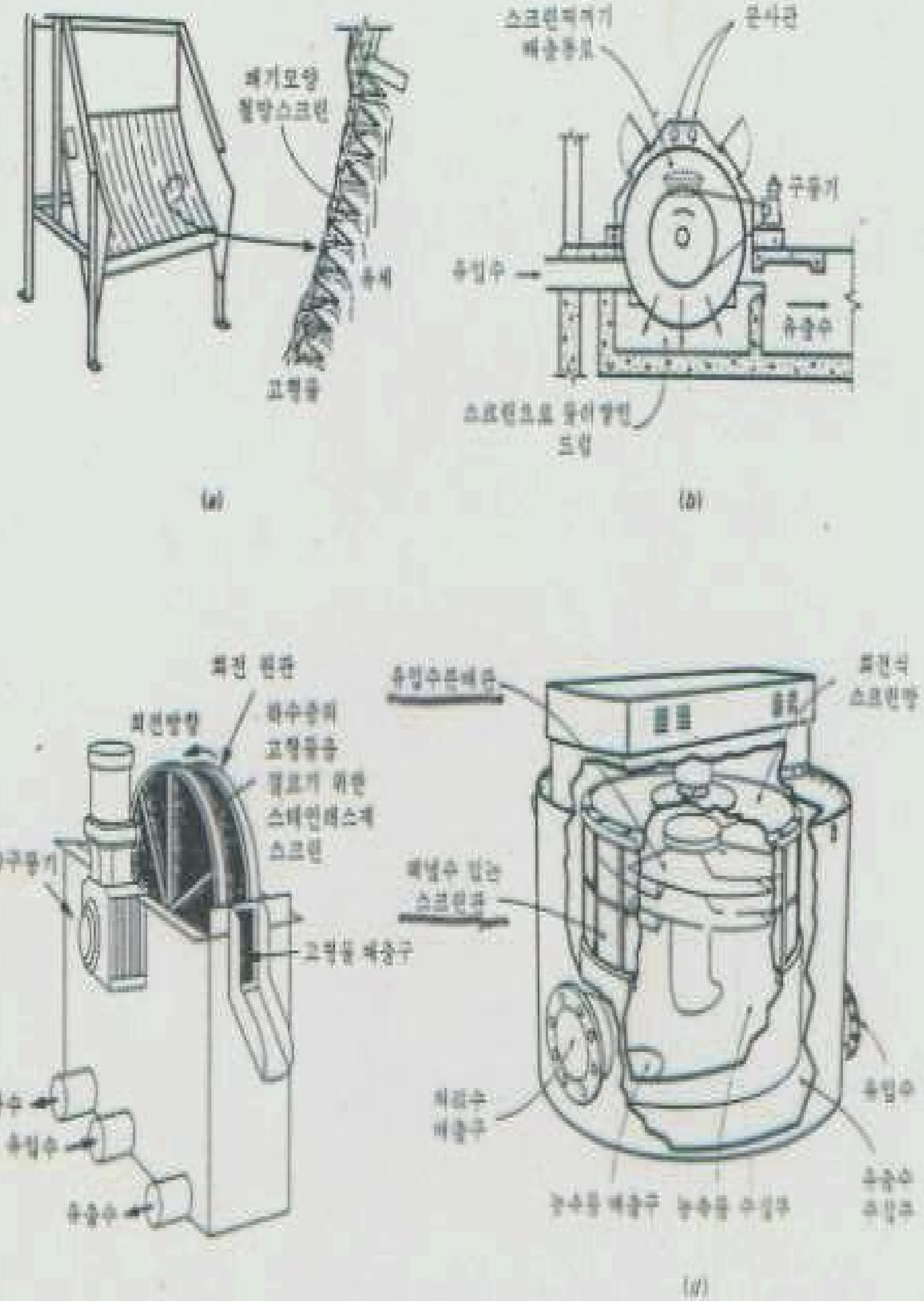
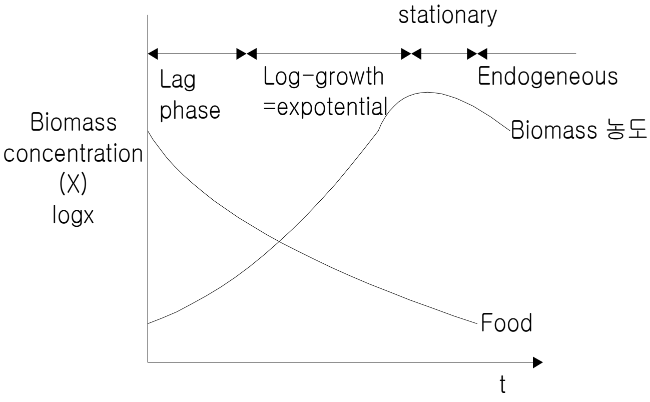


그림 8-3. 하수처리에 사용되는 대표적인 스크린 장치 : (a) 경사식 고정스크린(뚜껑을 열고 본 상태), (b) 회전식 드럼스크린, (c) 회전 원판식스크린 (d) 원심력 스크린

Growth kinetics (Growth & Food Utilization)



0) aerobic condition

ⅰ) batch reaction

ⅱ) 충분한 Food

ⅲ) 균접종

<Biomass growth and food utilization>

ⅰ) log-growth phase에서의 균체의 growth rate

$$\frac{dX}{dt} = \mu X \text{ ------ ①}$$

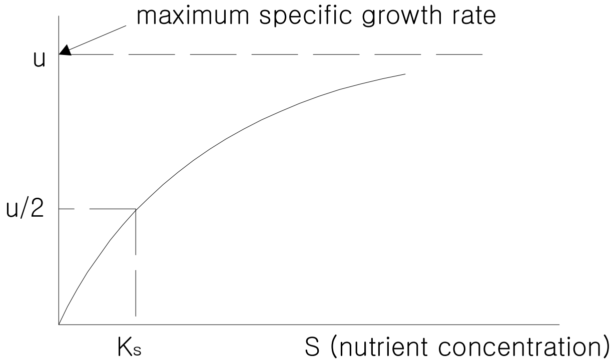
X = concentration of biomass $[M/L^3]$

μ = specific growth rate $[\Theta^{-1}]$

= growth rate constant

ⅱ) Monad equation

$$\mu = \bar{\mu}\frac{S}{K_s + S} \text{ ------ ②}$$



K_s : μ=μ/2일때의 기질 농도

㉠ K_s << S μ= μ zero order

~ μ는 Sp 무관

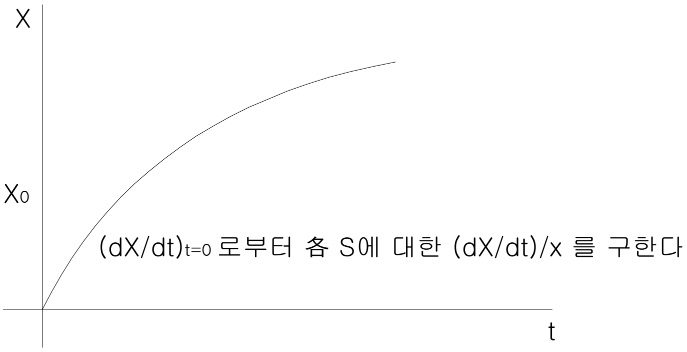
㉡ K_s >> S μ=μ*S/K_s (s에 대하여 1st order)

* Michaelis-Mentan eq

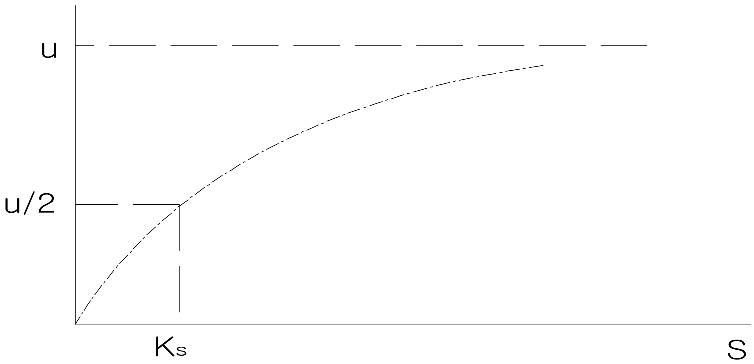
$$E + S \rightleftharpoons ES \rightarrow E + P \qquad \frac{dp}{dt} = v = v_{max}\frac{S}{K_s + S}$$

ⅱ-①) S 變化에 따른 μ 작성 방법

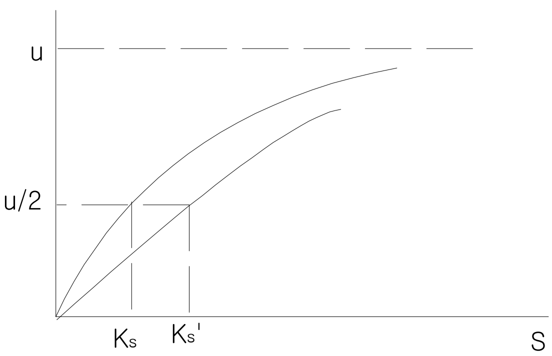
㉠ S const, 초기 균체수 X_0



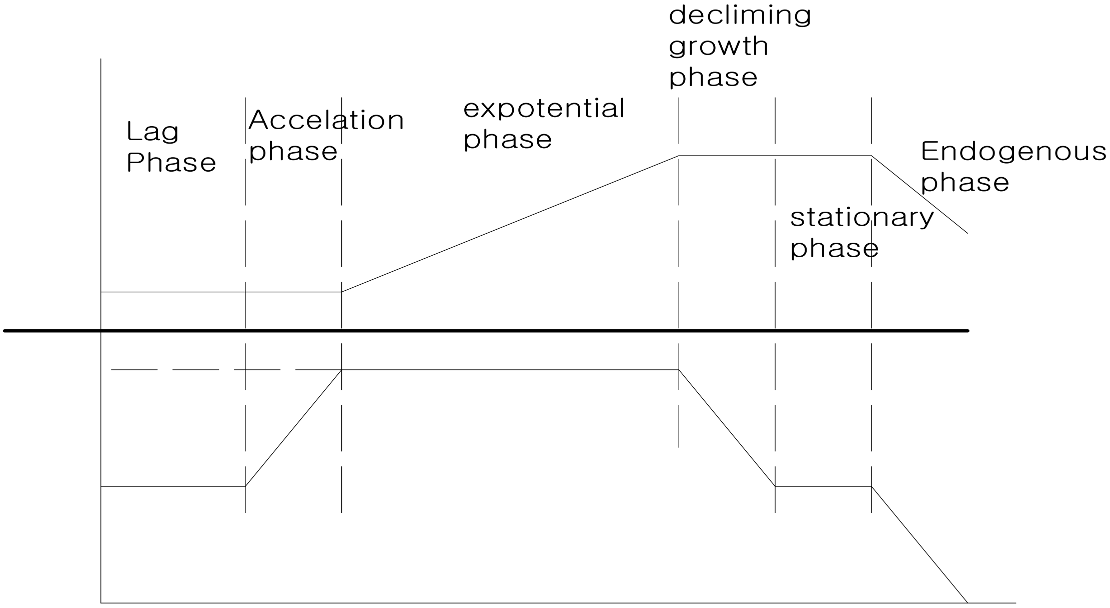
㉡ S 變化에 따른 $\frac{(\frac{dx}{dt})}{X}$를 구한다.



ⅱ-②) K_s의 의미…K_s↑ 할수록 증식속도가 느리다.



* batch system with excess nutrient



iii) endogeneous decay phase에서의 균체 생성속도

$$\frac{dx}{dt} = -k_a X \text{ ------ ③}$$

(k_a →) endogeneous decay rate constant $[\Theta^{-1}]$

from ①③

net charge of biomass concentration

$$\rightarrow \frac{dX}{dt} = \mu X - k_a X = \frac{\mu S}{K_s + S} X - k_a X$$

growth decay

* Nutrient Utilization

i) $\frac{dx}{dt}$(biomass production rate)와 $\frac{dS}{dt}$(food utilization rate)와의 관계

→ food는 anabolism (동화작용) … 새로운 cell 생성
catabolism (이화작용) … enegy 생성

$$\rightarrow \left|\frac{dS}{dt}\right| > \left|\frac{dx}{dt}\right| \text{(부호는반대)}$$

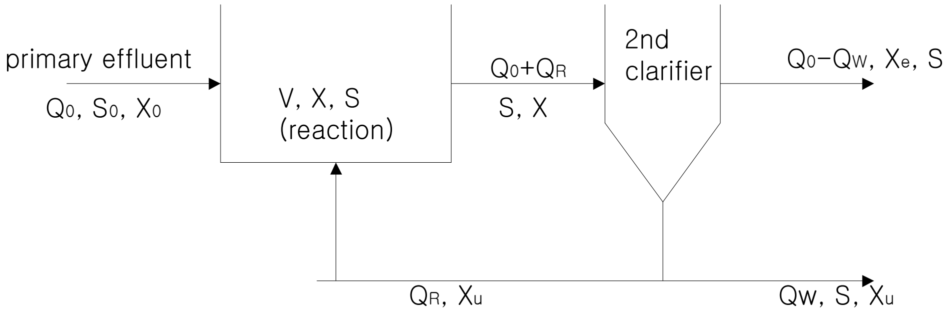
ii) $\frac{dS}{dt} = -\frac{1}{Y}\frac{dx}{dt}$

(Y →) mass fraction of food converted to biomass (0 < Y < 1)

$$-r_s = \frac{ds}{dt} = -\frac{1}{r}\mu\frac{S}{K_s + S}X$$

5-10 Suspended culture system

*Activated sludge process (CSTR)



i) biomass의 mass balance at steady state (system = activated sludge 정체)

input + gen = output + consumption + Accumulation

$$Q_0X_0 + V(\frac{k_0SX}{K_s+S} - k_dX) = (Q_0 - Q_n)X_e + Q_wX_w \text{ ------ ①}$$

ii) food (organic substrate) mass balance at S-S

input + gen = output + consumption + Accumulation

$$Q_0S_0 = \{(Q_0 - Q_w)S + Q_wS\} + V(+r_s)$$

$$Q_0S_0 = \{(Q_0 - Q_w)S + Q_wS\} + V \cdot \frac{k_0SX}{Y(K_s+S)} \text{ ------ ②}$$

iii) Assumption

㉠ influent, effluent 中의 biomass 농도 무시 (X_0 = X_e = 0)

㉡ reaction은 반응기 안에서만 일어나고 complete mixing

from ① X_0 = X_e = 0이므로 $\frac{k_0S}{K_sS} = \frac{Q_wX_u}{VX} + k_a$ ------ ①′

from ② $\frac{k_0S}{K_s+S} = \frac{Q_0Y}{VX}(S_0 - S)$ ------ ②′

from ①′②′

$$\frac{Q_w X_u}{VX} = \frac{Q_0 Y}{VX}(S_0 - S) - k_d \text{ ------ ③}$$

$\frac{V}{\Theta_0} = \Theta$ ~hydraulic detention time for the reaction (based on influent flow)

$\frac{VX(\text{반응기内의균체량})}{Q_w X_u(\text{wastesludge량})} = \Theta_c$ ~mean cell residence time (일반적으로 $\Theta_c > \Theta$)

③에 代入하면 $\frac{1}{\Theta_c} = \frac{Y(S_0 - S)}{\Theta X} - k_d$

반응기 內의 X(MLSS : mixed-liquor suspended solid)

$$X = \frac{\Theta_c Y(S_0 - S)}{\Theta(1 + k_d \Theta_c)}$$

Θ↑ 하면 MLSS 농도 ↓한다 = Θ↓하면 MLSS↑한다

Θ↑ 하면 MLSS 농도 ↑한다

X↓하면 $S_0 \approx S$ (no treatment)

* Activated sludge process의 설계변수

i) volumetric loading rate (=BOD Loading rate)

$$V_L = \frac{QS_0}{V} = \frac{\text{단위시간당 } influent\text{의 } BOD \ mass}{\text{반응기부피}} \quad [\text{kg}BOD/\text{m}^3 \cdot day]$$

ii) F/M ratio (food/microorganism 比)

$$F/M = \frac{Q(S_0 - S)}{VX} = \frac{\text{단위시간당 제거된 } BOD \ mass}{\text{반응기 內 } biomass \text{ 질량}} \quad [\text{kg}BOD/\text{kg} \ biomass, day]$$

iii) mean cell residence time (Θ_c)

$$\Theta_c = \frac{VX}{Q_w X_w} \quad [day^{-1}]$$