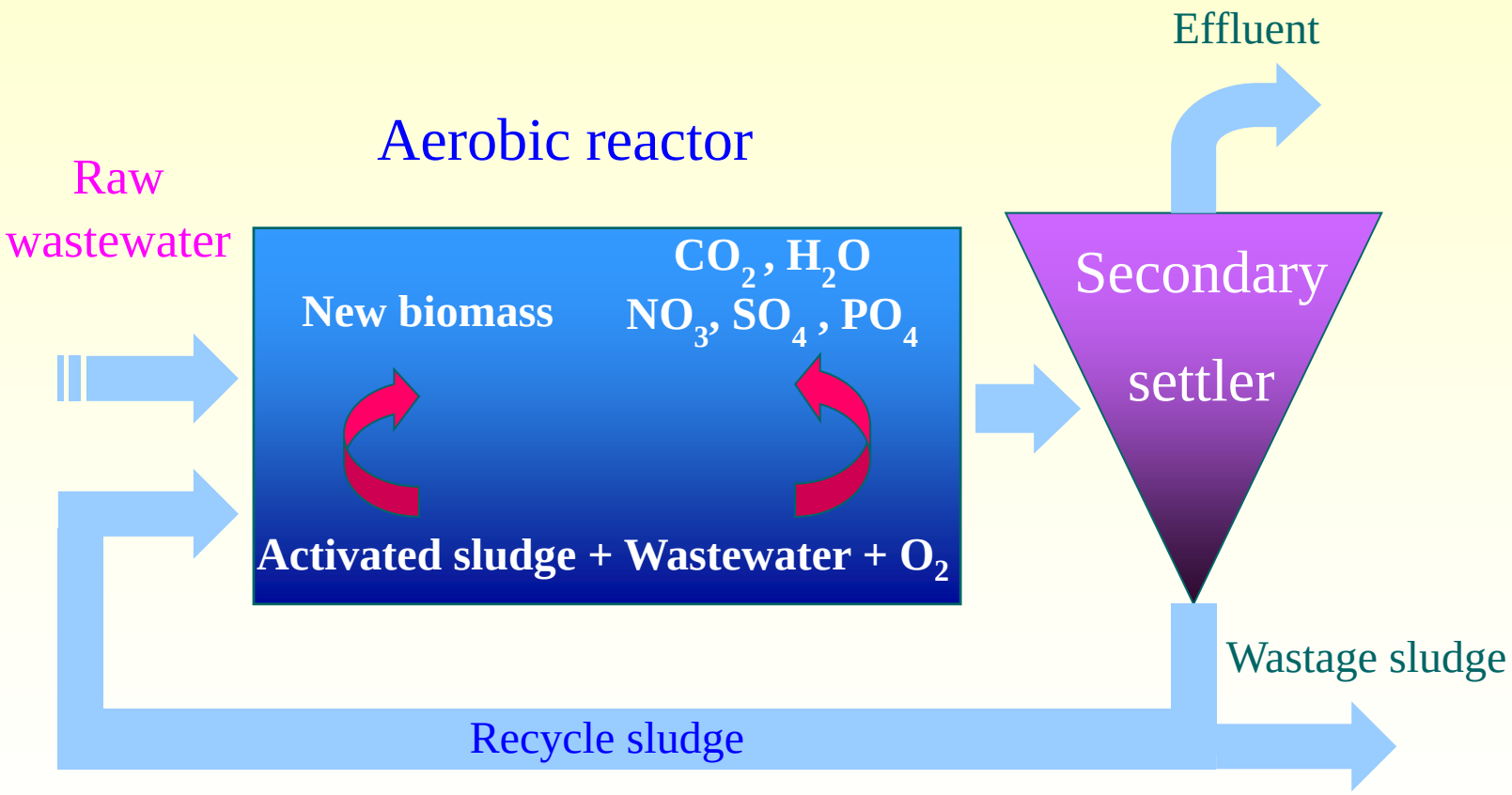
Dynamic modeling of activated sludge process

POSTECH
Department of Chemical Engineering
PSE Lab.

1. Modeling of Activated Sludge Process

- ✓ IAWQ activated sludge model No.1
- ✓ Secondary settler modeling
- ✓ Integrated modeling
- ✓ Benchmark study model (predenitrification process)

1.1 Outline of Activated Sludge Process



1.2 Modeling

- Bioreactor modeling
  - IAWQ (International Association on Water Quality)
    Activated sludge model No.1 (1987, Henze *et al*.)
- Secondary settler modeling
  - Solid flux theory (1986, Vitasovic)
    and double exponential velocity theory (1991, Takâcs)
- Integrated modeling (predenitrification process)
  - COST682 Working group : Benchmark study model

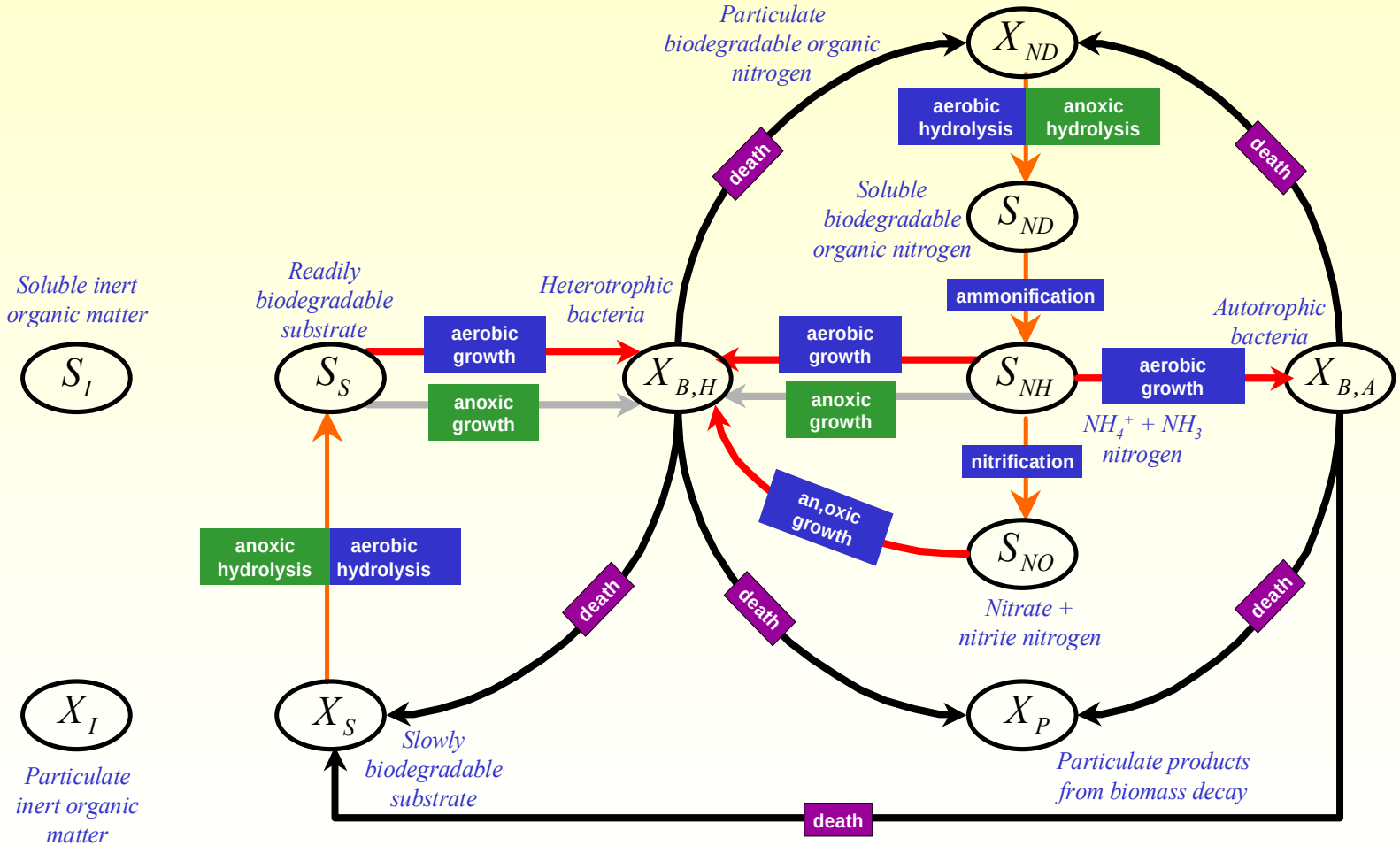
1.3 IAWQ ASM No.1 (1)

- 13 components
  - Microorganisms (X_{BH}, X_{BA})
  - Carbonaceous compounds (S_I, S_S, X_I, X_S, X_P)
  - Nitrogenous compounds (S_{NO}, S_{NH}, S_{ND}, X_{ND})
  - Auxiliary states (S_O, S_{ALK})

- 8 reactions
  - Oxidation of organic carbon, Nitrification, Denitrification, etc.

- Basic structure (mass balance) $$\frac{dC_i}{dt} = \frac{Q_{in}C_{i,in} - Q_{out}C_i}{V} + r_i$$

1.4 IAWQ ASM No.1 (2)



1.5 IAWQ ASM No.1 (3)

- Important equations

$$\frac{dX_{B,H}}{dt}=\left[\hat{\mu}_H\left(\frac{S_S}{K_S+S_S}\right)\left\{\left(\frac{S_O}{K_{O,H}+S_O}\right)+\eta_g\left(\frac{K_{O,H}}{K_{O,H}+S_O}\right)\left(\frac{S_{NO}}{K_{NO}+S_{NO}}\right)\right\}-b_H\right]X_{B,H}+\frac{Q_{in}}{V}X_{B,H,in}+\frac{Q_r}{V}X_{B,H,r}-\frac{Q}{V}X_{B,H}$$

$$\begin{aligned}\frac{dS_S}{dt}=&\left[-\frac{\hat{\mu}_H}{Y_H}\left(\frac{S_S}{K_S+S_S}\right)\left\{\left(\frac{S_O}{K_{O,H}+S_O}\right)+\eta_g\left(\frac{K_{O,H}}{K_{O,H}+S_O}\right)\left(\frac{S_{NO}}{K_{NO}+S_{NO}}\right)\right\}\right.\\&\left.+k_h\frac{X_S/X_{B,H}}{K_X+(X_S/X_{B,H})}\left\{\left(\frac{S_O}{K_{O,H}+S_O}\right)+\eta_h\left(\frac{K_{O,H}}{K_{O,H}+S_O}\right)\left(\frac{S_{NO}}{K_{NO}+S_{NO}}\right)\right\}\right]X_{B,H}\\&+\frac{Q_{in}}{V}S_{S,in}+\frac{Q_r}{V}S_{S.r}-\frac{Q}{V}S_S\end{aligned}$$

$$\frac{dS_O}{dt}=-\hat{\mu}_H\left(\frac{1-Y_H}{Y_H}\right)\left(\frac{S_S}{K_S+S_S}\right)\left(\frac{S_O}{K_{O,H}+S_O}\right)X_{B,H}-\hat{\mu}_A\left(\frac{4.57-Y_A}{Y_A}\right)\left(\frac{S_{NH}}{K_{NH}+S_{NH}}\right)\left(\frac{S_O}{K_{O,A}+S_O}\right)X_{B,A}+K_La(S_{O,sat}-S_O)$$

1.6 Modeling of Secondary Settler

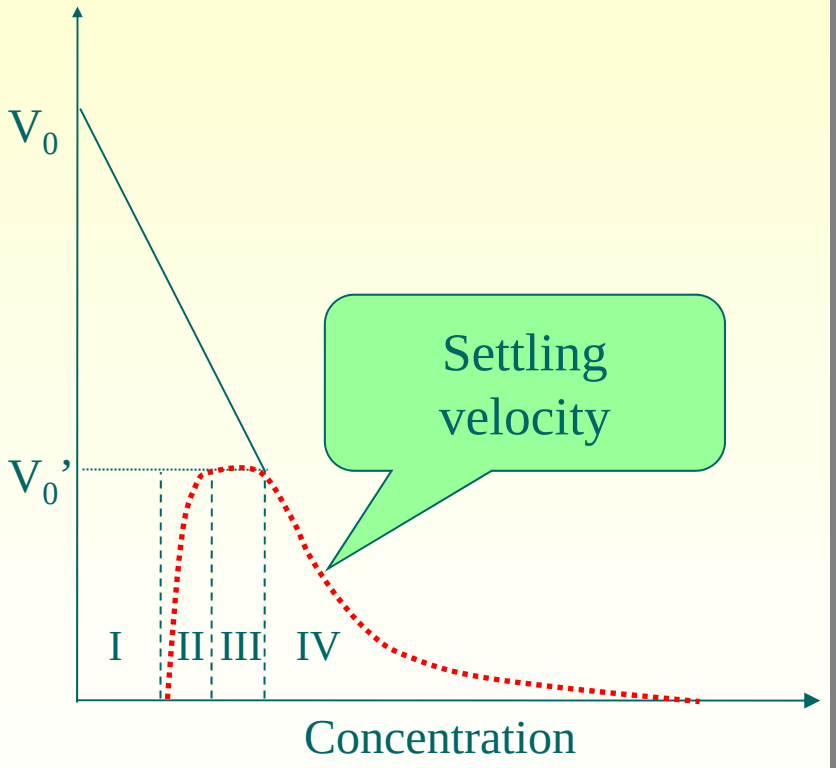
- Solid flux theory

$$J = J_s + J_{dn}, \quad J_j = X_j v_{sj} + X_j v_u$$

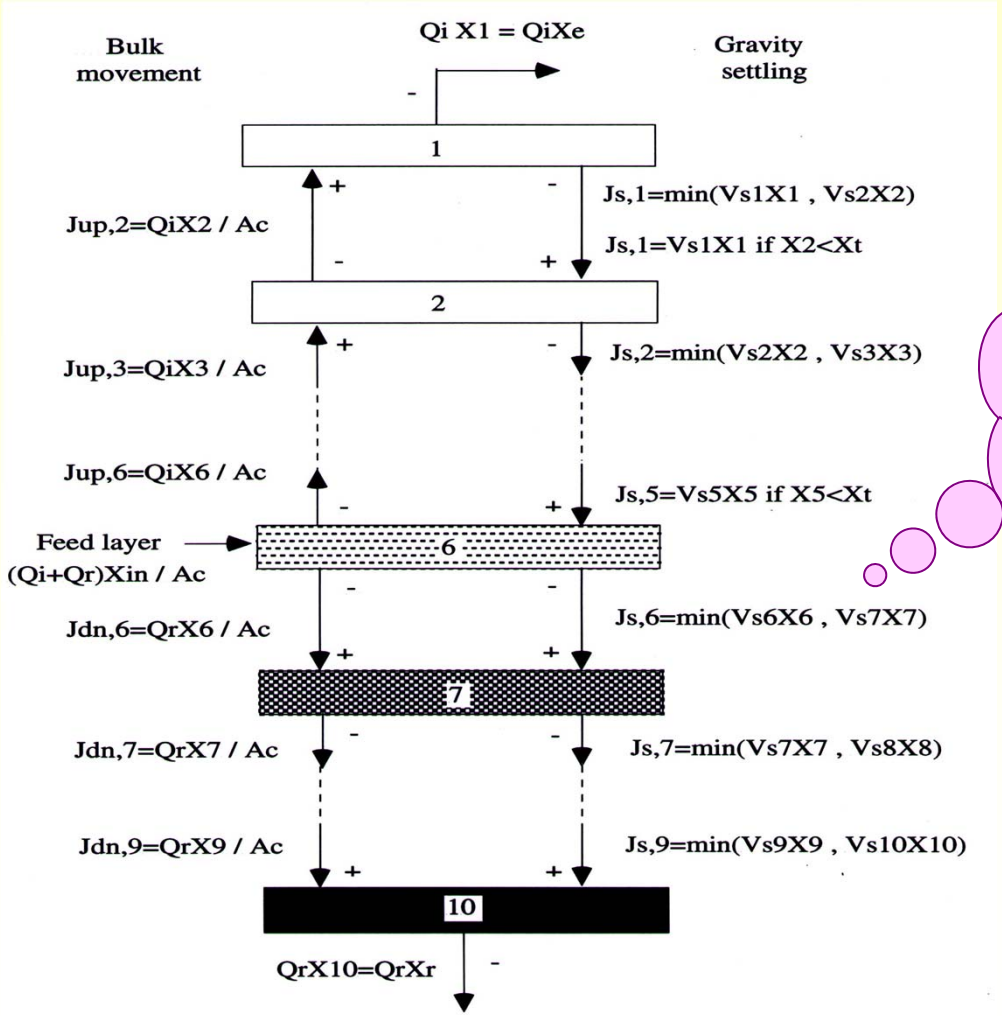
(bulk movement + gravity settling)

- Double exponential-velocity theory

$$v_{sj} = v_0 e^{-r_h X_j^*} - v_0 e^{-r_p X_j^*} \quad \left(0 \le v_{sj} \le v_0^{'}\right)$$



1.7 General Settler Model



Limiting solid flux

1.8 Integrated Modeling

- Combination of reactor and settler

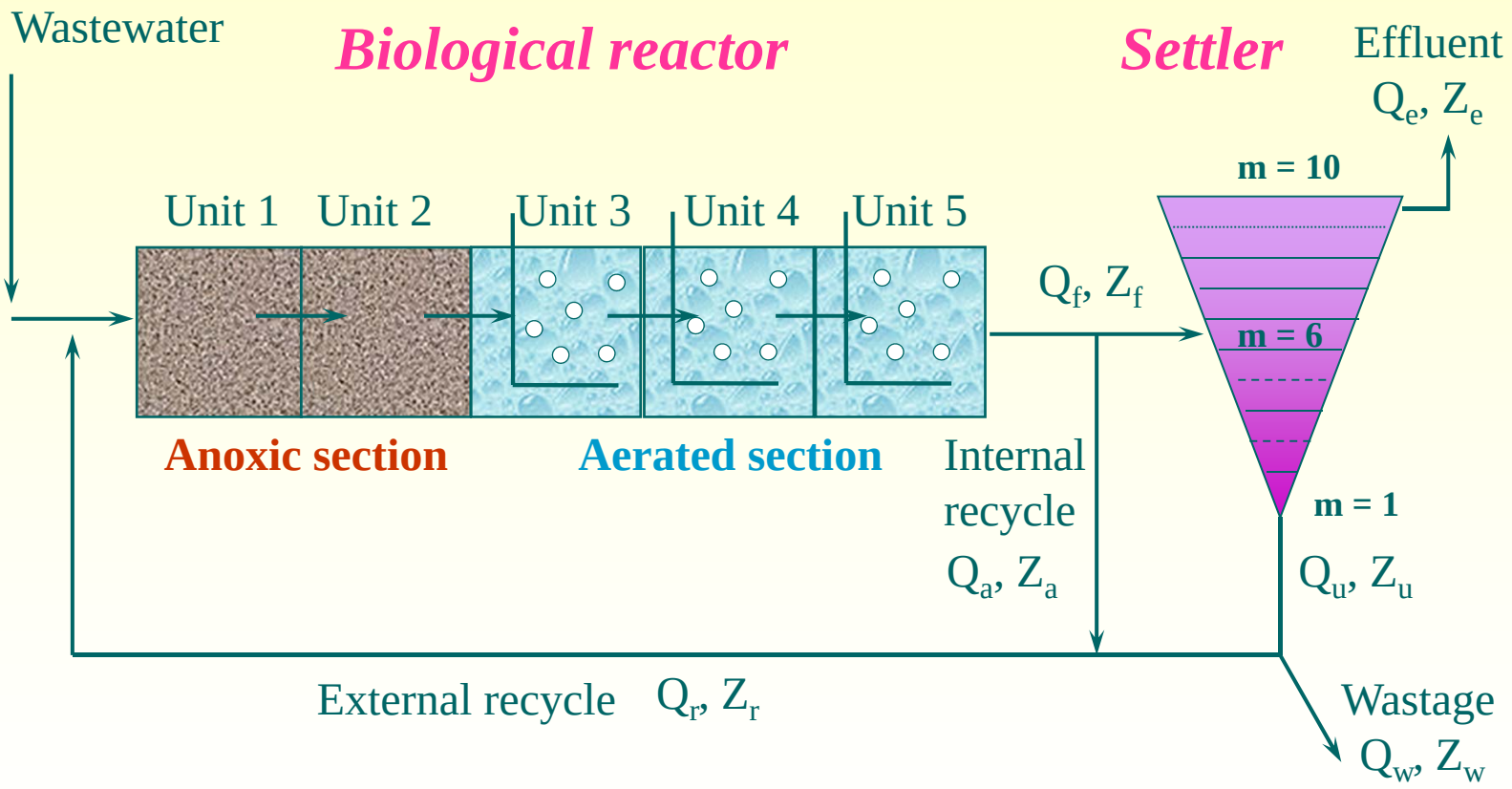
$$\frac{X_{S,5}}{X_f} = \frac{X_{S,u}}{X_u}$$ (fraction equality)

- Predenitrification process
  - Advanced wastewater treatment process (nitrogen removal)
  - The most economic nitrogen removal process (1991, Henze)
  - Benchmark study model (COST 682 & 624 Group)

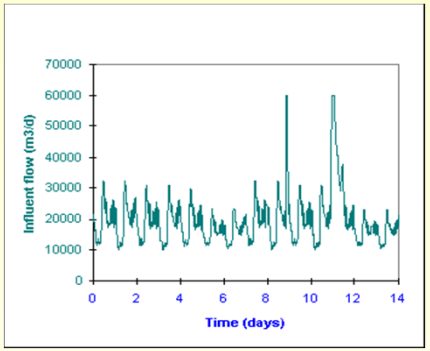
COST
European Cooperation in the field of Scientific and Technical Research

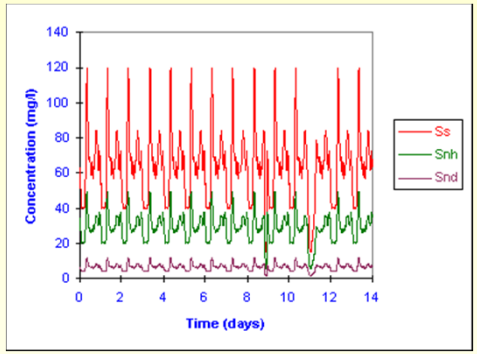
  - Five-compartment reactor and secondary settler

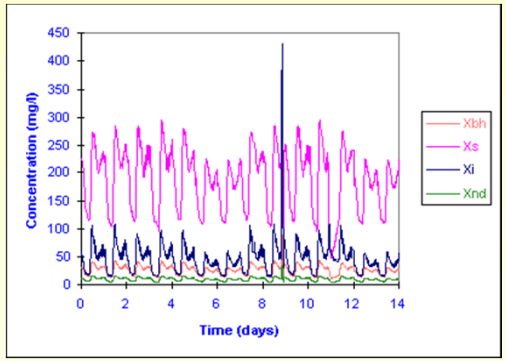
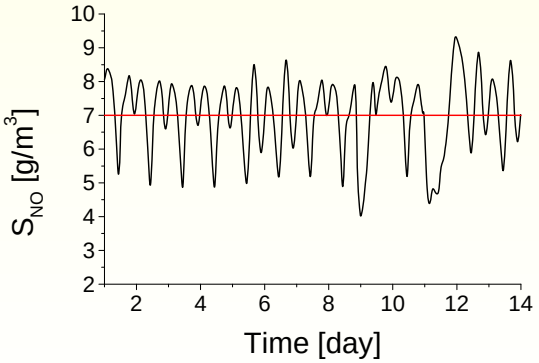
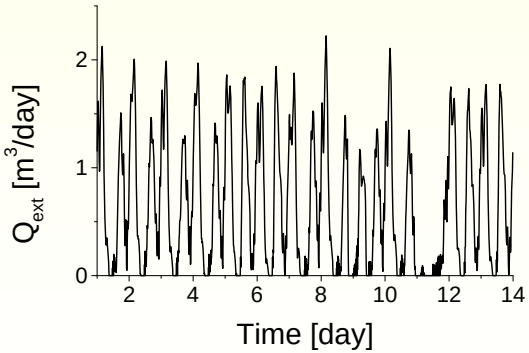
1.9 Benchmark Study Model



1.10 Simulation Results







Storm-weather condition