Analysis and Optimization of the WaterCycle™

Nathan Peal, Paul Duchow; **Instructor:** Dr. Jorge E. Gatica

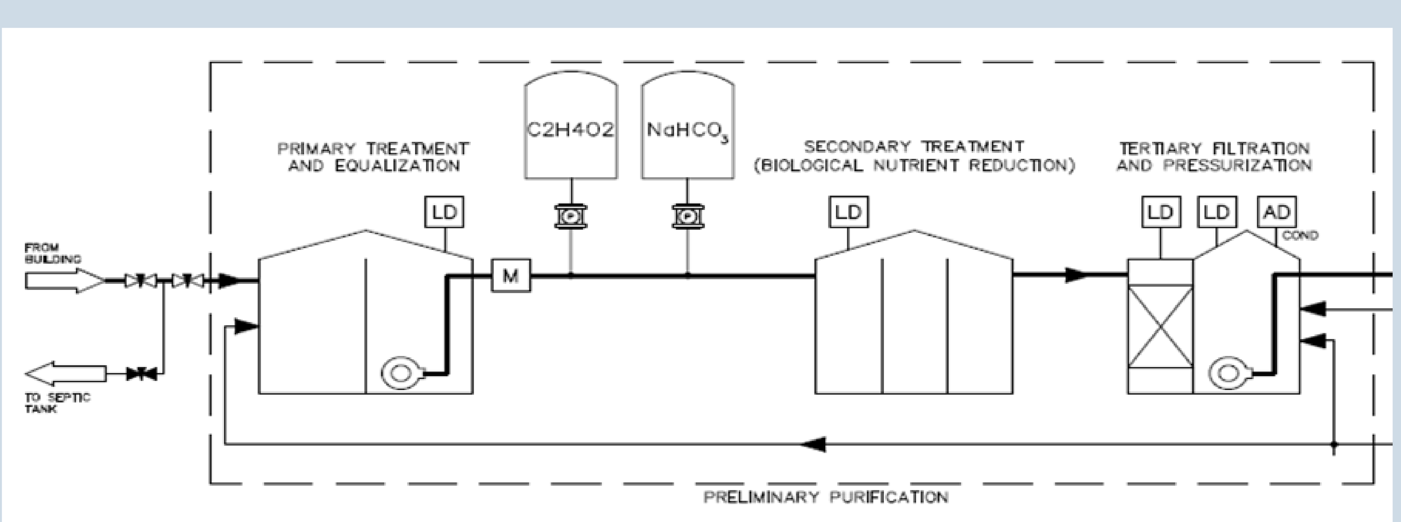
Tangent Company; Company Supervisor: Adam Arnold

Department of Chemical Engineering, Washkewicz College of Engineering

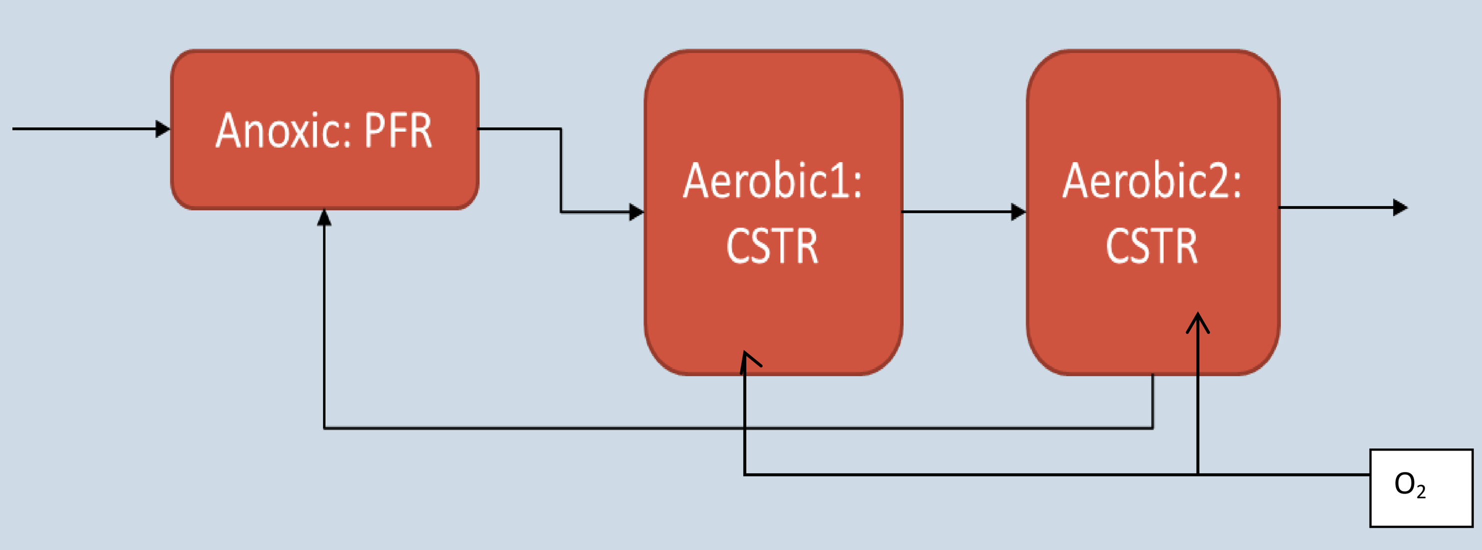
Cleveland State University

Background:

- Nitrogen is a very important component of water purification
- In water based environments nitrogen can be present in the form of nitrates, nitrites, and ammonia
- These nitrogen based compounds when found in drinking water must meet concentration requirements in the parts per billion range
- Denitrification is a process which uses bacteria to convert these unwanted components into nitrogen gas which is released into the atmosphere
- The bacteria exist in either an oxygen rich (aerobic) or an oxygen poor (anoxic) environment depending on the type of bacteria and the effect they have on nitrogen species.
- The goal of the project is to characterize the kinetics of the reactors in Tangent Company's Watercycle™ purification system using custom modeling software



- Above is the P&ID for the Watercycle™ system's waste water treatment. A simplified diagram of the just the reactor portion is below. The mathematical model used in this project assumed the pair of constantly stirred tank reactors (aerobic reactors) were a single tank for simplicity.



Modeling:

- The overall reactor contains four reactions of concern to this project which can be seen in the following figure:

Anoxic Reactions

$$NO_3^- + \frac{1}{3}CH_3OH \rightarrow NO_2^- + \frac{1}{3}CO_2 + \frac{2}{3}H_2O$$

$$NO_2^- + \frac{1}{2}CH_3OH \rightarrow \frac{1}{2}N_{2(GAS)} + \frac{1}{2}CO_2 + \frac{1}{2}H_2O + OH^-$$

Aerobic Reactions

$$NH_4^+ + \frac{3}{2}O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + \frac{1}{2}O_2 \rightarrow NO_3^-$$

- The reactants and products here were simplified to four measureable quantities which could be used
- The key to modeling the system comes from solving for the reaction
- These can be found through the following correlations

$$r_1 = k_1 C_A {C_{O_2}}^{\frac{3}{2}} \cong \widetilde{k_1} C_A$$

$$r_2 = k_2 C_B {C_{O_2}}^{\frac{1}{2}} \cong \widetilde{k_2} C_B$$

$$r_3 = k_3 {C_c}^3 C_D$$

$$r_4 = k_4 {C_B}^3 C_D$$

$$r_A = -r_1$$

$$r_B = r_1 - r_2 + 3\langle r_3 \rangle - 3\langle r_4 \rangle$$

$$r_C = r_2 - 3\langle r_3 \rangle$$

$$r_D = [\,\langle r_3 \rangle - \langle r_4 \rangle\,]$$

$$r_n = -\frac{{F_n}^o - F_n}{V_2}$$

- The above correlations make it possible to solve for the reaction rates for each individual reaction

Results:

- The graph below shows the resulting reaction rates for the Watercycle™ system
- These rates will be used to predict the behavior of the system
- Some rates favor the reverse reaction which is undesired