Bioreactor Volume Calculation

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Goal: To find a good target volume for my bioreactor based on how much nitrogen and phosphorus it needs to remove, and for efficient CO_2 fixation.

1. Key points of consideration:

→ Nitrogen Removal (HRT): Aiming to let the water stay within the bioreactor for 6-7 days.

→ Phosphorus Uptake Rate: Chlorella Vulgaris can take up to 45.16 milligrams of Phosphorus (P) per liter of water per day ($mg\ P\ L^{-1}\ d^{-1}$)

→ Algae carbon content: About 50% of dry weight of algae is carbon. This helps link CO_2 capture and algae growth.

2. Assumption Section

→ With no real wastewater to treat, it is important to make educational guesses.

1. How much wastewater will flow in each day?

HRT (days) = Bioreactor Volume (Liters) / Daily Wastewater flow (Liters/Day)

Size of population or area my bioreactor could serve?

⇒ ~4 small homes (each home has about 4 people)

4 homes x 4 people/home = 16 people

Daily Wastewater Flow (Q):

⇒ Common average of 150 Liters per person per day (L/person/day)

Q = 16 people x 150 L/person/day = 2400 L/day

Waste water flow (Q): 2,400 L/day

* This is based on 4 small homes with 4 people each (16 people in total) Assuming 150 L/person/day wastewater generation.

2. How much Phosphorus (P) is in the dirty water coming in?

Assumed Influent Phosphorus Concentration (P_in): 7mg/L

3. How much Nitrogen (N) is in the dirty water coming in?

- Nitrogen concentration (N_in): 20-80 mg/L

→ Assumed Influent Nitrogen Concentration (N_in): 40mg/L

4. What percentage of P and N do I want to remove?

- Assumed Target Removal Efficiency: 90%

3. Calculation 1 - Volume based on Nitrogen Removal (HRT)

1) HRT range is 6-7 days. So taking Average of 6.5 days

Formula: Bioreactor Volume (V) = Daily Wastewater Flow (Q) x HRT

V = 2,400 L/day x 6.5 days = 15,600 L

So, based on Nitrogen Removal, the bioreactor needs to be about 15,600 L

4. Calculation 2 - Volume based on Phosphorus Uptake

Total P in = Influent P concentration (P_in) x Daily Wastewater Flow (Q)

= 7mg/L x 2,400 L/day = 16800 mg P/day

P to remove = Total P in x Target Removal Efficiency

P to remove = 16,800 mg P/day x 0.95

P to remove = 15,960 mg P/day

Bioreactor Volume = P to remove (mg P/day) / phosphorus Uptake Rate ($45.16\ mg\ P\ L^{-1}\ d^{-1}$)

V = 15,960 mg P/day / $45.16\ mg\ P\ L^{-1}\ d^{-1}$

V = 353.41 L

So, based on Phosphorus Removal, the bioreactor needs to be about 353.41 L

5. Comparing and relating to CO_2 capture

→ From Nitrogen (HRT): V = 15,600 L

→ From Phosphorus Uptake: V = 353.41 L

Decision:

I have decided my target bioreactor volume to be approximately 15,600 Liters because it is the larger of the two calculated volumes, ensuring sufficient capacity for both nitrogen and phosphorus removal.

CO_2 capture link:

My chosen bioreactor volume of 15,600 L supports growth of algae required to remove nitrogen and phosphorus. This same algae growth will be able to consume CO_2 naturally from air. My bioreactor design specifically the bubbling in the airlift column and good light distribution from flat panel, is highly important for making sure CO_2 can transfer efficiently into the water for the algae to capture and grow