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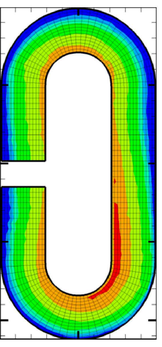
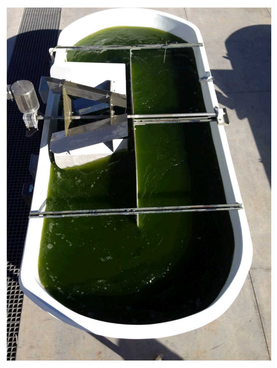
Effects of Viscosity on Turbulence Mixing in Pilot Scale Open Raceway Ponds

Eric Monroe[a]*, Carlos Quiroz-Arita[b], Myra Blaylock[a], David Smernoff[c], Rocco Mancinelli[c], and Ryan Davis[a]

[a]*Sandia National Laboratories, Livermore, CA; *emonroe@sandia.gov*

[b]*Mechanical Engineering, Colorado State University, Fort Collins, CO;* [c]*HelioBioSys, Woodside CA*





Introduction

One of the fundamental assumptions for most algae growth models is that the medium is well mixed so that the algae experience the same nutrient conditions everywhere and the concentration of algae is also homogeneous throughout. While this is a good first order assumption, it is likely that for some scenarios (larger ponds, slower mixing velocities, etc.) that this might not be the case. One example where this assumption might not hold is when the algae has a very high viscosity. In this poster we compare the velocity and turbulence intensity in a pilot scale open raceway pond used to grow algal polyculture for the conditions at lag phase (low viscosity) and stationary phase (high viscosity) of the growth curve.

Approach

We have measured the viscosity of a cyanobacteria consortium that produces extra cellular polymeric sugars which produces a very large dynamic viscosity (up to 10 mPa-s, which is ~10 times more viscous than water) through-out one growing cycle. Velocity measurements for the pilot scale open raceway pond used to grow this cyanobacterium were made for the conditions at the beginning (low viscosity) and at the end (high viscosity) of the cycle. We compare the velocity and the turbulence for these two conditions, which give insight into the well mixed assumption.

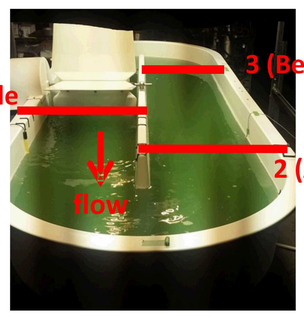
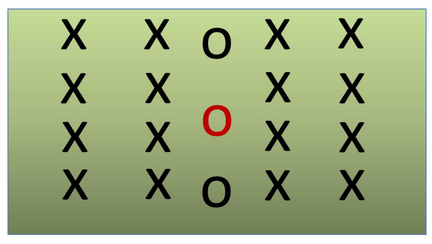


Figure 1: Location of cross sectional planes for experimental velocity measurements

- **Measurement Strategy**
  - The same velocity measurements were taken for both the initial and final times of the growth period.
  - Velocity measurements were made at three planes perpendicular to the flow in the raceway pond:
    - 1. Directly behind the paddle wheel
    - 2. After the first turn
    - 3. Before the second turn
  - At each plane, measurements were made in a 4 x 4 grid pattern.
  - Three confirmation points were also taken at different depths along the centerline for plane 1 and plane 3.

Figure 2: The "x's" show the location of the 16 velocity measurements for each plane indicated in Figure 1. The "o's" show the measurements along the centerline of planes 1 and 3.



- **Measurement Procedures**
  - Acoustic Doppler Velocimetry by Vectrino
  - Sampling rate of 100 Hz
  - Each point measured for 25 minutes
  - Care was taken to avoid taking measurements too close to walls and the floor to avoid errors.
  - Additionally "dampeners' were used on the Vectrino velocimeter to limit background noise.

Results

- **Viscosity**

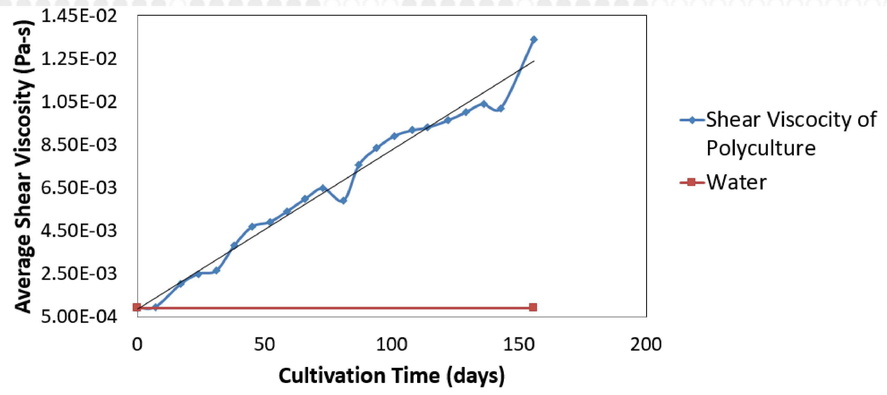


Figure 3: The viscosity of the polyculture was measured throughout the growing cycle.

- **Turbulence**

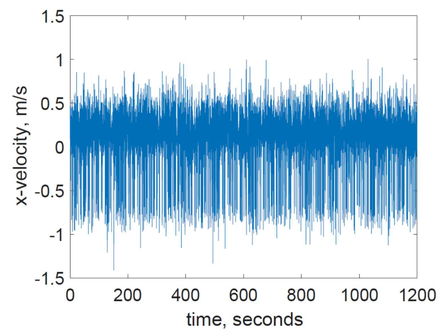


Figure 4 : Illustration of experimental turbulence measured at pilot open raceway pond at low viscosity condition.

- **Velocity Comparison:**

Different turbulent flow regimes are observed for the conditions at the stationary phase (high viscosity) relative to lag phase (low viscosity), particularly at the second and third cross-section of the open raceway pond. The two flows are most alike directly after the paddle wheel.

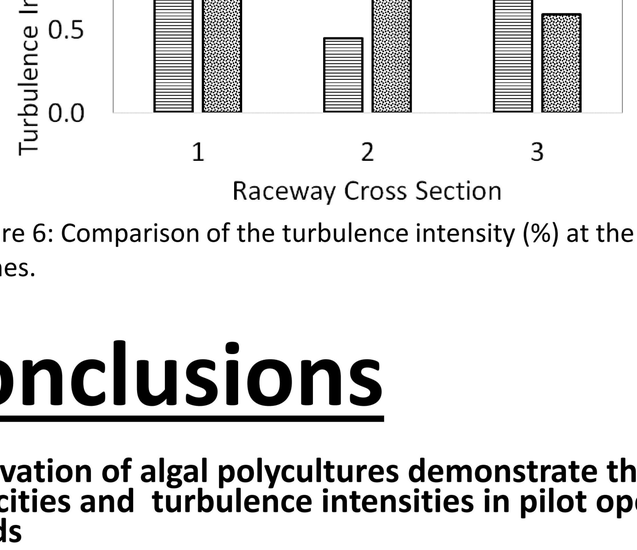


Figure 5: Comparison of the velocity (m/s) at the three planes.

- **Turbulence Intensity Comparison:**

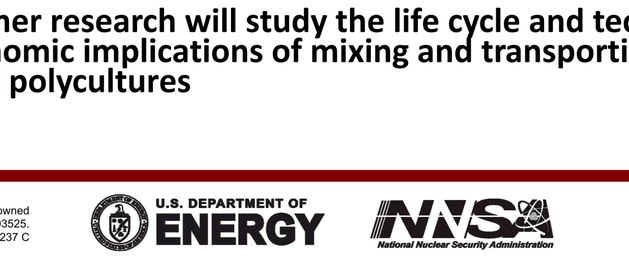


Figure 6: Comparison of the turbulence intensity (%) at the three planes.

Conclusions

- **Cultivation of algal polycultures demonstrate the change in velocities and turbulence intensities in pilot open raceway ponds**
- **Differences in viscosities and turbulence observed in algal polycultures could change the energy requirements to mix and transport cultures in these systems to insure a well mixed state**
- **Further research will study the life cycle and techno-economic implications of mixing and transporting viscous algal polycultures**

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