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Simulation of the nitrogen cycle in a circular aquaculture vessel using ANSYS CFX

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Highlights

- The nitrogen cycle in an aquaculture vessel was studied using a fluid dynamics program.
- Pollutant distribution varied with the combinations of inlet and outlet position.
- Increasing flow rate and DO concentration reduced nitrite level in the tank remarkably.
- The vessel should be designed to minimize exposure of resident fish to toxic pollutants.

1. Introduction

Effective design of aquaculture vessels plays an important role in not only maintaining ideal fish health and condition, but also improving productivity of inland fish farming. This is particularly true when culturing fish at high density in multiple tank system, which is common practice in the European Union and South Korea. The aquaculture vessels were operated under specific conditions to rapidly discharge target contaminants to effluent as well as to obtain suitable hydraulic characteristics of flow pattern for resident fish. However, the removal mechanisms of different types of contaminants that were coupled with the flow motion were not carefully addressed in the phase of the design process, which made it difficult for farmers to manage the given system properly. Therefore, this study aims to investigate how the position of the inlet and outlet modulate the flow motion and contaminant distribution in the specific circular tank to provide guidance on operation and monitoring for fish farming such as eels.

2. Methods

For this study, we used a computation fluid dynamics package ANSYS CFX to simulate the hydraulic behaviors as well as chemical reactions involved at the nitrogen cycle in the circular vessel. Figure 1a illustrates the schematic diagram of 3-D computational model domain. Figure 1b shows the alignment between the inlet and outlet flow at different angles in the circular vessel. Simulation was performed under the following operating conditions (see Table 1).

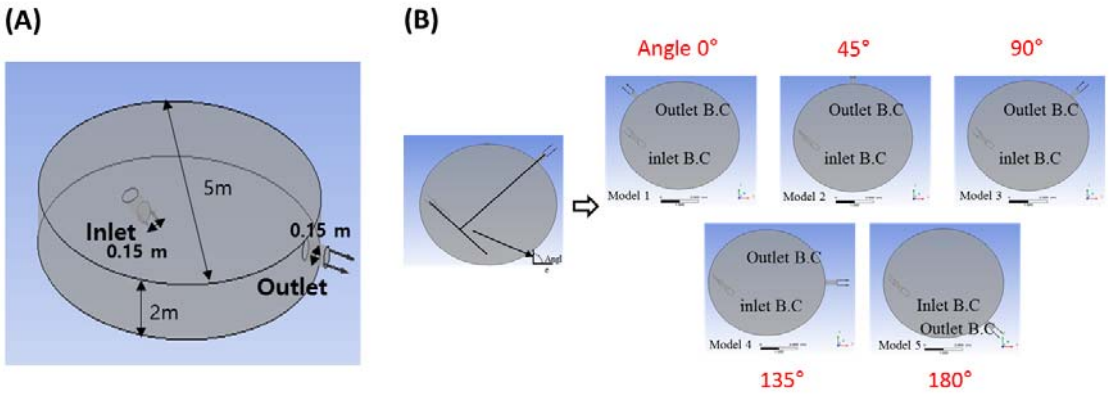

Figure 1. (a) Model domain and (b) five different types of inlet and outlet positioning (Models 1 through 5).

Table 1. Summary of simulation conditions applied to the circular vessel.

Parameters	Values	Units
Water density	1,000	[kg/m^3]
Dynamics viscosity	1.1×10^{-2}	[Pa·s]
Pre-exponential factor	5.11×10^{-9}	[-]
Water temperature	303.15	[K]
Activation energy	52,000	[J/mol]
Feed flow rate	0.1, 0.2, and 0.3	[m/s]
Dissolved oxygen	10, 20, and 30	[mg/L]
Ammonium	10	[mg/L]

3. Results and discussion

3.1. Effect of geometry on the contaminant levels

Out of five different angular alignments between the inlet and outlet flow, Model 2 was found to show the lowest low nitrite level as well as a more uniform distribution of nitrite in the circular vessel. Therefore, the Model 2 was selected for the subsequent works that adopted other operating conditions.

3.2. Effect of flow rate on the contaminant levels

With increasing the inlet flow rate, the mixing energy inside the circular vessel was increased, which resulted in reducing the concentrations of dissolved oxygen (DO) and nitrite (Figure 2a).

3.3. Effect of DO concentration on the contaminant levels

Increasing both the DO level and inlet flow rate simultaneously (in Model 2) contributed to a considerable reduction in the nitrate concentration, lowering risk of death of resident fish in the circular vessel as compared to other vessel designs (Figure 2b).

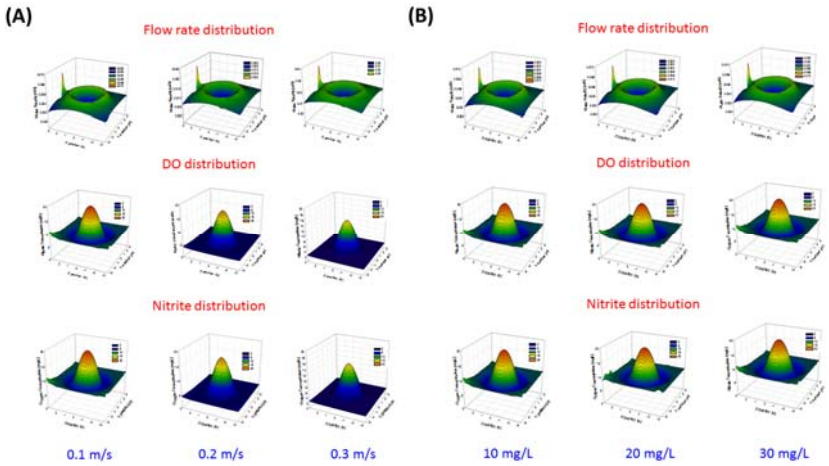

Figure 2. Distribution of flow rate, DO, and nitrite under varying (a) the inlet flow rate and (b) DO concentration.

4. Conclusions

In this study, we evaluated the effect of geometry, flow rate, Do concentration on the nitrogen cycle in the circular aquaculture vessel. We believe that the research outcomes provide insights that help optimize the operation of the aquaculture tank to control target contaminant more efficiently, thus improving the productivity of inland fish farming.

References

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Keywords
Chemical reaction; Nitrogen cycle; Aquaculture vessels; Computation fluid dynamics